PURBAWIDYA
p-ISSN: 2252-3758, e-ISSN: 2528-3618 ■ Terakreditasi SINTA 2
berdasarkan SK Dirjen Riset dan Pengembangan KEMENDIKTISAINTEK Nomor: 10/C/C3/DT.05.00/2025
Vol. 15 (2), November 2026, pp 1018 – 1032 ■ DOI: https://doi.org/10.55981/purbawidya.2026.16247
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EVIDENCE OF *PIKUKUH TILU* PHILOSOPHY: ANALYSIS OF LAND USE SUSTAINABILITY IN THE BADUY INDIGENOUS AREA

Hermawan Setiawan[1*)], Zaharah[1)], Ulfah Fajarini[1)], and Mochammad Noviadi Nugroho[1)]

[1] Pendidikan Ilmu Pengetahuan Sosial, Fakultas Ilmu Tarbiyah dan Keguruan, UIN Syarif Hidayatullah Jakarta
Jl. Ir. H. Djuanda No. 95, Ciputat, Kota Tangerang Selatan, Banten 15412, Indonesia
**e-mail: Hermawan.setiawan@uinjkt.ac.id (Corresponding Author)*

Naskah diterima: 21 Juni 2026 - Revisi terakhir: 13 Oktober 2026
Disetujui terbit: 26 Oktober 2026 - Terbit: 11 November 2026

Abstract

The change of land from vegetated areas to built-up areas has a negative impact on the ecosystem if not managed and controlled. This study aims to analyze the dynamics of land use change and its relation to local values and the Pikukuh Tilu philosophy in the Baduy area in 2017 and 2026. The *Pikukuh Tilu* philosophy in this research relates to land use divided into *leweung larangan* and *leweung tutupan* with low NDBI class, while middle and high NDBI classes fall into the classification of *leweung badalahan.* This research uses a descriptive spatial quantitative approach through remote sensing with the Normalized Difference Built-up Index (NDBI) algorithm, based on Landsat 8 and 9 data. NDBI classification is divided into three categories: low class, which indicates forest or *leweung larangan* and *leweung tutupan*; middle class, which indicates agricultural areas or *leweung baladahan*; and high class, which indicates settlements and open land or *leweung baladahan*. The data are analysed using overlay and heatmap techniques to observe changes and their spatial distribution. The results showed that the majority of the Baduy area remains unchanged, with an area of 2,216.570 hectares in Baduy Luar and 1,145.391 hectares in Baduy Dalam. For land use change, the low and medium classes to high class total 66.693 hectares, while the medium and high classes to low class total 259.101 hectares in Baduy Dalam. Changes in Baduy Luar from high and medium classes to low class cover a total area of 513.581 hectares, and changes from low and medium classes to high class amount to 142.091 hectares. Land use indicates dynamic and controlled changes, realized through the Pikukuh Tilu concept. These findings provide empirical evidence that the philosophical values of local wisdom serve as a conservation instrument to maintain the sustainability and preservation of land use in the future. This philosophical value can certainly serve as a lesson for communities and the government in managing environmentally friendly spatial planning.

Keywords: *Pikukuh Tilu*, Remote Sensing, NDBI, Land Use, Baduy

INTRODUCTION

Land-use change has become one of the most significant environmental challenges, especially in developing countries, caused by urbanization and population growth (Tilahun et al. 2025). Urbanization drives the conversion of productive land into

buildings, while the population, in addition to promoting urbanization, increases the consumption of staple foods and encourages the opening of new agricultural land (Deb et al. 2025). Indonesia is a developing country facing the challenge of land change (Mustain and Djaja 2017; Juniyanti et al. 2021). Data shows that the net deforestation in 2024 amounts to 175.4 thousand hectares out of a total of 216.2 thousand hectares (Krisdianto 2024). The conversion of forests is mainly dominated by agricultural and plantation land (Juniyanti et al. 2021). This land change not only affects ecological systems (Wang et al. 2021), but also leads to economic losses (Yuping Bai et al. 2021) and social disturbances within local communities (Şahin et al. 2025).

The issue of land use change is not only a concern in the general community but also in indigenous communities (Onyeneke et al. 2024), which views nature not only as an economic resource but also as a cultural and spiritual asset (Alejo et al. 2025). Land use changes in indigenous communities are occurring alongside the challenge of food security needs (Lone and Mayer 2019) and an increasing population (Borelli et al. 2020). However, indigenous communities often maintain traditional ecological knowledge that regulates interactions between humans and nature (Alejo et al. 2025). This is reflected in environmental ethics, which emphasizes prohibitions and social norms against damaging nature for personal gain (Onyeneke et al. 2024).

