Herança - History, Heritage and Culture Journal
2026, 9(1), 82-97
ISSN: 2184-3090
https://revistaheranca.com

Research Article

Post-2018 Disaster Behavioral Adaptation and the Role of Buvu Bionga in Petobo Settlement, Palu City, Indonesia

Irdinal Arief [1*]

[1] Doctor, Department of Architecture and Planning, Faculty of Engineering, State University of Tadulako, Mantikulore, Palu, Central Sulawesi, 94148, Indonesia
* **Corresponding Author:** irdinal@untad.ac.id

Citation: Arief, I. (2026). Post-2018 disaster behavioral adaptation and the role of Buvu Bionga in Petobo settlement, Palu City, Indonesia. *Herança, 9*(1), 82-97. https://doi.org/10.52152/heranca.v9i1/1200

ARTICLE INFO

Received: 29 Oct 2025
Accepted: 21 Jan 2026

ABSTRACT

Environmental changes occurred in the Petobo settlement, Palu City, Indonesia, following the 7.5 Mw tectonic earthquake on 28 September 2018. The disaster was accompanied by a tsunami and liquefaction that caused extensive mudflows in Balaroa, Petobo, and Jono Oge. Petobo was one of the most severely affected areas, with approximately 200.4 hectares impacted and widespread destruction of infrastructure and housing. One affected zone was the settlement surrounding Buvu Bionga, a water well inhabited by the Kaili Ledo community. After the disaster, several households continued to reside near the well. This persistence indicates a spatial phenomenon that warrants further investigation. This study examines whether Buvu Bionga functioned as a determining spatial element in the historical development of the Petobo settlement. The study employs a qualitative approach using diachronic analysis based on historical sources and field observations. The results are then examined synchronically through an urban morphology framework. Adaptation theory is applied to assess settlement resilience in the post-disaster context. The findings reveal three key points. First, Buvu Bionga historically functioned as a central spatial anchor that shaped residential patterns in Petobo. Second, proximity to the well influenced post disaster settlement persistence despite severe environmental change. Third, the well continues to act as a cultural and spatial reference that supports community resilience after liquefaction.

Keywords: Post-Disaster Settlement; Liquefaction Disaster; Urban Morphology; Spatial Resilience; Cultural Landscape; Indigenous Community.

INTRODUCTION

Environmental changes in the post-disaster phase occurred in the Petobo settlement, Palu City, Indonesia, following the 7.5 Mw tectonic earthquake that struck Palu on 28 September 2018. The disaster was compounded by a tsunami and large-scale liquefaction that triggered massive mudflows in Balaroa, Petobo, and Jono Oge (Jalil et al., 2021). Petobo was among the most severely affected areas, with approximately 200.4 hectares of land experiencing extensive damage to infrastructure and housing. One of the impacted residential areas was the neighborhood surrounding Buvu Bionga, a traditional water well belonging to the Kaili Ledo community. This well is recognized as a historical heritage site of the Sigi-Biromaru Kingdom and remained physically intact after the disaster, along with several nearby houses that also survived. The residents of Petobo are bound by strong kinship ties formed through generations of intermarriage, which have fostered a cohesive and resilient community structure. Historically, Petobo and Pombewe in the Sigi-Biromaru region originated from Loru, an area formerly under the Biromaru domain. Their social cohesion is deeply rooted in a shared philosophical worldview that emerged during the era of the Sigi-Biromaru Kingdom, when territorial expansion was accompanied by strategic inter-kingdom marriages conducted by the Madika (leader). This historical process shaped the lineage of the Kaili Ledo community. Furthermore, communal life is guided by a unifying kinship philosophy known as “Nosarara,” meaning “together we build the territory,” which continues to be embedded in everyday social practices.

This belief system remains strongly reflected in post-disaster conditions. Many Petobo residents who currently live in temporary shelters have firmly refused relocation outside their original settlement area. Their

collective stance emerged in response to government policies mandating relocation due to the classification of Petobo as an extremely high-risk liquefaction zone based on updated disaster risk maps. From a disaster management perspective, relocation is often considered the most rational mitigation strategy. As Smith (2013) explicitly states, "disasters have recurrence periods, and rebuilding in hazard-prone areas inevitably prolongs vulnerability." Similarly, Jha (2010) argues that post-disaster relocation is necessary due to "widespread displacement and housing loss, the unsuitability of damaged sites for habitation, the need to reduce future vulnerability, and the prevention of escalating recovery costs when rebuilding is forced in the same location." These arguments frame relocation as a logical and preventative response to future risk.

However, in contrast to these theoretical perspectives, the residents of Petobo demonstrate a strong preference to remain in temporary shelters rather than relocate to permanent housing outside their ancestral homeland. This condition reflects the notion that a place holds meanings that extend beyond its physical or functional attributes. As Putri (2020), explains, "place is not merely a spatial container but a lived entity whose meaning cannot be fully captured through analytical or scientific reasoning alone." In line with this perspective, Tuan (1977) describes place as "a center of experiential value," where space acquires meaning through lived experiences, social relations, and the fulfillment of basic biological and cultural needs. Morales-Ramirez (2025) further emphasizes that place attachment emerges from continuous interactions between people, memory, and everyday practices.

In the context of Petobo, the area surrounding Buvu Bionga embodies profound symbolic and existential significance rooted in cultural heritage and collective memory. This place is deeply intertwined with daily life practices of the Kaili Ledo community, reinforcing its role not merely as a physical setting but as a meaningful locus of identity and belonging (Tuan, 1977).

Despite the high level of disaster risk and official policies mandating relocation, the Kaili Ledo community in Petobo continues to resist permanent resettlement outside their original territory. Existing disaster management frameworks largely emphasize technical risk reduction and often overlook the cultural, philosophical, and place-based meanings that shape community decision-making. This study therefore addresses the following problem: what form of behavioral adaptation and place-based attachment underlies the spatial decision of the Kaili Ledo community to remain in Petobo despite extreme disaster risk? Understanding this phenomenon is crucial for developing post-disaster relocation policies that are not only technically sound but also culturally responsive and socially sustainable.

LITERATURE REVIEW

Environmental adaptation explains that interaction between humans and their environment continuously occurs, and such interaction generates habitual behavioral patterns. A community group considered highly competent in terms of education, health, and financial capacity may still fail to adapt well to an environment that does not align with their needs, (Lawton & Nahemow, 1973; Zhang et al., 2022). Adaptation undertaken to align human needs with environmental conditions has its limits; when the gap between the two exceeds these limits, adaptation can no longer be sustained, reaching a saturation point of human adaptive capability. However, the situation is different when a place contains strong historical values and unique cultural practices distinct from the common norm. Human psychological processes in interacting with the environment produce behavioral adaptation patterns, which are studied in environmental psychology. Several elements of environmental psychology are involved when humans engage with their surroundings, as proposed by (Kals et al., 2025; Lazarus & Folkman, 1984). These include: attention, which refers to humans' awareness of environmental conditions and their constituent elements; cognitive perception, through which individuals interpret their environment based on prior knowledge or previous experiences; and preference, where humans naturally seek environments that align with their personal comfort, enabling them to feel confident, competent, and secure (Ntoumanis, 2001; Sussman & Hollander, 2021).

