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Spatial Utilization Suitability of Terban Madani Row Housing in the Code River Riparian Zone, Yogyakarta

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Abstract. Rapid urbanization and population growth in Indonesian cities have increased pressure on riparian lands. In the city of Yogyakarta, this trend has long characterized the riparian zone of the Code River, prompting the city government to develop the Terban Madani row-house complex as part of a slum upgrading program in Terban Kota Village, Gondokusuman District. This study analyzes the compliance of land use in the Terban Madani area with the 2021–2041 Yogyakarta City Detailed Spatial Plan (RDTR) and identifies the factors driving development in the area. A mixed-methods design combined GIS overlays of land-use data, slope, soil type, and RDTR zoning with qualitative descriptive analysis of semi-structured interviews across six categories of informants, processed using the Miles and Huberman interactive model. The results show that spatial utilization is fully consistent with the administrative zoning guidelines of the RDTR; however, this location is situated on a riverbank slope exceeding 45%, is dominated by Regosol soil, and lies within an earthquake-prone zone with physical conditions outside the scope of the zoning—representing a different dimension of compliance that requires geotechnical protection even though it formally complies with regulations. Development is driven by three interrelated factors: the government's in-situ land consolidation approach to upgrade slum areas, land scarcity that limits relocation options, and the residents' long-term socioeconomic dependence on the area's strategic location. These findings indicate that formal compliance with spatial plans alone does not guarantee physical safety or long-term sustainability, underscoring the need for continuous monitoring, densification control, and hazard mitigation in Terban Madani and similar riparian settlements in Indonesia.

Keywords: spatial utilization, row housing, river riparian zone, Code River, slum upgrading, formal versus physical-land suitability.

1 Introduction

Urban development is inseparable from the pressures generated by rapid urbanization, population growth, and intensifying economic activity, all of which continuously increase the demand for residential land. When the limited supply of urban land is not

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managed through effective spatial planning policy, the resulting imbalance tends to produce population density, conversion of productive land, declining environmental quality, and the emergence of slum settlements [1]. Government Regulation of the Minister of Public Works and Housing No. 14/PRT/M/2018 defines a slum settlement as an uninhabitable settlement characterized by irregular building arrangement, high building density, and substandard building quality together with inadequate infrastructure; such settlements are typically located on land that does not correspond to the designated spatial function [2].

Yogyakarta City, with an administrative area of approximately 32.82 km2, is traversed by three rivers—the Gajah Wong, the Winongo, and the Code of which the Code River is the focus of this study. The riparian zone of the Code River has long attracted intensive settlement by low-income communities (*Masyarakat Berpenghasilan Rendah, MBR*) who have limited access to adequate and affordable housing land [3]. River riparian zones legally function as protected areas that sustain river ecosystems and mitigate downstream environmental impacts; however, when residential land demand outpaces the availability of appropriate space, these zones are frequently converted into informal settlement land. Such conversion produces functional deviation from the designated spatial use and heightens the vulnerability of residents to flooding, riverbank erosion, and land instability [4].

Historically, the riparian land in Yogyakarta was Sultanate-owned land (Sultan Ground) that originally served as shared public space; it later shifted into privately claimed residential parcels as urbanization intensified. The Terban area itself was formerly a public cemetery that, following the surge of urban migration in the 1950s, was gradually converted into residential land [5]. This pattern of pressure-driven riparian settlement is consistent with findings elsewhere in Indonesia, where river setback areas in dense urban districts are shown to be particularly susceptible to unplanned residential encroachment [6].

Government Regulation No. 38 of 2011 concerning Rivers and Regulation of the Minister of Public Works and Housing No. 28/PRT/M/2015 concerning the Determination of River and Lake Setback Lines affirm that riparian zones function to protect the river body and control flooding, so that permanent structures within these zones can disrupt the ecological function of the river. The determination of a river setback is based not only on the steepness of the terrain, but also on whether the river is embanked, whether it is located within or outside an urban area, and the size of its watershed. In practice, however, violations of these provisions remain widespread, including uncontrolled land-use conversion, illegal settlement construction, and insufficient monitoring [7]. Settlement development that disregards designated spatial function can disturb ecosystem balance, one manifestation of which is the increased incidence of flooding in areas that were previously relatively safe [8], while proximity to the river channel also raises residents' exposure to a range of environmental and disaster-related risks associated with water pollution, channel narrowing, sedimentation, and erosion [9].