There are many indigenous communities in Indonesia, one of which is the Baduy community, located in Banten Province (Hasim et al. 2026). The Baduy people maintain a traditional worldview that emphasizes harmony between humans and nature. Their land management system is governed by customary rules known as *Pikukuh Tilu*, which divide the landscape into three functional zones: *leweung larangan* or protected forest, *leweung tutupan* or buffer forest, and *leweung baladahan* or cultivation area (J. Iskandar and Iskandar 2017; Asteria et al. 2024). This zone is considered sacred and is strictly protected under Baduy customary law (*pikukuh*), which functions as an ecological balance and is off-limits for exploitation or human activity (Hasim et al. 2026). *Leuwueng Larangan* is a sacred customary forest that is forbidden and off-limits, not to be entered or exploited freely, which is a legacy from ancestors and a protection of nature (Silalahi and Purwanto 2025). *Leweung Tutupan* is a zone between protected forests and human activity areas, emphasizing the sustainability of environmental preservation (Asteria et al. 2024). *Leweung Baladahan* is designated for agricultural activities, including swidden farming or *ngahuma*, which is central to Baduy livelihoods. (J. Iskandar and Iskandar 2017). This zoning system is interesting to study, to see whether it is indeed true or not in the context of land changes.

Based on the latest information, since 2021 in the Cijahe area along the Cibarani River, the western part of Baduy, which borders Leuwidamar District, has been

experiencing frequent flash flooding (Kompas 2026). Flash floods indicate potential disturbances in upstream vegetation cover and watershed conditions (Brookhuis and Hein 2016). This can be linked to landscape transformation, which changes forest areas into agricultural land or built-up areas, which are caused by the growing population or economic pressures (Hurtado-Pidal et al. 2022). That's interesting, whether the incident was caused by changes within the Baduy area or outside of it.

Monitoring these changes requires an approach capable of capturing spatial patterns across large areas and long periods (Pushpalatha et al. 2024). Geographical information systems and remote sensing can be used to monitor these, utilizing the Normalized Difference Built-up Index (NDBI) (Isgenderzade et al. 2026). NDBI has been widely used to identify and map built-up areas because it can effectively distinguish artificial surfaces by using spectral information from the near-infrared (NIR) and shortwave infrared (SWIR) bands (Yaqing Bai et al. 2020). NDBI is very effective for analyzing land use changes, especially in built-up areas, compared to normalized difference vegetation index (NDVI) (Yaqing Bai et al. 2020). Satellite data from Landsat 8 and 9 can be used to analyze long-term trends and detect changes in built-up land (Isgenderzade et al. 2026). In relation to the philosophy of *Pikukuh Tilu*, the NDBI classification is divided into three, namely low-value NDBI which depicts a forest landscape, classified as *Leweung Larangan and Leweung Tutupan*; NDBI with a middle value indicates that plantations enter *Leweung Baladahan*, and NDBI with a high value represents built-up areas and bare land entering *Leweung Baladahan* areas.

Previous studies on the Baduy community have predominantly focused on traditional ecological knowledge (J. Iskandar and Iskandar 2017), cultural values (Hasim et al. 2026), environmental conservation (Silalahi and Purwanto 2025), and agricultural practices (Habiyaremye and Korina 2021). While these studies provide valuable insights into the relationship between culture and the environment, quantitative analyses of spatial land-use changes remain limited (B. S. Iskandar et al. 2024; Asteria et al. 2021; J. Iskandar and Iskandar 2017). In particular, there remains insufficient understanding of how settlement distribution and land-cover patterns have evolved over time within the Baduy region, and whether these changes differ between Inner and Outer Baduy areas.

Therefore, this study aims to analyse the spatio-temporal dynamics of land use, which is based on *Pikukuh Tilu* in the Baduy region, using the Normalized Difference Built-up Index (NDBI) derived from Landsat 8 and 9 *imageries*. It is then conducted with spatial overlay analysis and heatmap analysis, which can seek to identify patterns of land-cover transformation, assess the extent of settlement development, and provide empirical evidence regarding landscape changes within a traditional indigenous territory. The findings are expected to contribute to the understanding of land-use dynamics in

customary landscapes and support future conservation and sustainable land management strategies in the Baduy areas.

