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What Maps Reveal and Generational Views of Peri-Urban Landscape Change in Hulu Langat, Malaysia

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Abstract
This study examines the relationship between spatial landscape change and community perception within Hulu Langat's peri-urban region. LANDSAT imagery from 1989 to 2019 revealed substantial land-use/ land-cover (LULC) changes identified through unsupervised classification. A structured survey (n = 406) captured residents' perceptions of these changes. Findings show that forest loss was consistently recognized across all age groups, whereas agricultural land and water bodies change diverged, particularly among younger cohorts. This divergence underscores how older respondents link landscape transformation with fading cultural identities and suggests that the gradual loss of generational memory may diminish recognition of the earlier peri-urban landscape character.

Keywords: Peri-urban; LULC change; GIS; Generational views

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1.0 Introduction

Peri-urban landscapes are increasingly pressured by urban expansion, infrastructure development, and population growth. These transitional zones often undergo rapid land-use changes, which alter ecological systems and impact community identity (Salem et al., 2025). In Southeast Asia, such areas are exceptionally dynamic, combining intense development pressures with remnants of traditional rural environments (Smith, 2021). Hulu Langat in Selangor, Malaysia, exemplifies this transformation. Once dominated by forest, agricultural land, and river-based livelihoods, the district has experienced rapid industrialization, suburban growth, and infrastructure expansion in recent decades (Majid et al., 2018; Mat Isa et al., 2023). These physical changes also reshape how communities perceive and remember their environment, influencing attitudes toward conservation, land management, and policy acceptance.

Integrating GIS-based land cover mapping with perception studies has been increasingly recognized as essential for understanding landscape change holistically (Rane et al., 2023). GIS and remote sensing provide measurable evidence of land use/land cover (LULC) transformation, while social surveys capture lived experience, attachment, and awareness (Gebeyehu et al., 2023). Together, these approaches bridge the gap between "what maps reveal" and "what people perceive," enabling planning decisions that consider both spatial realities and human values. However, few Malaysian studies have systematically compared satellite-derived LULC change with generational differences in perception. Most research focuses on either biophysical mapping or environmental awareness, with limited

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integration of the two. Even less attention has been given to how younger, middle-aged, and older cohorts interpret landscape transformation, despite their differing experiential baselines and implications for long-term stewardship.

From a cognitive perspective, landscape perception is shaped by visibility and selective attention, where individuals notice change that is visually prominent or symbolically significant in everyday life (Chen et al., 2023). Built-up expansion and infrastructure growth are therefore more readily recognized than gradual ecological transitions. Perception is also filtered through memory and place attachment, where long-term residents rely on historical comparisons, while younger residents interpret the landscape through contemporary visual cues (Zhang et al., 2025). Cohort and period effects further reinforce these differences by linking life-stage experience with the timing of development pressures.

Understanding landscape change requires recognizing that people's perceptions do not always reflect actual spatial transformation but are shaped by what is visible, remembered, and experienced over time. This study therefore aims to integrate GIS-based land use/land cover (LULC) analysis with a community perception survey in Hulu Langat. The objectives are to: (i) identify changes in key landscape elements between 1989 and 2019 using GIS analysis; (ii) examine how different age groups perceive these landscape changes; and (iii) compare mapped LULC changes with perceived landscape change across five landscape elements: forest, water bodies, cleared land, agricultural land, and built-up areas. By combining spatial data with community perceptions, this study provides insights into generational differences in interpreting peri-urban landscape change and supports more responsive planning strategies.

2.0 Literature review

Peri-urban areas are increasingly recognized as transition zones where rural and urban characteristics intersect. Global scholars have highlighted the rapid transformation of their communities under urban expansion, infrastructure development, and population growth (Lv et al., 2012). These pressures contribute to forest loss, agricultural land decline, and the expansion of built-up areas, resulting in ecological impacts such as habitat fragmentation and sociocultural effects, including the erosion of traditional practices and the loss of landscape identity (FAO & UNEP, 2020). In Asia, where urbanization is particularly intense, peri-urban transformation presents significant spatial and policy challenges.