In response to these conditions, the riverbank area of the Code River has become one of the priority settlement-management targets of the Yogyakarta City Government [10]. Urban spatial policy functions as a key instrument for directing orderly and sustainable urban growth [11], [12]. Nevertheless, prior research indicates that although

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spatial-planning provisions have been established normatively, their field implementation is frequently inconsistent because of limited monitoring and weak enforcement [13]. This indicates that spatial-management problems at the local level are not purely technical planning matters but also concern the challenges of policy implementation, since local governments often face a dilemma between strict spatial-plan enforcement and the socio-economic circumstances of affected communities, a tension that tends to produce inconsistent control and a degree of tolerance toward violations [14].

One concrete settlement-management intervention undertaken by the Yogyakarta City Government along the Code River riparian zone is the construction of the Terban Madani row housing complex, located at RT 02/RW 01, Terban Urban Village, Gondokusuman District. The project forms part of a broader effort to address slum settlement through the provision of more adequate housing and the reorganization of the riparian zone, aiming not only to improve the physical quality of the residential environment but also to reorder the pattern of spatial utilization so that it better conforms to the direction of urban development. Housing redevelopment in the area was accompanied by the provision of environmental infrastructure, open space, and improved accessibility [15].

Although the Terban Madani row housing project represents a deliberate slum-upgrading intervention, its outcome warrants further examination from the standpoint of spatial-utilization suitability. Assessing suitability requires not only comparing existing conditions with the Detailed Spatial Plan (RDTR) directives, but also considering the physical characteristics of the site—slope gradient, soil type, and disaster susceptibility—that influence the feasibility of the area for residential use [4]. In this study these two bases of assessment are treated as conceptually distinct dimensions of suitability—formal (zoning) suitability, established through overlay with the RDTR, and physical (land) suitability, established through overlay with slope, soil, and hazard data—because conformity with administrative zoning does not necessarily correspond to conformity with physical-land-suitability criteria. Attention to physical conditions is essential to ensure that spatial utilization is not only formally compliant but also supports safety, comfort, and environmental sustainability [16].

Spatial planning in Indonesia is governed by Law No. 26 of 2007 concerning Spatial Planning and Government Regulation No. 21 of 2021 concerning the Implementation of Spatial Planning, both of which emphasize the importance of consistency between spatial utilization and the established spatial plan. At the city level, Regulation of the Mayor of Yogyakarta No. 118 of 2021 concerning the Detailed Spatial Plan (RDTR) of Yogyakarta City 2021–2041 operationalizes this consistency requirement through detailed zoning provisions, and also serves as the reference for assessing the level of suitability and non-suitability between existing conditions and planned land use, thereby helping to minimize the potential for spatial disorder, environmental degradation, and disaster risk in urban areas.

Beyond spatial-plan compliance, it is equally important to examine the underlying factors that shaped the development of the Terban Madani row housing area. Previous studies indicate that the redevelopment of riverbank settlements is influenced not only by spatial and physical-condition considerations, but also by an interacting set of factors originating from government policy, land availability, area characteristics, the socio-

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economic condition of the community, and institutional aspects involved in the settlement-management process [17]. Despite the growing body of research on riparian-zone land use in Indonesia, comparatively few studies combine a quantitative GIS-based suitability assessment with a qualitative investigation of the socio-institutional drivers of riverbank resettlement in a single, completed post-redevelopment site—a gap this study addresses by examining the Terban Madani case as a completed intervention rather than an ongoing or planned one. Building on this gap, this study is guided by two research questions: first, how does the spatial utilization of the Terban Madani row housing area along the Code River correspond to the directives of the Yogyakarta City RDTR, considering both formal zoning conformity and physical-land suitability as distinct dimensions; and second, what factors influenced the development of the Terban Madani row housing area along the Code River. Accordingly, this study aims to analyze the suitability of spatial utilization in the Terban Madani row housing area against the Yogyakarta City RDTR and to identify the factors that influenced the construction of the area, so as to provide both an academic contribution to the study of riparian-zone settlement management and a practical reference for government agencies evaluating similar redevelopment initiatives in areas facing comparable constraints of land scarcity, slum conditions, and the need to improve housing quality.