METHOD

Study Area

The study was conducted in the Baduy customary territory, located in Lebak Regency, within the southern part of Banten Province. The population of Baduy in 2024 is 10,172, with 5,478 males and 4,694 females. This region covers approximately 4,895.87 hectares and is administratively divided into two customary zones: Inner Baduy *(Baduy Dalam)* with an area of about 1,637.88 hectares and Outer Baduy *(Baduy Luar)* covering approximately 3,257.99 hectares (BPS 2025). This area includes Leuwidamar District, which borders Bojongmatik and Cirinten villages to the west, Bojong Menteng, Cisimeut Raya, and Nabayari to the north, Cigemblong to the south, and Sobang to the east. The area is characterized by hilly topography, dense tropical vegetation, and a traditional land management system that is strongly governed by customary law (BIG 2025).

Data Preparation

This study utilizes multi-temporal satellite imagery and geospatial data to analyze land-use dynamics and settlement patterns within the Baduy customary territory. To ensure high accuracy and precision, all primary datasets underwent rigorous geometric and radiometric corrections before analysis (Yaqing Bai et al. 2020). The spatial data acquisition focused on the Normalized Difference Built-up Index (NDBI) as the primary indicator for mapping artificial surfaces, such as infrastructure and residential structures (Benoumeldjadj et al. 2025). For this purpose, multi-temporal Landsat 8 and 9 imagery were employed to capture land-use changes, especially in built-up areas, over 9 years, from 2017 to 2026.

The NDBI calculation was performed using the spectral information from the Shortwave Infrared (SWIR) on band 5 and Near-Infrared (NIR) on band 6, leveraging the characteristic high reflectivity of built-up areas in the SWIR band compared to the high energy reflectance of vegetation in the NIR band (Bhatti and Tripathi 2014; Yaqing Bai et al. 2020). The data is required from U.S. Geological Survey (*https://earthexplorer.usgs.gov*/). Furthermore, supporting geospatial data, including regional administrative boundaries and topographical characteristics, were integrated to provide a comprehensive landscape context. Those data are obtained from the Geospatial Information Agency (BIG) (*https://tanahair.indonesia.go.id/).* These combined datasets enable a robust assessment of settlement development and land-use transformation within the unique ecological zoning of the Baduy areas.

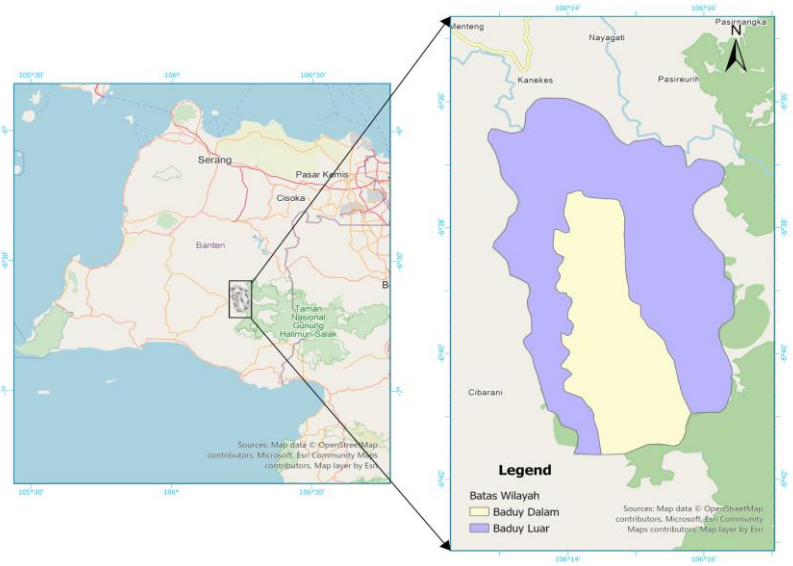


Figure 1. Location of Study

Data Processing

The Normalized Difference Built-up Index (NDBI) is a spectral index used to analyze built-up areas such as roads, infrastructure, and settlements (Bhatti and Tripathi 2014). The first step in processing the Landsat 8 and 9 satellite image data is geometric correction to make it accurate and precise (Setiawan et al. 2023). This correction emphasizes aligning the coordinate system to match the study area. In this research, WGS UTM 48S was used, which is precisely located in the Baduy areas. The second is radiometric correction to display pixel changes by adjusting TOA radiance and surface reflectance (Zhang et al. 2018). The third step is to cut the satellite image with the study area, Baduy, using the boundary vector data (Zhu 2024).