To support the theoretical framework of environmental adaptation, it is first necessary to clarify the concept of space and its transformation into place. Space is initially a neutral physical entity; however, when contextual meaning derived from cultural values, lived experiences, and local potential is assigned to it, space is transformed into place. As emphasized by Tuan (1977), the meaning of space is inseparable from the meaning of place. When space acquires definition and meaning, it becomes a center of experiential value where fundamental biological needs such as food, water, rest, and reproduction are fulfilled (Tuan, 1977). Human perception of space is formed through multiple experiential modes, including sensorimotor, tactile, visual, and conceptual dimensions, which together shape how space and place are interpreted as representations of the environment (Tuan, 1977).

Within the context of spatial planning, place is understood not merely as a physical container but as a setting

in which individuals and communities develop emotional, spiritual, and material-cultural attachments (Arief et al., 2024b; Relph, 1976). Place also functions as a medium through which humans manifest their existence in accordance with local cultural contexts (Putri, 2020). This perspective highlights that place is a product of both spatial configuration and socio-cultural meaning, making it central to studies of human-environment interaction.

Building upon this understanding, place theory particularly Figure Ground Theory explains the importance of physical factors in establishing spatial clarity, structure, and sequence. The spatial composition between open spaces and building masses can be deliberately arranged to reinforce spatial order, for example by defining macro-scale spatial hierarchies based on comparative dimensions and geometric configurations. According to Trancik (1986), as cited in Subroto (2012), the elements that constitute spatial enclosure must address spatial, visual, and detailed aspects. The integrative components of physical factors — spatial organization, visual continuity, and detailing require urban spaces to be structured and to possess a clear hierarchical organization. All spatial fragments must be interconnected within a cohesive framework that reflects a distinct character, thereby creating unity and balance within the overall spatial structure (Subroto, 2012; Trancik, 1986). Moreover, large-scale physical elements play a crucial role in shaping neighborhood spatial patterns by expressing local identity through form and placement, while reinforcing functional and morphological character through articulation and accentuation.

While physical structure provides the framework of space, environmental psychology explains how humans perceive, interpret, and adapt to that framework. Environmental adaptation theory posits that interactions between humans and their surroundings occur continuously, producing habitual patterns of behavior. Even communities with relatively high levels of education, health, and economic capacity may experience maladaptation when environmental conditions fail to correspond with their needs (Lawton & Nahemow, 1973; Zhang et al., 2022). Human adaptive capacity is not unlimited; when the discrepancy between environmental demands and human needs exceeds a certain threshold, adaptation reaches a saturation point and can no longer be sustained. However, this limitation is often mitigated in places that possess strong historical significance and distinctive cultural practices, where psychological attachment to place supports continued adaptation despite environmental challenges.

Environmental psychology further examines the psychological mechanisms underlying human environment interaction. According to Lazarus and Folkman (1984) and Kals et al. (2025), several key processes are involved. Attention refers to an individual's awareness of environmental conditions and elements; cognitive perception involves interpreting the environment based on prior knowledge and experience; and preference reflects the tendency to seek environments that provide comfort, safety, and a sense of competence and control (Ntoumanis, 2001; Sussman & Hollander, 2021). These mechanisms explain why individuals respond differently to similar spatial conditions and why certain environments foster stronger attachment and adaptive behavior.

Recent empirical studies in environmental psychology (2023-2025) provide further evidence of the role of psychological processes in shaping place-based behavior. Research on urban green spaces demonstrates that perceptions of environmental change, including climate-related stressors, significantly influence emotional, functional, and social dimensions of place attachment. These attachments, in turn, mediate the relationship between environmental awareness and pro-environmental behavior, indicating that place attachment serves as a crucial psychological mechanism linking perception to action. Other studies reveal that natural design elements such as visibility, spatial integration, and interactive natural features enhance place attachment through increased nature connectedness and biophilic responses. Such findings confirm that environments rich in experiential and symbolic meaning not only improve psychological well-being but also strengthen long-term adaptive capacity and social resilience.

Relevance of the theories to the research objectives: The theoretical perspectives discussed above provide a comprehensive framework for analyzing how physical spatial structure and psychological processes interact in shaping human adaptation to the environment. Place theory and Figure Ground Theory explain how spatial form and hierarchy create the physical conditions for human activity, while environmental psychology elucidates how attention, perception, preference, and place attachment influence behavioral responses to those conditions. Together, these theories directly support the objectives of this research by offering conceptual tools to examine how culturally meaningful spatial structures foster adaptive behavior, reinforce place attachment, and sustain human environment relationships within the studied context.

METHODOLOGY

This research employs a qualitative approach through an in-depth diachronic analysis, followed by synchronic interpretation within the framework of urban morphology. The diachronic perspective is applied to examine spatial and architectural transformations across different temporal phases, while the synchronic perspective is used to analyze the relationships among morphological elements within a specific period. The integration of both approaches enables a comprehensive understanding of the settlement's historical development and its spatial adaptation processes.

Historical Reading and Diachronic Analysis

The primary analytical method used in this study is diachronic analysis, conducted through historical reading (Chartier, 2004; Surakhmad, 1994). This method is aligned with documentary historical research commonly applied in historiography, involving the systematic examination of written records, maps, archives, and visual documentation to reconstruct past spatial conditions.

Historical reading was applied to identify key phases of settlement formation, transformation, and post-disaster reconstruction. Documentary sources included colonial-era records, regional planning documents, historical maps, academic literature, and local historical narratives. These materials were critically examined to trace the evolution of settlement structure, building typologies, and spatial organization before, during, and after the liquefaction event. The diachronic analysis enabled the identification of major morphological shifts, patterns of continuity and rupture, and adaptive strategies employed by the community over time.

Data Sources

This study utilizes both primary and secondary data sources:

Primary data were collected through semi-structured interviews and direct field observations.

Secondary data consisted of archival documents, historical texts, satellite imagery, maps, and previously published research.

The theoretical framework on adaptation and building morphology was reviewed over a minimum two-year period, corresponding to the minimum duration required to observe post-disaster reconstruction processes and spatial adjustments following the liquefaction event. Based on this theoretical review, key analytical variables such as building form, material transformation, spatial orientation, and land-use adaptation were formulated to guide data collection and analysis.

Interviews

Interviews were conducted using a semi-structured format to capture local knowledge, collective memory, and lived experiences related to settlement change and adaptation. A total of 15 informants were selected using purposive sampling, consisting of: (1) long-term residents (living in the area for more than 20 years), (2) community elders (Totua), and (3) local community leaders.

This selection ensured representation of both historical continuity and leadership perspectives within the Kaili Ledo community. Interviews were conducted in the local language and Indonesian, depending on informant preference, and each session lasted between 45 and 90 minutes. With the consent of participants, interviews were audio-recorded and later transcribed verbatim. Interview questions were organized into thematic clusters focusing on: (1) historical settlement patterns and migration narratives, (2) changes in building forms, (3) spatial adaptation strategies before and after the liquefaction event, and (4) community perceptions and responses to environmental and spatial transformation. The interview process was iterative, allowing emerging themes from early interviews to inform subsequent questioning. This approach enhanced the depth and reliability of qualitative findings and allowed triangulation with historical and spatial data.