Remote sensing and GIS serve as primary tools for documenting these dynamics, with LANDSAT imagery widely used to analyze multi-decadal LULC change. Both supervised and unsupervised classifications have detected deforestation, urban sprawl, agricultural conversion, and hydrological modification (Selmy et al., 2023). In Malaysia, GIS-based studies report substantial restructuring around metropolitan regions, typically showing declining forest cover and continuous expansion of built-up zones (Ma et al., 2024). Although geospatial analyses offer objective evidence, they do not capture how communities interpret or assign meaning to such changes. Landscape perception research emphasizes that responses to environmental change are shaped by cultural values, social memory, and generational experience (Su et al., 2025). Studies indicate that older generations often frame landscape transformation in terms of concerns about heritage loss and ecological decline, while younger cohorts may perceive the same changes in terms of modernization and development opportunities (Bowden et al., 2025). Surveys, interviews, and participatory mapping show that perceptions of landscape change are influenced not only by biophysical conditions but also by lived histories, attachments, and shifting temporal baselines, issues that are particularly salient in peri-urban settings experiencing rapid transformation.

Recent scholars, therefore, argue that integrating GIS-based mapping with perception studies provides a more holistic understanding of landscape change (Taye et al., 2023). Such integration helps identify where community perceptions align with or diverge from verified land transformations, revealing gaps in awareness, limitations in policy communication, or intangible cultural values not captured in spatial datasets. Generational analysis enriches this approach by recognizing that age cohorts construct distinct perceptual baselines shaped by life stages and historical exposure to developmental pressures, an aspect still underexplored in landscape studies. Despite the growth of research on peri-urban change internationally, existing studies rarely examine how perceptual baselines vary by age, or how communities interpret landscape change beyond biophysical metrics. These gaps highlight the need for research that attends to visibility, lived experience, and the temporal depth of resident-landscape relationships in rapidly urbanizing contexts.

3.0 Material and Methods

3.1 Study area

The study was conducted in the Hulu Langat sub-district, a peri-urban area on the southeastern fringe of the Klang Valley, Selangor, Malaysia (Figure 1). It represents one of the state's fastest urbanizing zones, characterized by a transition from forested highlands to agricultural valleys and expanding residential areas. Proximity to Kuala Lumpur and major transport routes, such as the Cheras-Kajang Highway and the SILK Expressway, has intensified land conversion along forest and agricultural edges, despite extensive gazetted reserves under the National Forestry Act. Hulu Langat sub-district was selected as the study area due to its rapid peri-urban transformation and its strategic location at the urban-rural fringe of the Klang Valley. The area exhibits a clear transition from forested and agricultural landscapes to residential and infrastructural development, making it representative of peri-urban dynamics occurring across many fast-growing regions in Malaysia. Additionally, the availability of long-term satellite imagery and demographic diversity within the district provides a suitable context for examining both spatial landscape change and generational perception differences.

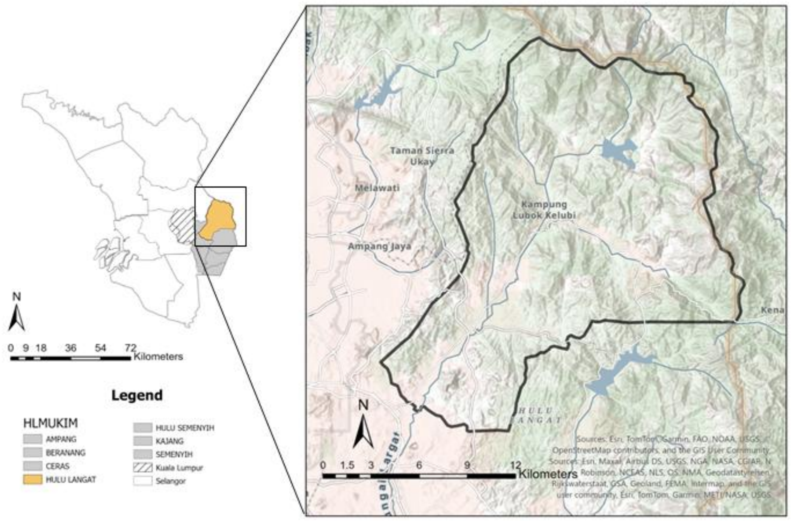


Fig. 1: Location of the Hulu Langat study area within Selangor, Malaysia, showing sub-district boundaries
(Source: Esri basemap; produced by Author)