The last step is processing using NDBI indices. In Landsat 8 and 9 satellite imagery data, it uses band 6 (SWIR) and band 5 (NIR). Band 6 is able to reflect built-up land more strongly than other bands, while NIR can detect high-energy reflections from vegetation, so the formula can be written as follows (Magpantay et al. 2019):

$$\text{NDBI} = \frac{SWIR-NIR}{SWIR+NIR} \quad \text{..... (1)}$$

Where :
SWIR :Band 5
NIR : Band 6

Using this formula, it is known that the area that is dense with buildings is low,

which can be seen in Table 1. Then an overlay analysis was carried out to find out the pattern and spatial distribution of each class, and a heatmap analysis was used to find out the location where the most changes from one class to another (Bhatti and Tripathi 2014).

Table 1. Correlation of NDBI, Land use, and Pikukuh Tilu

No	NDBI Classification	Land Use	*Pikukuh Tilu*
1	Low	Forrest	*Leweung Larangan and Tutupan*
2	Middle	Plantations	*Leweung Baladahan*
3	High	Bare land and Settlement	*Leweung Baladahan*

RESULTS AND DISCUSSION

Spatial Distribution of NDBI

The results of the NDBI index analysis over a nine-year period (2017-2026) show the dynamics of land use in the Baduy areas. Based on Figure 1, the spatial distribution exhibits a uniform pattern: the northern part is forested or classified as low, the central to southern areas are plantation regions, while *bare land* or built-up areas are scattered in the western and eastern regions. Besides that, Figure 2(B), the changes that occurred were not in all areas, which indicated that the unchanged area was 1,145,391 hectares for the Inner Baduy, and 2216,570 for the Outer Baduy. Figure 2(A) shows the change in Inner Baduy, the data shows from the low class to the middle class and the middle class to the low class has an area of 112,689 hectares and 242,044 hectares, respectively. As for the change of land from the low class and the middle class to the high class, it has an area of 12,565 hectares and 54,129 hectares, respectively. Therefore, the low and middle class to the *high-class* total 66,693 hectares, while from the middle and high class to the low class it totals 259,101 hectares. This shows that there is a balance and sustainability related to land use in the Inner Baduy area (Habiyaremye and Korina 2021).

This condition explains the very good ecological balance that occurs in Inner Baduy. The increase in NDBI values indicates that the potential expansion of open land or built-up areas does not show significant dominance compared to the change from bare land or built-up areas to forest vegetation. This finding certainly reinforces previous research that explains that the Baduy community is very conservative in maintaining the noble values of *Pikukuh Tilu*, which are divided into three, namely *Leweung Tutupan*, *Leweung Baladahan*, and *Leweung Larangan* (Silalahi and Purwanto 2025).

Meanwhile, the Outer Baduy from the high to low class and the middle to low class, with an area of 31,786 hectares and 481,795 hectares, respectively. This condition indicates a change from built-up land and bare land to vegetated areas, either plantations

or forests, which shows a very strict effort to preserve nature. Meanwhile, the areas from low to high class and middle to high class are 87,706 hectares and 54,385 hectares, respectively. This suggests a change from forest and plantation vegetation to built-up areas. Therefore, the change from the low and middle classes to the high is smaller compared to the change from the middle and high classes to the low.