Field Observation

Field observations were conducted over a three-month period, involving repeated site visits to document existing physical conditions and ongoing spatial changes. Observations focused on: (1) building typologies and construction materials, (2) spatial organization, orientation, and clustering of dwellings, (3) conditions of surviving, abandoned, and reconstructed structures, and (4) land-use patterns in relation to historical spatial elements.

Observational data were systematically recorded through field notes, photographic documentation, and spatial sketches. These observations provided empirical grounding for interpreting interview narratives and historical records, particularly in identifying visible traces of adaptation and reconstruction practices.

Spatial Analysis, GIS, and Grid Sampling

Spatial analysis was conducted using satellite imagery (Google Earth) and Geographic Information Systems (GIS) to assess land-use change, vegetation cover, building density, and reconstruction patterns. A grid sampling method was applied to ensure systematic and comparable spatial assessment. The study area was divided into standardized grid cells measuring 1 hectare (100 m × 100 m). Each grid cell was analyzed based on: (1) number and distribution of buildings, (2) proportion of built versus unbuilt land, (3) degree of structural damage, (4) presence and intensity of new construction, and (5) changes in vegetation cover.

Sampling focused on areas adjacent to historical elements, surviving buildings, and the surroundings of Buvu Bionga, which functions as a key spatial and cultural reference point within the settlement. This approach enabled comparative analysis between historically significant zones and newly developed or relocated areas.

Data Analysis

Data analysis was conducted through a multi-stage qualitative and spatial analytical process. First, interview transcripts and observational notes were subjected to thematic analysis involving data reduction, coding, categorization, and synthesis. Themes related to spatial memory, adaptation strategies, building transformation, and cultural continuity were identified and cross-referenced, (Figure 1). Second, spatial data were analyzed diachronically to trace changes in settlement structure over time, and synchronically to examine relationships among morphological elements such as plots, buildings, pathways, and open spaces within the same temporal frame. Finally, findings from historical reading, interviews, field observations, and GIS-based spatial analysis were triangulated to ensure analytical validity. The integration of these methods enabled a robust interpretation of post-liquefaction adaptation processes and settlement morphology in the Kaili Ledo community of Petobo.

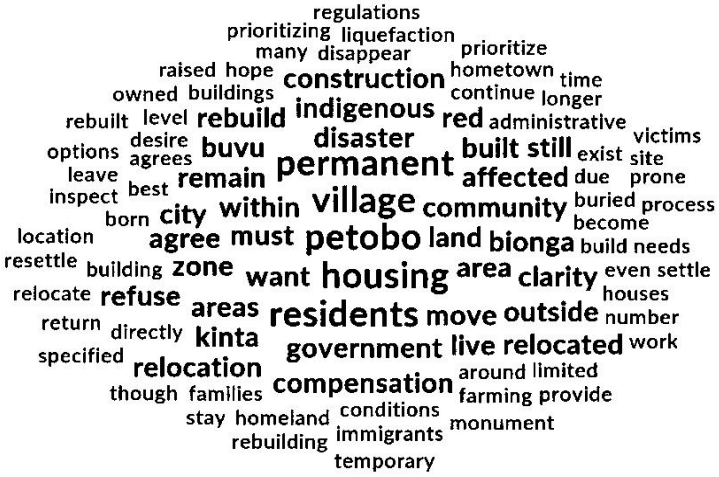

Figure 1. Visualization Of Word Count in Petobo, Based on Interview Results

Study Location: The Kaili Ledo Settlement in Petobo

Adaptation has been practiced since prehistoric times, as narrated by the Totua (community elders), who recount that the Kaili Ledo settlement originated from the mountainous area of Lando, Mount Sindura, specifically in the settlement of Raranggonau. The community later descended following the river flow and eventually settled along the coastal area known as TopoPevo, or referred to by coastal residents as Tolare meaning "mountain people" who are now recognized as the indigenous Kaili people (To Kaili). Their expansion occurred through inter-tribal and inter-kingdom marriages, resulting in the distribution of the Kaili Ledo people throughout most of Central Sulawesi. This historical development was also influenced by Dutch colonial forces. The Kaili Ledo community in Raranggonau once defeated the Dutch in warfare strategies, leading them to return to the mountainous region (To Lare), now known as the present-day Raranggonau settlement located in the highlands of the Palu Valley, which is acknowledged as the ancestral origin of the Kaili Ledo. As they migrated, new settlements were established near riverbanks to ensure protection from surrounding threats. Dwellings were constructed without formal architectural knowledge (Samalavičius & Traškinaitė, 2021), developed simply as shelters in the form of Sou (huts), using natural materials provided by the environment (Oliver, 1997, 2007; Vellinga et al., 2024), The construction typically consisted of round timber posts with roofing made from rattan leaves, thatch, or nipa leaves. These dwellings were constructed in two basic forms: elevated high above the ground on tree trunks accessible by a single notched-log ladder, or built directly on the ground using round wooden posts as supports.

Figure 2. A. Palu City and Delineation of Petobo Subdistrict, B. Petobo Settlement. C. Boya Pantaleddoke and Kinta, in Petobo settlement

They live in groups by establishing settlements, and the process of forming such a settlement, known as Boya, begins with several families constructing houses in specific locations, which typically consist of only a few households that are still bound by kinship relations (Arief et al., 2024a). Usually, a Boya (settlement) has its own designated names based on significant social events, such as Pantaladoke (a place where weapons such as spears are stored for warfare), as well as communal spaces for deliberation (Bantaya), and Buvu (wells) which function as venues for ceremonies or rituals, as observed in the Petobo settlement. At a larger scale of settlement compared to the Boya, Kinta represents a settlement pattern in which the population has increased, transitioning into what evolves into a village. Meanwhile, the densely clustered settlement pattern (Ngapa) is a continuation from Kinta that has fully developed into a village. The social relationships of the community members are characterized by increasing estrangement, wherein individuals begin to lose familiarity with one another, particularly among those who are not related by kinship (Figure 2).

RESULTS

Three themes were identified from the empirical analysis. First, place attachment within the Petobo settlement, which is rooted in the historical continuity of Kampung Kinta as the earliest settlement nucleus. Second, the cultural genesis of Buvu Bionga, represented by the Doke as the ancestral instrument that signifies the creation of the well and its enduring symbolic meaning. Third, the continued existence and functional integration of Bantaya and Buvu Bionga, together with the influence of the No Balia healing ritual, which collectively sustain cultural practices, spatial continuity, and community resilience in the post-disaster context.