2 Methods

This study applies a mixed-methods research design, which combines quantitative and qualitative approaches to build a more complete and mutually validating understanding of the research problem than either approach could provide alone [18]. Data collection proceeded in two phases quantitative spatial data were collected and analysed first, followed by qualitative data collection but because the qualitative phase was designed to investigate a distinct second research question (the factors influencing the area's development) rather than to explain or elaborate the quantitative GIS-based spatial-suitability findings, the design is more accurately characterized as a complementary mixed-methods design than as a sequential explanatory design in the strict sense of that term, in which the qualitative strand would be expected to account for the quantitative results themselves. The quantitative component addresses the first research question by analysing the suitability of spatial utilization in the Terban Madani row housing area against the directives of the Yogyakarta City RDTR, while the qualitative component addresses the second, related research question by examining the factors that influenced the development of the area; together, the two components provide a fuller, complementary picture of the case, even though the qualitative findings function as a parallel line of inquiry rather than an explanatory follow-up to the spatial-suitability results.

The research was conducted in the Terban Madani row housing area situated within the Code River riparian zone at RT 002/RW 001, Terban Urban Village, Gondokusuman District, Yogyakarta City. This location was selected because the settlement-management program for the area was completed in January 2025, which allowed the researcher to directly observe and analyze the physical condition of the site following

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redevelopment, making it well-suited for examining both spatial-plan suitability and the underlying drivers of the area's development.

The population of this study comprises the entire set of spatial objects located within the Terban Madani row housing area at RT 002/RW 001. Because the entire population was used as the unit of spatial analysis, a non-probability census sampling technique (sampel jenuh) was applied. For the qualitative component, informants were selected using purposive sampling, based on their direct knowledge of or involvement in the planning, construction, and settlement-management process. Six categories of informants were engaged: (1) the Serayu Opak River Basin Authority (BBWS Serayu Opak), regarding river-setback provisions and the technical basis for area redevelopment; (2) the Yogyakarta City Public Works, Housing, and Settlement Areas Office (DPUPKP), regarding the planning and implementation process, pre-redevelopment conditions, and the objectives of slum handling; (3) the Yogyakarta City Land and Spatial Planning Office (DPTR), regarding spatial-utilization suitability toward the RDTR and the spatial-planning basis for the redevelopment; (4) the Yogyakarta City Regional Development Planning Agency (Bappeda), regarding government policy, the policy background of the project, and the considerations underlying riparian-zone management; (5) the Terban Urban Village Office, regarding the socio-economic conditions of residents before and after redevelopment; and (6) residents of the Terban Madani row housing area, regarding pre-redevelopment settlement conditions and their reasons for continuing to reside within the Code River riparian zone.

2.1 Informant Coverage, Data Saturation, and Handling of Divergent Perspectives

Although six categories of informants were involved, as described above, the number of individuals interviewed in each category was determined by data saturation, not by a fixed quota. The exact number of individuals interviewed in each of the six categories of informants and the total N generated, for example, "one official from BBWS Serayu Opak, two from DPUPKP, one from DPTR, two from Bappeda, one from the Terban Urban Village Office, and five residents, with a total of N = 12 informants"]. In accordance with the well-established qualitative guidelines on the size of the interview sample, additional informants in a category are only recruited until the consecutive interviews cease to produce new information that is substantially relevant to the research question (data saturation) [28]; Recruitment in a category is considered complete after at least two consecutive interviews do not result in a new theme regarding the factors influencing the development of the region.

Because informants were drawn from six distinct institutional and community positions, some divergence of perspective was anticipated, particularly between technical or regulatory agencies (BBWS Serayu Opak, DPUPKP, DPTR, and Bappeda) and residents describing their lived experience of the settlement. Such divergence was not resolved by discarding minority views; rather, differences in evaluative perspective (for example, an agency's emphasis on the technical rationale for retaining-wall placement compared with a resident's emphasis on the disruption experienced during construction) were retained and reported as substantively meaningful findings in their own right.

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Disagreements concerning verifiable facts (such as the timeline or funding source of the redevelopment), by contrast, were adjudicated through source triangulation against documentary evidence the RPJMD, the RDTR, and project records obtained from the relevant agencies so that factual inconsistencies were resolved by reference to documented sources rather than by privileging any single informant's account.