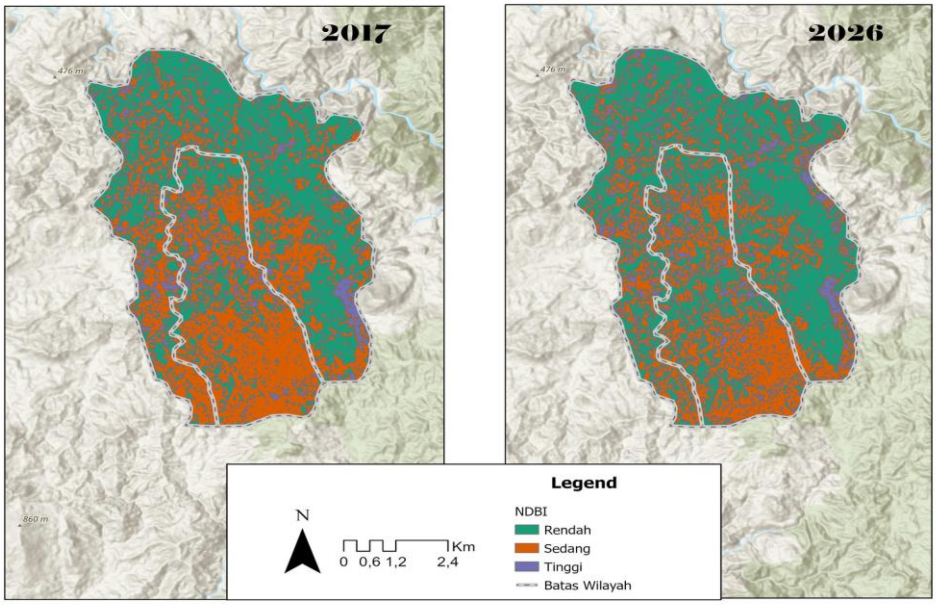
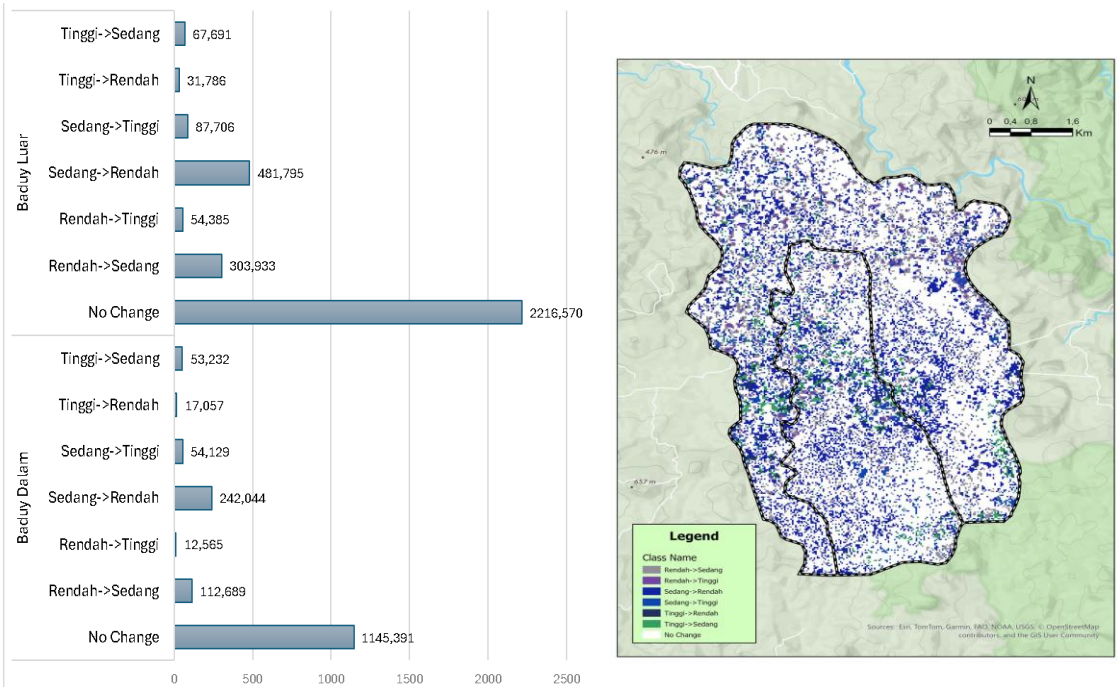


Figure 2. Map of Distribution of NDBI change in the Baduy Areas

Based on the data, it can be inferred that the Outer Baduy is not only the ruler of nature but also part of the ecological system that maintains balance and sustainability (Asteria et al. 2021). Change cannot be completely avoided, but it can be directed and limited so as not to damage the environment (Damanhuri et al. 2026). The Outer Baduy serves as an example of how indigenous communities can adapt to various pressures of modernity without losing the principles of sustainability (Kenedy and Deffinika 2022). This finding reinforces previous research stating that the Baduy community highly preserves wisdom and environmental conservation based on strong customary mechanisms.



(A) (B)

Figure 3. (A) Change in the area of Baduy from 2017 to 2026 (hectares), (B) Map of land use change between 2017 and 2026.