Place Attachment, Starting with Kampung Kinta

The phenomenon of place attachment within which values of life, ancestry, and kinship (Arief et al., 2024b). Based on interviews conducted in Petobo, there is a narrative concerning a settlement known as Kampung Kinta (shown in Figure 3), which became a refuge for dozens of survivors who managed to escape while fleeing collapsed buildings, ruptured ground, and advancing mudflows. Kinta is an old village and represents one of the earliest residential areas established when the surrounding environment was still dominated by shrubland, community gardens, and rice fields. In the Kaili language, Kinta refers to a veranda, terrace, or courtyard, symbolizing a transitional and communal space. Since its establishment as a settlement, Kinta has maintained deeply rooted customary traditions. According to long-standing Kaili indigenous beliefs, the area could only be

inhabited by no more than 60 people; exceeding this number was believed to result in outbreaks of disease as a form of customary sanction. Over time, rapid population growth and increasing demand for residential land gradually altered these traditions. Today, Kinta has become an integral part of Petobo Village. Covering an area of approximately 10.40 km^2 , the settlement has an average slope of around 5%, consists largely of flat terrain, lies at an elevation of about 180 meters above sea level, and is characterized by relatively high density and activity. Notably, Kampung Kinta remains intact within Petobo and suffered no physical damage from the liquefaction disaster. The community continues to reside in and maintain their presence in the Petobo area, demonstrating a strong persistence of place attachment despite post-disaster environmental changes.

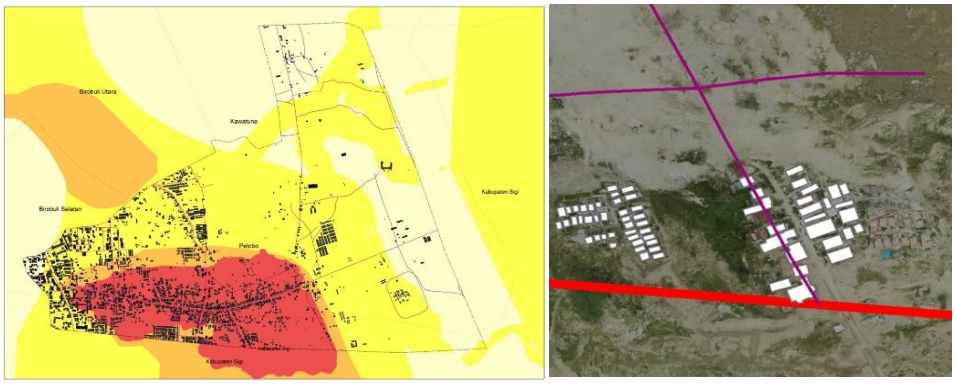

Figure 3. The Location of the First Village in Petobo Called "Kinta" Which Still Survives.

The Influence of Buvu Bionga on the Petobo Settlement

Buvu Bionga is in the Petobo settlement with a GPS location of -00.56’ 26.894” S 119054’ 39.8637” E Street of Moh Soeharto with the area name Street of Buvu Bionga No. 55, Petobo, South Palu District, seen in (Figure 4).

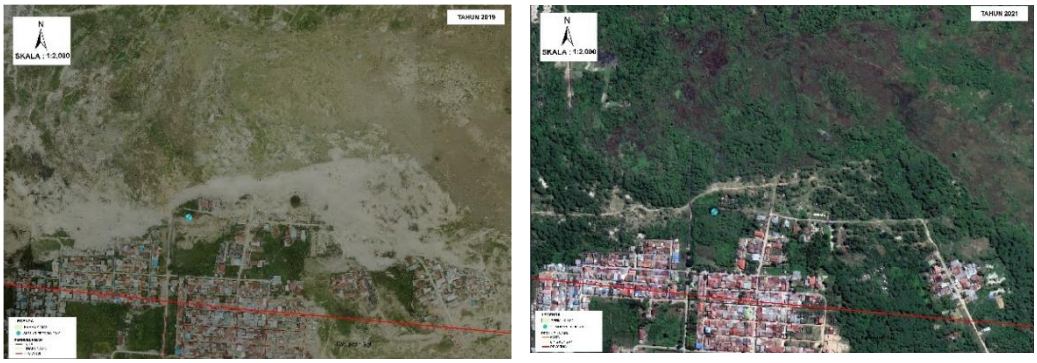

Figure 4. Figure A. Buvu Bionga Point in 2019 and Figure B. Buvu Bionga Point in 2021 Post-Liquefaction Disaster in Petobo

The study area is a former liquefaction zone that predominantly includes the Petobo settlement. According to local accounts, during the disaster residents sought refuge at the Bantaya, which was believed to be spiritually protected by ancestral forces. As shown in Figure 4 of the historical reading analysis, processes of spatial adaptation occurred in the area surrounding Buvu Bionga, as further elaborated in Table 1. Over a period of approximately 2-5 years, the density of buildings and the emergence of new structures increased in accordance with the broader development of the area. However, no construction took place directly around Buvu Bionga. Instead, this area remained an open space, traditionally recognized as a communal venue for dances and customary ritual activities. Following the October-November 2018 disaster, a decline in housing density around Buvu Bionga was observed. This was followed by a gradual increase beginning in early 2019, reaching its highest level in 2021, as local residents undertook efforts to rebuild and repair houses in the surrounding area. Post-disaster adaptation demonstrates a strong continuity of cultural practices and beliefs. Despite changes in environmental conditions, community members continue to collect water from the well near Buvu Bionga,

maintaining long-established routines. Although the water has become turbid, it is still believed to possess healing properties. Ritual activities, particularly the annual Balia ceremony, continue to be conducted using water from the old well, reinforcing the spiritual significance of the site and its role in sustaining cultural identity across generations. From a morphological perspective, the area around Buvu Bionga exhibits a persistent spatial structure. The open field adjacent to the site remains undeveloped, as it is collectively owned and regarded as shared communal space. Accessibility to both the well and the Bantaya remains a key factor influencing settlement patterns. In the post-disaster period (2018-2021), resettlement occurred both near the original site and in off-site locations, including temporary housing (Huntara), where some residents continue to live despite official regulations limiting occupancy to two years.

Table 1. Post-Disaster Adaptation and Morphology of Places Around Buvu Bionga

Subject	Variable	Indicator
Adaptation	Time	- More Than 10 To 20 Years - +/-52 Years - Personal from generation to generation - The level of accessibility is close to the well and *Bantaya*, as well as close to relatives who are still alive, as well as those who have died in the liquefaction area
	Adaptive Behavior	There was no change in behaviour after the disaster. They still take water from the well, which is usually done once a week and every two weeks in the post-disaster period from 2019 to 2021. Even though the well is cloudy, they believe it can cure disease.
	Action	- Rebuild - Repairing Buildings - Done in secret - Balia ritual activities are carried out with water from an old well, which is routinely held every year - A well will be made at the Permanent Residential in Petobo using a spear (Doke).
Morphology	Time and Place	- +/-1985-2017 - There is a field that is not touched by development because it belongs to all residents - Activities in open spaces and covered by immigrants (Privacy) - Accessibility level close to wells and *Bantaya*
	Post Disaster	- 2018-2021 - Resettlement is close to the site. Those in Huntara (Temporary Settlements) also continue to live even though the rules are limited to 2 years - Obtained 12 houses (near site) and 18 houses (off site)