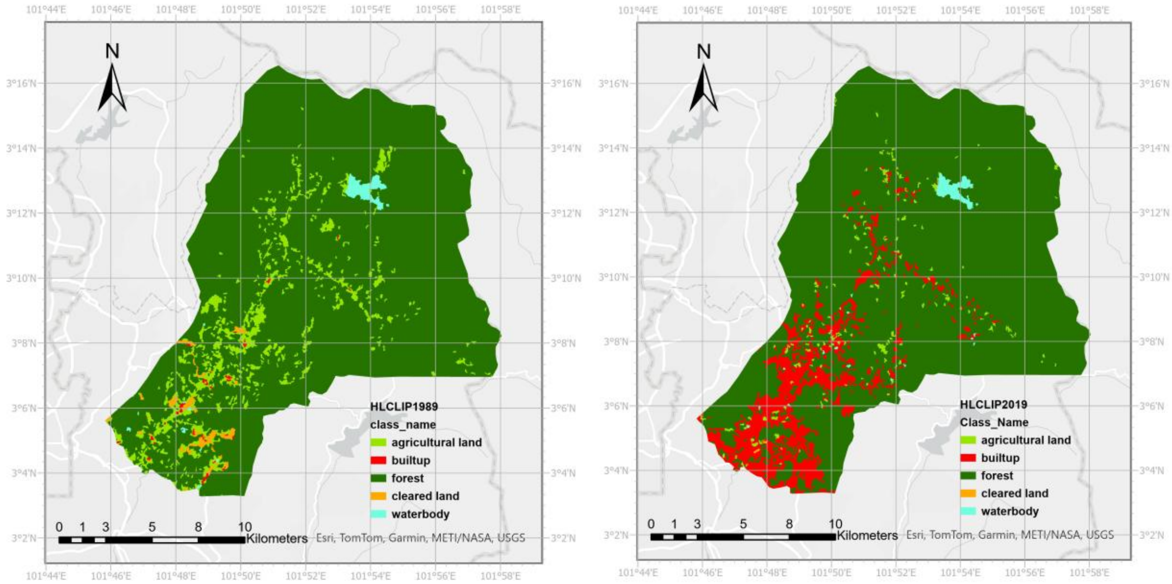
3.2 Remote sensing data
LANDSAT imagery served as the primary dataset for examining three decades of peri-urban landscape transformation for this study. LANDSAT 5 TM (1989) and LANDSAT 8 OLI (2019) scenes were obtained from the USGS Earth Explorer platform and subset to the Area of Interest (AOI) covering the Hulu Langat district. Processing was conducted in ArcGIS 10.2 at 30 m resolution, with atmospheric correction and geometric rectification performed in ERDAS Imagine 9.2. An unsupervised ISODATA classification was applied to derive five land-use classes of forest, agricultural land, waterbodies, cleared land, and built-up areas. Accuracy assessment was conducted for the entire Hulu Langat district classification to ensure the overall reliability of the model, using 250 random validation points per year, with reference data sourced from the Department of Agriculture (DOA). For reporting, the validated district-wide classification was clipped to the Hulu Langat sub-district to match the boundary of the perception survey. This ensured spatial and social datasets shared the same geographic extent while retaining the accuracy values of the original district-wide model.

3.3 Perception data
Community perception data provided the social dimension for interpreting landscape change. A structured questionnaire survey was administered to 406 residents of the Hulu Langat sub-district, complementing the GIS-based LULC analysis. Respondents were Malaysian citizens aged 18–70 years and long-term residents of the local landscape, selected using a stratified random sampling procedure proportional to the sub-district population (~250,000), ensuring adequate representation across settlement types and age groups. The survey instrument, developed through a systematic literature review and expert validation, captured perceptions of changes across five key landscape elements: forest, agricultural land, water bodies, built-up areas, and cleared land. Items were rated on a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). An example item includes*:* "Over the past 20-30 years, the amount of built-up development in my area has increased significantly". Respondents were grouped into three age cohorts: those below 20 years (born after 2004), 20-39 years (born 1985-2004), and above 40 years (born before 1985), representing different levels of temporal exposure to landscape change. To avoid priming effects, participants were not shown maps or satellite imagery; all responses reflected memory-based and experiential perception. The instrument demonstrated strong internal consistency (Cronbach's $\alpha = 0.815$), exceeding the recommended threshold of 0.70 for exploratory studies. Cronbach's α was computed to verify that the five items formed a coherent perceived-change scale, though subsequent analyses examined each element separately. Data were coded and analyzed using SPSS v.29, applying descriptive statistics and one-way ANOVA to test for significant generational differences ($p < 0.05$) in perceived landscape changes.