Therefore, this research provides novelty by integrating geographic information system (GIS) and remote sensing approaches using NDBI in 2017 and 2026. The novelty emphasises the spatio-temporal aspect to analyse land use changes, especially built-up areas, and serves as evidence that *Pikukuh Tilu* depicted in land use management, namely *leweung larangan* and *leweung tutupan* reflected in low NDBI, while *leweung baladahan* are shown in the middle and high NDBI classes. It turns out that it is not only a philosophical concept but has also been manifested in the activities of the Baduy community both inside and outside. (Silalahi and Purwanto 2025). The recovery of vegetation and environmental stability maintained by the Baduy community demonstrates a preserved socio-cultural system (Şahin et al. 2025). It is hoped that this can contribute to sustainability and serve as a model for environmental management for Indonesian society and globally.

Pikukuh Tilu and the Sustainability of Land Use

The Pikukuh Tilu, in this context, is a concept of land-use division that exists in Sundanese society and is found in Baduy. It is divided into three: *Leweung Tutupan, Leweung Baladahan, and Leweung Larangan*, and has proven to be an effective conservation instrument. In Figure 2 (A), the Inner Baduy tends to be stable with a decrease in built-up land of 3,329 hectares, from 85,963 hectares to 89,292 hectares, while

the Outer Baduy experienced a decrease of about 80 hectares, from 228,168 hectares to 184,88 hectares. This indicates that there are relatively small changes in built-up or bare land conditions, suggesting the *Pikukuh Tilu* philosophy. Additionally, it serves as evidence that the Baduy community has dynamic and well-maintained land changes. The *ngahuma* system or shifting cultivation, which causes the appearance of bare land in satellite data, is not a sign of permanent deforestation but part of a rain-fed agricultural cycle that will eventually revert to forest vegetation.

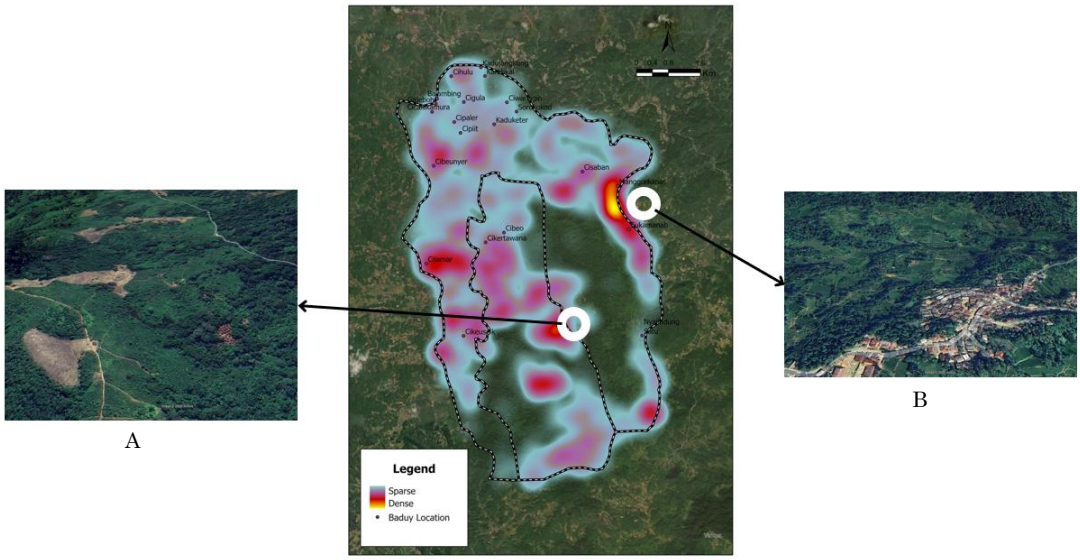


Figure 4. Heatmap Analysis

Figure 3. heatmap analysis explains the pattern of land use changes in the Baduy area, illustrating a gradient from blue to yellow, which indicates that the closer to yellow, the more developed the area is, and vice versa. Figure 3 (A) shows open land surrounded by low vegetation, indicating a shifting or swidden farming system, known as *huma* in Baduy Sundanese (Lindawati et al. 2024). This farming system provides land for fallow periods after planting, allowing the area to become lush again. This is a manifestation of the *Pikukuh Tilu* system (Figure. 4) (Taryana et al. 2020). Meanwhile, Figure 3 (B) shows a densely populated settlement area, which, upon closer analysis, is not inhabited by the Baduy community but by outsiders living within the Baduy territory. This is indicated by the roofing material of the buildings using tiles and the presence of irrigated rice fields. The Baduy community has houses with roofs made from *'injuk'*—fiber from the aren palm—and practices shifting cultivation rather than irrigated rice farming, which indicates an expansion of surrounding residents' land into the Baduy customary area (Yulia et al. 2018; Ichwandi and Shinohara 2007).