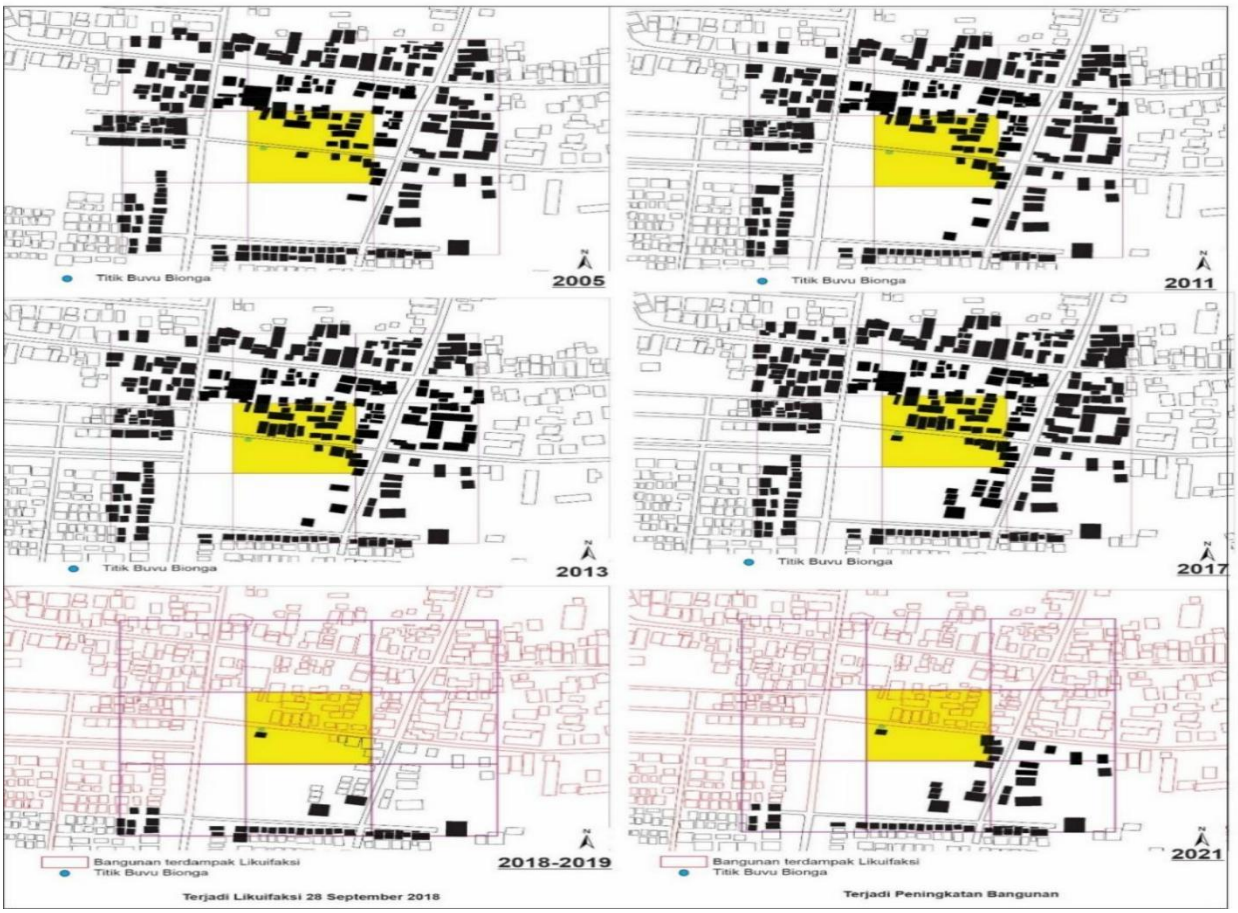

Figure 5. Density of Buildings and New Buildings Adjacent to Well Points and Bantaya in Petobo Before the Disaster. A. 2005**.** B. 2017. And Post-Disaster C. 2019, D. 2021.

Table 2. New Buildings in Buvu Bionga Area, 2005 - 2021

No	Years	New Buildings	Percentage
1	2005	0	0.0%
2	2009	9	32.1%
3	2011	6	21.4%
4	2013	9	32.1%
5	2015	1	3.6%
6	2017	1	3.6%
7	2019	0	0.0%
8	2021	2	7.1%
s		28	100%

Table 2 shows an increase in settlement density in the Buvu Bionga area between 2005 and 2021. This trend is identified through a comparison of built-up and non-built-up land within a 1-hectare analytical unit, as revealed by the historical reading assessment (Figure 5). The data indicate that the most significant increases in new buildings occurred in 2009 and 2013, each accounting for 32.1% of the total new constructions, followed by moderate growth in 2011 (21.4%). In contrast, development activity declined substantially after 2015, with minimal or no new buildings recorded in several subsequent years.

Further analysis examines the spatial distribution of new buildings at varying distances from Buvu Bionga, covering the period from 2005 to 2017 (prior to the disaster) and extending to the post-disaster period up to 2021. The findings demonstrate that settlement expansion has increasingly encroached upon the surroundings of Buvu Bionga. Despite changes in environmental conditions particularly the turbidity of the water Buvu Bionga continues to function as an important source of water for healing purposes and as a site for ritual practices, which

are still conducted annually.

Local narratives emphasize the cultural and spiritual significance of Buvu Bionga, which is believed to be inhabited by ancestral spirits. From the perspective of spatial adaptation, the construction and reconstruction of buildings are fundamentally driven by the need to create spaces that support human activities, (Lang, 1987). Beyond routine daily activities such as walking, observing, working, sleeping, and eating, the area accommodates distinctive cultural practices that differ from ordinary spatial use. These practices have been preserved and transmitted across generations by the Madika and Panda ancestors of the Kaili people, particularly through the Tutua Bimbine (elder women), who play a central role in maintaining ritual knowledge and cultural continuity.

Doke as the Creator of Buvu Bionga

Traditional rituals originating from the prehistoric era in Petobo continue to be practiced today, such as the Raego and Nobalia ceremonies, which are conducted at Pantaledoke Petobo literally translated as a temporary place for placing the Doke, a type of short spear (Figure 6). Historically, the Doke (spear) is an instrument used by being thrust into the ground to generate Bionga (water). This act was performed by a woman named Panda, one of the Kaili people (to Kaili), who is referred to as a Tutua Bimbine (elder woman) and also known as a Madika (leader). The Doke is likewise used in other customary ceremonies, such as Notambuli (a wedding ritual). Buvu Bionga (a water well) and Doke are integral to traditional ceremonies, centered around the Bantaya a communal hall functioning as a medium and center of village information where important messages are delivered to the community. The Bantaya serves as a venue for traditional deliberations, communal feasts, ritual performances, and customary judicial processes (Arief et al., 2025).