4.0 Findings

4.1 Land Use/Land Cover (LULC) Change
The overall classification accuracy reached 88.4 % for 1989 and 86.7 % for 2019, with corresponding Kappa coefficients (κ) of 0.83 and 0.81, indicating 'almost perfect agreement' between classified and reference data (Landis & Koch, 1977). Class-level accuracies were highest for built-up (>90 %) and forest (>85 %) categories, while moderate confusion occurred between cleared and agricultural classes. Both values exceed the commonly accepted benchmark of 85%, indicating strong agreement beyond chance and validating the robustness of the classification results (G. Congalton & Green, 2008). Between 1989 and 2019, the built-up areas increased by 3,079.83 ha, primarily at the expense of forest, agricultural land, and cleared land. Specifically, forest decreased by 1,008.30 ha, water bodies by 16.53 ha, cleared land by 252.41 ha, and agricultural land by 1,802.58 ha. The relatively small percentage of forest loss reflects the

presence of extensive gazette forest reserves within the Hulu Langat sub-district, which remain legally protected under the National Forestry Act. These areas constitute a large proportion of the sub-district's total land area, thereby stabilizing forest cover over the 30 years. However, urban expansion has intensified along the forest periphery, particularly near the boundary zones adjoining residential and road networks, indicating progressive edge development pressures. These changes reflect the dual pressures of urban expansion and demographic growth in the peri-urban fringe.



(a) 1989 (b) 2019

Fig. 2: Land-use/land-cover (LULC) in Hulu Langat sub-district, Selangor, Malaysia for (a) 1989 and (b) 2019, classified into five classes (forest, agricultural land, cleared land, built-up, water bodies) from district-wide land-use data. Both maps use the same symbology

(Source: Author)

To calculate the percentage change for each land-use class between 1989 and 2019, the total LULC change was computed using:

$$LULCChange(\%) = \frac{A_{2019} - A_{1989}}{A_{1989}} \times 100 \quad (1)$$

Where A_{1989} and A_{2019} represent the area (ha) of each land-use category in the base and final year, respectively. This formula provides proportional change over the 30-year period and aligns with common practice in land-change studies for summarizing category-level transformations.

Table 1. LULC change rate from 1989 to 2019

Sub-district	Change information	Land use type				
		Forest	Water bodies	Cleared land	Agricultural land	Built-up
Hulu Langat	Area change (ha)	-1008.30	-16.53	-252.41	-1802.58	+3079.83
	Percentage Change (%)	-1.88	-3.55	-91.61	-68.58	+95.14
	Rank	2	3	5	4	1

Note: Negative values indicate area loss between 1989 and 2019; positive values indicate area gain. Rank values correspond to the magnitude of percentage LULC change, ordered from the largest positive gain (Rank 1) to the largest negative decline.

(Source: Author)

4.2 Perception of landscape change

To evaluate internal consistency, a reliability analysis was conducted for the perceived changes scale, which comprised items related to landscape transformation (forest, water bodies, cleared land, agricultural land, and built-up areas). Cronbach's Alpha coefficient was 0.701, meeting the acceptable threshold of 0.70 for exploratory studies (García-García et al., 2024). This confirms that the items were sufficiently interrelated to justify aggregation on a composite scale. Table 2 revealed significant age-related differences in perceptions of landscape change across several land use categories. ANOVA revealed a significant effect of age on perceived agricultural change ($F(2,403) = 4.91$, $p = .008$, partial $\eta^2 = .02$). Post-hoc tests indicated that the ≥40 group reported significantly greater change than the younger cohorts. No statistically significant differences were found for perceptions of forest, water bodies, or cleared land. These results suggest that older individuals may perceive landscape transformation more acutely, potentially due to the influence of longer-term memory and personal experience.

4.3 Synthesis of GIS and Perception Results

Integrating GIS-based LULC analysis with age-stratified perception data clarifies how different generations interpret landscape change in Hulu Langat. While GIS results show clear biophysical transformations from 1989 to 2019, perceptions vary across age groups, influencing how respondents assess the intensity and visibility of landscape change.