Agriculture in the Baduy region is cultivated once a year, as part of maintaining

soil fertility and treating the land like family. In the context of *Pikukuh Tilu*, the sustainability and continuity of farming in Baduy society are formed through a balance between protected areas (*Leweung Larangan*), which serve as buffers (*Leweung Tutupan*), and the areas that are utilised (*Leweung Baladahan*) (Asteria et al. 2024; Silalahi and Purwanto 2025). Stable land changes within the Baduy area and the regeneration patterns of vegetation in outer Baduy further strengthen this customary system's ability to preserve and control space according to its ecological boundaries (Taryana et al. 2020). Additionally, the Baduy community does not reject change but manages it through traditional values and culture that sustainably balance human needs with environmental preservation. Given these conditions, the flash flood event on the Cijahe River is driven by land-use changes outside the Baduy area.

The geographic information system approach is capable of analyzing and providing strong evidence in the application of the *Pikukuh Tilu* philosophy in the daily life of the Baduy community (Yaqing Bai et al. 2020). Heatmap analysis illustrates that the traditional landscape is not static but undergoes controlled dynamics, shifting functions according to environmental capacity (Maciejewski et al. 2010). These findings enrich previous studies that viewed the Baduy areas and community from social (Asteria et al. 2024) , architectural (Hasim et al. 2026), and environmental perspectives (Silalahi and Purwanto 2025), without providing empirical evidence that cultural systems can serve as sustainable land use systems.



(A) (B)

Figure 5. Huma Process in Baduy Community
Source : (A) *https://www.porosjakarta.com/nusantara/062903403/hari-ini-petani-badui-mulai-tanam-padi-huma* , and (B) *https://hypeabis.id/hypephoto/8543/menanam-padi-ala-suku-baduy*

CONCLUSION

Land use changes pose a challenge, especially when land shifts from vegetation to built-up areas, which can have negative impacts if not managed and controlled. The dynamics of land use in the Baduy customary area over a nine-year period (2017-2026) show controlled changes, characterised by the majority of land remaining unchanged,

with an area of 2,216.570 hectares in Outer Baduy and 1,145.391 hectares in Inner Baduy (Figure 2(A)). Meanwhile, the change from low (*leweung larangan and tutupan*) and middle class (*leweung baladahan*) to high class (*leweung baladahan*) totals 66.693 hectares, while from middle and high class (*leweung baladahan)* to low class (*leweung larangan and tutupan*) amounts to 259.101 hectares in Inner Baduy. Changes in Outer Baduy from high and middle classes (*leweung baladahan*) to low class (*leweung larangan and tutupan*) cover a total area of 513.581 hectares, and from low (*leweung larangan and tutupan*) and middle class (*leweung baladahan*) to high class (*leweung baladahan*) total 142.091 hectares. Both Inner and Outer Baduy exhibit controlled changes, including forest to plantation, to buildings, and vice versa.

The controlled land changes in Baduy demonstrate sustainability in environmental preservation. The community's adherence to the *Pikukuh Tilu* system and the practice of shifting cultivation called *huma or ngahuma* have become an inseparable part of daily life in the Baduy community. Additionally, the presence of bare land is part of the forest regeneration cycle after *huma* harvests, not permanent deforestation. In addition, the flash flood incident that occurred in the Cibarani River is a result of land changes outside of Baduy. The existence of settlements with irrigation systems and tiled roofs indicates infiltration by surrounding communities into Baduy territory. Therefore, future research is expected to combine qualitative approaches, such as in-depth interviews, to better understand the social dynamics influencing land use patterns or agriculture among the Baduy community. Furthermore, the use of empirical NDBI data can demonstrate the effectiveness of local wisdom in maintaining ecological balance within the area, which is useful for spatial planning on a broader scale.

Acknowledgement

Thanks are extended to the UIN Syarif Hidayatullah Jakarta, which has helped, and also to the colleagues who have supported in completing this manuscript.

AI Declaration

The paper of *"Evidence of Pikukuh Tilu Philosophy: Analysis of Land Use Sustainability in The Baduy Indigenous Area"* used Gemini, Scopus AI, and Grammarly for literature retrieval, research idea generation, and grammatical refinement, with all outputs thoroughly verified for academic integrity.

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