Figure 6. Figure A. The Heirloom Doke or Spear that has Been Passed Down Through Generations. Figure B. The Heirloom Doke or Spear Wrapped in Yellow Cloth

Based on an ethnographic map produced by the Dutch researcher Kaudern, (Kaudern, 1925) who documented the travel notes of A.C. Kruyt during his expedition to the Palu Valley in 1897, there was an area named Petobo previously known as Jajaki which functioned as a polibu, or a place for communal deliberation. Jajaki also once served as the capital of Sigi before the administrative center was later relocated to Djandja (Biromaru) (Asita, 2021). The territory of Jajaki consisted of several parts, namely: Kinta, Varo, Nambo, Ranjabori, Pantaledoke, Pompempeno, and Kaluku Lei. The lineage of Dake (spear) custodians can be traced across several locations on Buvuvionga Street, including Kinta/Tondei 1 Street, Ranjule/Suharto Street, and Ranjabori/Teratai Street. The naming of Petobo was also rooted in the historical event of Taboge Bulava, a woman who was to be married to a young Kaili man from Tara, for whom a dowry and a water canal from the Kawatuna River were prepared as part of the Petambuli ceremony (a communicative wedding ritual symbolizing respectful entry into the household). This event became the foundational origin of the name, which later defined the identity and residence of the Petobo community (Asita, 2021).

The Existence of Bantaya and Buvu Bionga

The presence of Bantaya and Buvu Bionga (Figure 7), based on interviews with traditional leaders and local residents around these sites, is illustrated in Figure 4 within the Petobo settlement. The findings indicate: (1) The well (Buvu Bionga) is estimated to be approximately 300 years old, dating back to the Sigi-Biromaru Kingdom

period. Knowledge regarding its origins and preservation has been transmitted orally across generations. (2) The well water is utilized for healing practices. Those who believe in its sacred qualities consider that, with divine permission, it can cure illnesses a tradition that continues today. (3) The Bantaya had been constructed previously but collapsed due to age. It was rebuilt in 2017 and relocated closer to Buvu Bionga, now situated approximately one meter from the well. The earlier Bantaya was also located near Buvu Bionga and, at that time, was still under construction up to the roofing stage. (4) The area surrounding Bantaya and Buvu Bionga used to function as a park with benches arranged around the well. (5) The Bantaya was established to support communal customary meetings and healing rituals, specifically the No Balia ceremony.

Figure 7. Figure A. Buvu Bionga (Old Well) and Figure B. Bantaya or the Meeting room in the Post-Liquefaction Disaster in Petobo

The influence of the determining factors of Buvu Bionga on the Petobo settlement is presumed to be highly significant, particularly on nearby houses during the post-disaster period. Interviews with residents living around the site reveal evidence related to adaptation and morphology corresponding to the defined variables and indicators. These findings indicate that both spatial adaptation and morphological transformation occurred within the Petobo settlement due to changes in the physical environment following the disaster. Adaptation is defined as a process of transitioning from one state to another, wherein such transformation leads to the production of beneficial outcomes (Brock, 2000). It is further agreed that adaptation is strongly associated with the capacity for resilience, in which cultural customs and traditions remain preserved through generations despite substantial physical changes in the environment although certain residents may exhibit maladaptive behaviors. Adaptive behavior refers to the ability to effectively fulfill social and community expectations for personal independence, physical needs, and interpersonal relationships deemed appropriate for an individual ' s age and cultural group (Agran, 2016). Conversely, behaviors that interfere with daily functioning are categorized as maladaptive behavior, commonly referred to as problem behavior. Maladaptive behavior is considered undesirable, socially unacceptable, or disruptive to the acquisition of necessary skills or knowledge (Robert K. Bruininks, 1996).

The Influence of the No Balia Ritual (Healing Ceremony)

The use of the well water has become a routine practice conducted every two weeks as a preventive measure against disease and sudden calamities. Traditional activities are also commonly performed in temporary shelters and are planned to be conducted as well in the permanent housing area built in post-disaster Petobo. These customary practices will continue to take place in the Bantaya and within the vicinity of Buvu Bionga, including the Balia ceremony (Figure 6), which is a ritual dance rooted in the ancestral belief system of the Kaili people of Central Sulawesi. This belief system is based on veneration of deities and ancestral spirits. The strong belief in supernatural powers and the spirits of forebears persists, even after the introduction of formal religions into their lives. Myths remain inherited through generations and serve as a form of acknowledgment of sacred powers believed to bring blessings or misfortunes. Due to this belief, the Balia healing tradition continues to be practiced as a hereditary ritual, functioning as a means of maintaining a relationship with these sacred forces while seeking to cure illnesses believed to be caused by their anger. The Kaili people believe that maintaining a harmonious relationship with the forces governing nature is essential. These governing powers are personified as ancestors and deities (Arwan & Pitriani, 2017).

Figure 8 illustrates the adaptation process in the Petobo settlement following the liquefaction disaster through the lens of the Competence Press Model adapted from Lawton and Nahemow (1973). The model explains the dynamic interaction between individual and community competencies and the environmental pressures

arising after the disaster. In the post-liquefaction context, extreme environmental press such as land instability, loss of housing, and disrupted infrastructure forced residents to activate social, cultural, and spatial competencies to survive and re-establish daily life. These competencies are reflected in collective evacuation practices, the reuse of culturally significant spaces, and the gradual reconfiguration of settlement patterns. Adaptation occurred when a balance was achieved between reduced environmental press and enhanced community competence, allowing residents to remain, reorganize, and reconstruct their living environment despite ongoing risks. The figure highlights adaptation not as a static outcome, but as a continuous process shaped by cultural attachment (buvu bionga area), environmental constraints, and social resilience.