Table 2. Perceived landscape change across age cohorts (ANOVA results)

Landscape Element	Age Group	N	Mean	SD	F	p	Partial η²	Rank
Forest	< 20 years	106	4.08	0.74	2.64	0.07	0.01	4
	20–39 years	165	4.02	0.84				5
	≥ 40 years	135	4.23	0.75				4
	Total	406	4.11	0.79				
Water bodies	< 20 years	106	4.18	0.71	0.45	0.64	0.00	2
	20–39 years	165	4.27	0.74				2
	≥ 40 years	135	4.23	0.76				4
	Total	406	4.23	0.74				
Cleared land	< 20 years	106	4.08	0.82	2.10	0.12	0.01	4
	20–39 years	165	4.04	0.95				4
	≥ 40 years	135	4.24	0.71				3
	Total	406	4.12	0.84				
Agricultural land	< 20 years	106	4.11	0.81	4.91	0.008*	0.02	3
	20–39 years	165	4.26	0.80				3
	≥ 40 years	135	4.42	0.69				2
	Total	406	4.28	0.77				
Built-up area	< 20 years	106	4.19	0.63	12.15	< 0.001*	0.06	1
	20–39 years	165	4.42	0.64				1
	≥ 40 years	135	4.58	0.55				1
	Total	406	4.41	0.63				

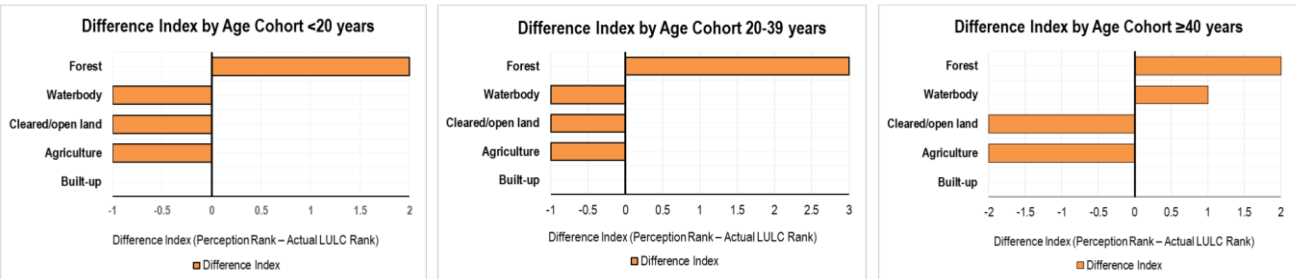
Note: * $p < 0.001$. Partial η^2 effect sizes small ($\eta^2 = .01$), medium (.06), large (.14). Age cohorts are defined as: <20 years (born after 2004), 20–39 years (born 1985–2004), and ≥40 years (born before 1985). Ranks are assigned per age cohort only; the total row is not ranked.
(Source: Author)

4.3.1 Perception-Reality Divergence by Age Cohort

Because actual LULC change (%) and perceived landscape change (mean Likert scores) are measured on different scales, both variables were independently ranked to enable direct comparison. A simple Difference Index (DI) was then computed to quantify perceptual divergence between perceived and actual LULC change for each age cohort:

$$DI = \text{Perception Rank} - \text{Actual LULC Rank} \quad (2)$$

Where positive DI indicates over-perception (respondents perceived more change than actual), negative DI indicates under-perception, DI = 0 indicates accurate alignment.



(a) (b) (c)

Fig. 3. (a-c) Difference index between perceived and actual LULC change across age cohorts (<20, 20–39, ≥40 years).
(Source: Author)

Figure 3 (a-c) shows that forest change was over-perceived across all cohorts, especially among adults aged 20-39 (DI = +3), despite minimal actual loss. Water bodies change showed minor perceptual differences, with slight under- or over-estimation across groups (DI = –1 to +1). In contrast, agricultural and cleared land were consistently under-perceived, with older respondents showing the largest divergence (DI = –2), and younger cohorts showing smaller under-perception (DI = –1), likely due to diminished day-to-day visibility and strong place-based familiarity. Built-up land was the only element with DI = 0 across cohorts, reflecting its high visibility and consistent recognition. Given multiple ANOVAs across five elements, the results were interpreted cautiously. The two significant findings (agricultural land and built-up areas) remain robust even under a conservative Holm–Bonferroni adjustment.

4.3.2 Built-Up Area
LULC shows built-up land increased by +95.14%. Perception scores were highest for this element across all age groups, with older adults reporting the greatest perceived change ($M = 4.58$). ANOVA confirmed significant differences ($F = 12.15$, $p < 0.001$, partial $\eta^2 = 0.06$). DI = 0 across all cohorts indicates complete alignment between mapped and perceived change.

4.3.3 Agricultural land
LULC change for agricultural land declined by –68.58%. Older respondents reported the greatest perceived change ($M = 4.42$), which was significantly higher than that of younger cohorts ($F = 4.91$, $p = 0.008$, partial $\eta^2 = 0.02$). DI values were -2 for individuals aged 40 and older and -1 for younger groups, indicating under-perception relative to the actual decline.