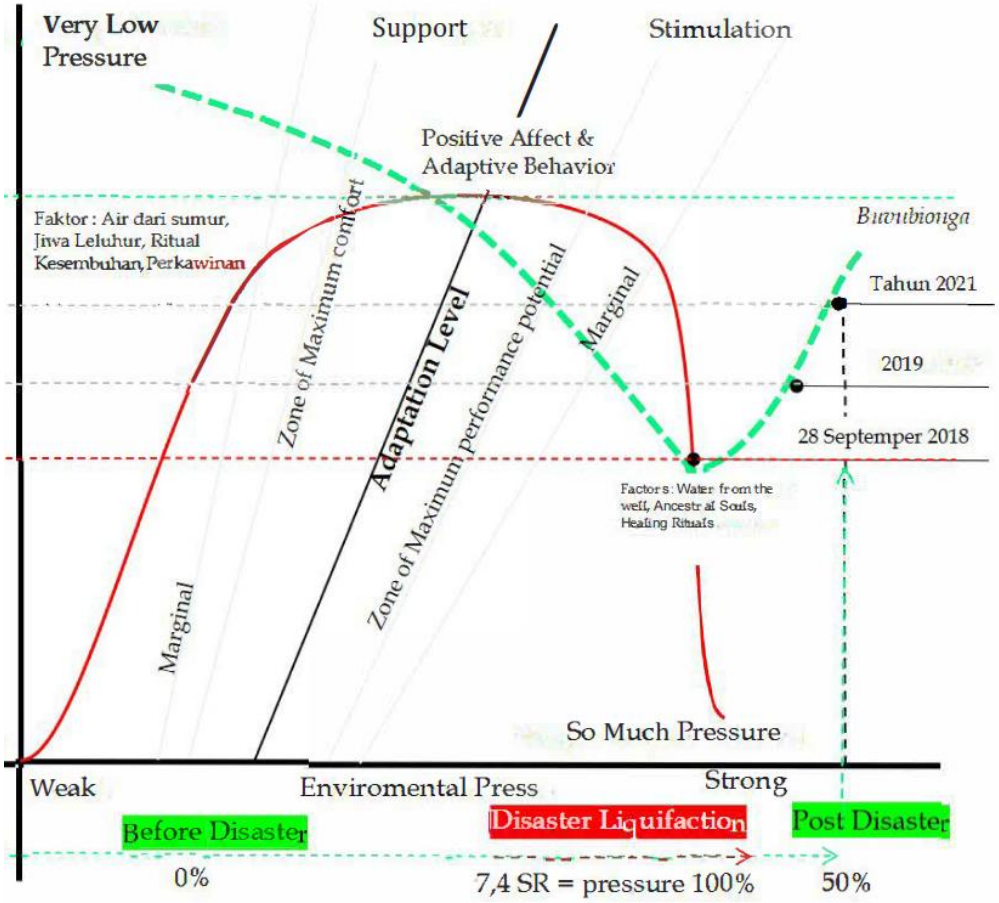

Figure 8. Adaptation in the Petobo Settlement after the Liquefaction Disaster ("Competence Press Model") (Adapted from (Lawton & Nahemow, 1973)

DISCUSSION

Recent information obtained from the Totua (traditional elders), who serve as customary council members and descendants of the custodians of the Doke (sacred spear), and who are also disaster survivors from Petobo, indicates that adaptive behavior has emerged within the new settlement environment (Huntap Satellite 800) or (Figure 9). This adaptive behavior reflects pre-liquefaction practices, including plans to construct a Bantaya (traditional gathering hall) and a new well to support ritual and customary activities. Although the new well does not possess the same symbolic status as the former one, the original well is planned to be restored and reused due to its significance as a powerful ancestral heritage. The development of this research therefore requires further investigation into the cultural meanings underlying the origins of the Kaili Ledo settlement in Raranggonau (Arief et al., 2024a), particularly from the perspective of cultural values embedded in spatial arrangements, housing forms, and communal activities, and how these elements are historically and symbolically connected to the Petobo settlement. These cultural continuities cannot be separated from the post-liquefaction disaster context in Petobo, where the interaction between water and soil during the earthquake generated massive mudflows. Historically, Petobo was favored as a settlement area due to its easy access to groundwater; residents were able to obtain water

by digging wells to a depth of approximately four meters. As a former wetland area, Petobo offered abundant water resources, which encouraged residents to establish their homes around the Petobo subdistrict.

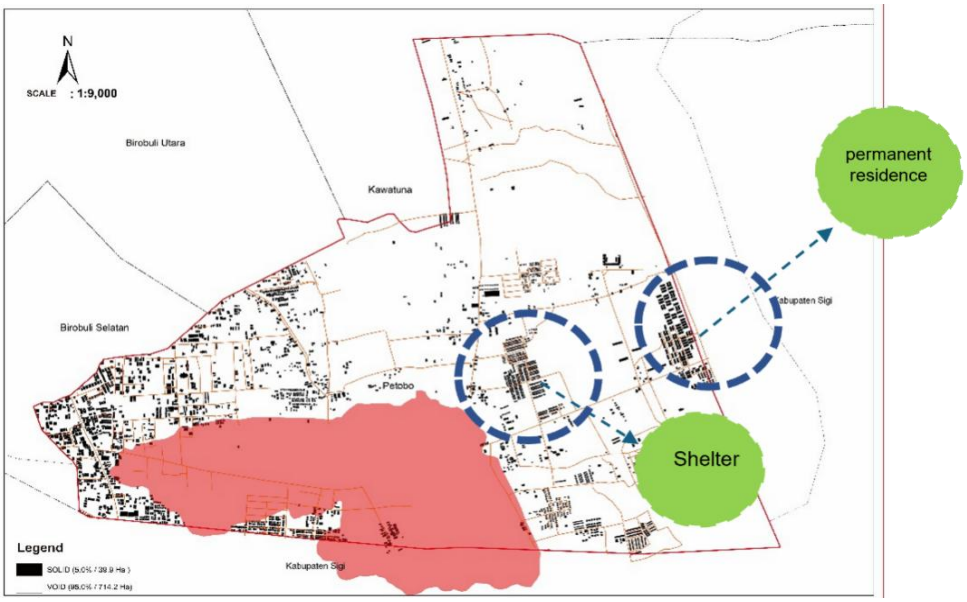

Figure 9. Locations of Temporary and Permanent Housing In Petobo. This Map is Adapted From the Hazard Map Published by the Government

CONCLUSION

This study demonstrates that post-disaster adaptation in the Petobo settlement cannot be understood solely through technical risk assessments or physical environmental change. Instead, it is deeply embedded in cultural meanings, historical continuity, and place-based attachment that shape community behavior following the 2018 liquefaction disaster. The findings confirm that Buvu Bionga has long functioned as a central spatial, cultural, and symbolic anchor in the historical development of the Petobo settlement and continues to play a decisive role in post-disaster adaptation.

First, diachronic analysis reveals that Buvu Bionga historically structured the spatial organization of Petobo by anchoring early settlement patterns, communal activities, and customary institutions such as the Bantaya. Its role as a water source, ritual center, and locus of collective memory established a durable spatial hierarchy that persisted across generations. This historical continuity explains why settlement patterns before the disaster were strongly oriented toward proximity to the well and associated communal spaces.

Second, the post-disaster period shows that proximity to Buvu Bionga significantly influenced settlement persistence despite extreme environmental disruption and official relocation policies. Although the area was classified as a high-risk liquefaction zone, residents continued to rebuild, repair, and occupy houses around the site often discreetly reflecting adaptive behavior rooted in cultural competence rather than technical rationality alone. Morphological analysis confirms that while building density fluctuated after the disaster, the open space around Buvu Bionga remained intentionally undeveloped, reinforcing its role as a protected communal and ritual landscape.

Third, Buvu Bionga continues to function as a powerful cultural and spatial reference that sustains community resilience. Ritual practices such as the No Balia healing ceremony, continued use of the well water, and collective activities centered on the Bantaya illustrate how cultural traditions mediate adaptation under conditions of environmental press. Interpreted through the Competence Press Model, the Kaili Ledo community demonstrates how cultural attachment, social cohesion, and shared beliefs enhance adaptive capacity, allowing residents to negotiate ongoing risk while maintaining continuity of identity and place.

Overall, this research highlights that post-disaster adaptation in Petobo is not merely a process of physical reconstruction but a culturally grounded negotiation between environmental pressure and community competence. The persistence of Buvu Bionga as a spatial and symbolic core underscores the importance of

integrating cultural landscapes, indigenous knowledge, and place attachment into disaster risk reduction and relocation policies. Ignoring these dimensions risks producing technically sound but socially unsustainable interventions. Future post-disaster planning in similar contexts should therefore adopt culturally responsive approaches that recognize historically significant spatial elements as integral to long-term resilience and community well-being.

REFERENCES

Agran, M. (2016). Book Review: Instruction of Students With Severe Disabilities by Brown, F., McDonnell, J., & Snell, M. E. (Eds.). *Research and Practice for Persons with Severe Disabilities*, *41*(4), 291-293. https://doi.org/10.1177/1540796916666803

Arief, I., Subroto, T. Y. W., & Marcillia, S. R. (2024a). Concentric Pattern of Spatial Setting in Raranggonau Village as the Ancestral Land Settlement of the Kaili Ledo Community, Central Sulawesi, Indonesia. *The International Journal of Architectonic, Spatial, and Environmental Design*, *18*(1). https://doi.org/https://doi.org/10.18848/2325-1662/CGP/v18i01/135-156

Arief, I., Subroto, T. Y. W., & Marcillia, S. R. (2024b). Family Bonds and Space Utilization in Indigenous Communities : The Sampesuvu-Roa Value in Kaili Ledo, Indonesia. *International Review for Spatial Planning and Sustainable Development*, *12*(3), 36-57. https://doi.org/10.14246/irspsd.12.3_36

Arief, I., Wahyu Subroto, T. Y., & Marcillia, S. R. (2025). Tambale: Behavior of Activities, Space, and Time in the Kaili Ledo Community, Central Sulawesi, Indonesia. *ALAM CIPTA International Journal Of Sustainable Tropical Design & Practice*, *18*(2). https://doi.org/https://doi.org/10.47836/AC.18.2.PAPER02

Arwan, A., & Pitriani, P. (2017). SYSTEMATIC REVIEWS: BALIA LOCAL WISDOM AS A HEALTHY SOLUTION TO KAILI. *Preventif: Jurnal Kesehatan Masyarakat*, *8*(2), 89-93.

Asita. (2021). Penguatan Pengetahuan Kekuatan Lokal Masyarakat dalam Kebencanaan Melalui Pengarsipan Digital [Prosiding]. *Prosiding International Conference of Indonesian Culture*. . https://doi.org/http://iconic.kebudayaan.online/wp-content/uploads/Prosiding-ICONIC2020.pdf

Bell, P. A. G. T. C. F. J. D. B. A. (2001). *Environmental psychology*. Lawrence Erlbaum.

Brock, J. P. (2000). 1 - Adaptation and the adaptive system. In J. P. Brock (Ed.), *The Evolution of Adaptive Systems* (pp. 1-26). Academic Press. https://doi.org/https://doi.org/10.1016/B978-012134740-6/50002-1

Chartier, A.-M. (2004). Teaching reading: A historical approach. In *Handbook of children's literacy* (pp. 511-538). Springer.

Jalil, A., Fathani, T. F., Satyarno, I., & Wilopo, W. (2021). Liquefaction in Palu: the cause of massive mudflows. *Geoenvironmental Disasters*, *8*(1), 21. https://doi.org/10.1186/s40677-021-00194-y

Jha, A. K. (2010). *Safer homes, stronger communities: a handbook for reconstructing after natural disasters*. World Bank Publications. http://documents.worldbank.org/curated/en/290301468159328458

Kals, E., Strubel, I. T., & Hellbrück, J. (2025). *Environmental psychology*. Springer. https://link.springer.com/book/10.1007/978-3-662-70739-5

Kaudern, W. A. (1925). *Ethnographical Studies in Celebes: Results of the Author's Expedition to Celebes, 1917-20* (Vol. 2). M. Nijhoff.

Lang, J. T. (1987). *Creating architectural theory : the role of the behavioral sciences in environmental design*. Van Nostrand Reinhold Co.

Lawton, M. P., & Nahemow, L. (1973). Ecology and the aging process. In *The psychology of adult development and aging*. (pp. 619-674). American Psychological Association. https://doi.org/10.1037/10044-020

Lazarus, R. S., & Folkman, S. (1984). *Stress, appraisal, and coping*. Springer publishing company.

Marzuki, B. (2012). *Adat Balia Petobo*. https://www.antarafoto.com/id/view/196152/adat-balia

Morales-Ramirez, C. A. (2025). Flags as Symbols of Place: Unpacking Geographic Meaning and Identity in Student Flag Designs.

Ntoumanis, N. (2001). A self-determination approach to the understanding of motivation in physical education. *British Journal of Educational Psychology*, *71*(2), 225-242. https://doi.org/10.1348/000709901158497

Oliver, P. (1997). *Encyclopedia of vernacular architecture of the world*.

Oliver, P. (2007). *Built to meet needs: Cultural issues in vernacular architecture*. Routledge. https://doi.org/https://doi.org/10.4324/9780080476308

Putri, T. N. (2020). Genius Loci Permukiman Nelayan Pantai Utara Tuban Jawa Timur (Studi Kasus: Kelurahan Kingking Dan Kelurahan Karangsari). *Jurnal Arsitektur ARCADE*, *4*(2), 101-106.

Relph, E. (1976). *Place and placelessness* (Vol. 67). Pion London.

Robert K. Bruininks, R. W. W., Richard F. Weatherman, and Bradley K. Hill. (1996). *SIB-R : Scales of Independent Behavior--revised*. Riverside Publiher Cooperation. (Riverside Pub)

Samalavičius, A., & Traškinaitė, D. (2021). Traditional Vernacular Buildings, Architectural Heritage and Sustainability. *Journal of Architectural Design and Urbanism*, *3*(2), 49-58.

Smith, K. (2013). *Environmental hazards: assessing risk and reducing disaster*. Routledge. https://doi.org/https://doi.org/10.4324/9780203805305

Subroto, T. Y. W. (2012). Latar as the Central Point of Houses Group Unit: Identifiability for Spatial Structure in Kasongan, Yogyakarta, Indonesia. *IPTEK The Journal for Technology and Science*, *23*(2). https://doi.org/http://dx.doi.org/10.12962/j20882033.v23i2.7

Surakhmad, W. (1994). *PENGANTAR penelitian ilmiah : dasar, metode dan teknik* (Ed.7,cet.5 ed.). Tarsito.

Sussman, A., & Hollander, J. (2021). *Cognitive architecture: Designing for how we respond to the built environment*. Routledge. https://api.pageplace.de/preview/DT0400.9781000403046A41594340/preview-9781000403046A41594340.pdf

Trancik, R. (1986). *Finding lost space : theories of urban design*. New York : Van Nostrand Reinhold, [1986] ©1986. https://search.library.wisc.edu/catalog/999573787802121

Tuan, Y.-f. (1977). *Space and place : the perspective of experience* (9 ed.). University of Minnesota Press. https://www.upress.umn.edu/9780816638772/space-and-place/

Vellinga, M., Oliver, P., & Bridge, A. (2024). *Atlas of vernacular architecture of the world*. Taylor & Francis. https://doi.org/https://doi.org/10.4324/9781003572459

Zhang, F., Loo, B. P., & Wang, B. (2022). Aging in place: From the neighborhood environment, sense of community, to life satisfaction. *Annals of the American Association of Geographers*, *112*(5), 1484-1499. https://doi.org/https://doi.org/10.1080/24694452.2021.1985954

ETHICAL DECLARATION

Conflict of interest: No declaration required. **Financing:** No reporting required**. Peer review:** Double anonymous peer review.