4.3.4 Forest and Water bodies
Forest (–1.88%) and water bodies (–3.55%) LULC changes were small, consistent with the absence of significant perceptual differences ($p > 0.05$). Forest was over-perceived by all cohorts, with the largest DI among adults aged 20–39 (DI = +3). Water bodies perception remained close to mapped change (DI = –1 to +1).

4.3.5 *Cleared Land*
Cleared land showed the largest decline in LULC mapped areas (–91.61%). Perception scores were moderate ($M = 4.04$ to 4.24) with no significant cohort differences ($F = 2.10$, $p = 0.12$). DI values (–1 to –2) indicate general under-perception of its magnitude.

5.0 Discussions

The results reveal apparent generational differences in how residents perceive landscape change in Hulu Langat. Older respondents reported higher awareness of agricultural land decline and built-up expansion, reflecting more prolonged exposure to the district's transition from agrarian landscapes to an increasingly urban environment. Younger cohorts, raised in a predominantly urban setting, showed reduced sensitivity to historical landscape features, a pattern consistent with environmental generational amnesia, where shifting experiential baselines redefine what is perceived as ‘normal’.

Built-up expansion was the only landscape element accurately perceived across all age groups, reflecting its strong visibility and functional prominence in daily life. Urban development is often encountered in residential areas, along road networks, and within commercial spaces, making it a cognitively dominant and easily recognizable feature. In contrast, the decline in agricultural land showed only partial alignment with perception: older adults recalled the district's agrarian past, whereas younger residents were less aware of the long-term decline in farmland. This divergence reflects Hulu Langat's trajectory, where agriculture and smallholder cultivation were central through much of the twentieth century before rapid urbanization in the late 1980s and 1990s reshaped the landscape.

Ecological elements such as forests and water bodies showed limited mapped change but varying perceptual divergence. Forest loss was over-perceived, especially among adults aged 20 to 39, indicating heightened ecological sensitivity despite minimal actual decline. Much of Hulu Langat's forest is legally protected, meaning change occurs mainly along edges; such subtle shifts are challenging to detect spatially but may be amplified through symbolic associations with environmental degradation. Water bodies’ perception was relatively accurate, likely due to their smaller extent and stable presence. Cleared land showed the most significant mismatch, despite a major decline, all cohorts underperceived its magnitude. As transitional and visually ambiguous spaces, neither entirely natural nor urbanized, lack perceptual stability and are easily misinterpreted. Overall, the synthesis of spatial and perceptual results reveals that landscape change in peri-urban settings is interpreted through visibility, experiential memory, and shifts in generational baselines. These dynamics underscore the need to incorporate demographic nuance into planning, communication, and design strategies, particularly in rapidly transforming regions like Hulu Langat. While this study is geographically focused on Hulu Langat, the findings offer insights that are transferable to other peri-urban regions experiencing similar patterns of rapid urban expansion, land-use transition, and demographic change. The results should be interpreted as context-specific rather than universally generalizable; however, the integrated GIS-perception approach provides a replicable framework that can be applied to other peri-urban settings in Malaysia and comparable Southeast Asian contexts.

6.0 Conclusion

This study documents significant peri-urban transformation in Hulu Langat from 1989 to 2019, with major built-up expansion and declines in agricultural and cleared land. While GIS data captured the extent of change, perception data revealed that older residents were more attuned to these shifts than younger cohorts, highlighting differences in their lived experiences and historical memories. Physical change and perceptual awareness evolve at different rates. Combining spatial evidence with perception data helps identify landscape elements of ecological and cultural values, such as forest edges, river corridors, and agricultural remnants, that can guide planning and design actions to retain local identity. A key limitation of this study lies in its focus on a single peri-urban district, which may constrain broader generalization; nevertheless, the depth of spatial and perceptual analysis strengthens its internal validity. Urban expansion is ongoing, but its effect on landscape character depends on how development is spatially organized. Preserving ecological and cultural fragments as design anchors supports continuity within new growth. Embedding GIS analysis, participatory tools, and landscape-literacy initiatives into planning practice can ensure that future peri-urban development remains ecologically resilient and culturally legible across generations.

Paper Contribution to Related Field of Study

This paper bridges GIS-based LULC analysis with community perceptions, advancing inclusive approaches to peri-urban planning.

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