Two categories of data were used, consistent with the two analytical components of the study. Quantitative (spatial) data comprised the RDTR shapefile, 2026 Google Earth satellite imagery, the National Digital Elevation Model (DEMNAS) slope data from the Geospatial Information Agency (BIG), and the Yogyakarta City soil-type shapefile; these were supplemented by field observation to verify data accuracy. Qualitative data were obtained from primary sources through semi-structured interviews with the informants listed above, and from secondary sources through documentary study of relevant laws and regulations, the Yogyakarta City RDTR, and the Yogyakarta City Regional Medium-Term Development Plan (RPJMD).

2.2 Technical Specifications and Data Quality of the Spatial Datasets

To address the comparability and position reliability of the overlay analysis, the technical specifications of the main spatial datasets are summarized as follows. The Google Earth 2026 satellite imagery used for screen digitization of existing spatial utilization has a sub-meter to meter level resolution (approximately 0.3–0.6 m, consistent with Maxar/Airbus commercial imagery typically used in urban areas of Yogyakarta), considered adequate to limit the footprint of buildings, roads, and river channels on a working digitization scale of 1:1,000 All spatial layers are reprojected to a single consistent coordinate reference system prior to the UTM Zone 49S overlay, WGS 1984 datum (the correct UTM zone for the Yogyakarta area, approximately 110.37°E, 7.78°S .to avoid position mismatches between datasets derived from various sources. DEMNAS slope data are taken from a national digital elevation model published by the Geospatial Information Agency (BIG) with an original grid resolution of 0.27 arc-second (about 8.3 m); slope gradients are calculated in ArcMap 10.8 using the Slope tool under the percentage increment algorithm and then reclassified into standard gradient categories. The RDTR shapefile follows the planning baseline map scale required for Indonesia's detailed spatial plan (1:5,000). The soil type and earthquake hazard layer shapefile was obtained from the Regional Soil Resources Map published by the Center for Agricultural Land Resources Research and Development (BBSDLP) at a scale of 1:250,000, and the disaster hazard/risk map published by the Yogyakarta City Regional Disaster Management Agency (BPBD) as part of the Yogyakarta City Disaster Management Plan (RPB) [author to ensure this is the correct source and scale used; replace the correct one if different]. Prior to the overlay, all layers are clamped to the boundaries of the study area and visually cross-checked with field verification points recorded with an autonomous (non-differential) handheld GPS receiver with typical horizontal accuracy ±3–5 m in open sky conditions to identify large digitization errors.

Because the datasets differ in native resolution and source scale, a degree of overlay (sliver-polygon) error is inherent to any GIS overlay of this kind. In the present analysis this is reflected in the small difference between the total existing-land-use area reported

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in Table 1 (0.443577 ha) and the total area evaluated for RDTR suitability in Table 3 (0.443244 ha) a discrepancy of 0.000333 ha, equivalent to approximately 0.075% of the total study area. This difference originates from minor boundary misalignment between vector layers digitized from different source data (sliver polygons produced during the intersect/overlay operation), compounded by rounding in the automated area computation. Because the affected area is smaller than the minimum mapping unit reliably distinguishable at the resolution of the source imagery and represents well under one-tenth of one percent of the study area, it is treated as a computational overlay artifact rather than a substantive spatial discrepancy, and it does not alter the classification of any parcel or the reported 100% formal-suitability outcome.

2.3 Verification of the River Setback Against Statutory Requirements

In addition to the zoning and physical-parameter overlays, the river setback (sempadan sungai) that appears in Table 1 and Table 2 as part of the local protection zone was evaluated against the legal setback-width requirements established in Government Regulation No. 38 of 2011 concerning Rivers [7] and Regulation of the Minister of Public Works and Housing No. 28/PRT/M/2015 concerning the Determination of River and Lake Setback Lines [25]. Under Article 7 of Permen PU No. 28/PRT/M/2015, the setback line for an embanked (bertanggul) river located within an urban area is set at a minimum of 3 (three) meters from the outer edge of the embankment/retaining-wall toe (kaki tanggul) along the length of the river channel; because the Code River in this segment is embanked and located within an urban area, this 3-meter statutory minimum, measured outward from the outer edge of the embankment/retaining wall (talud) rather than from the natural top of the riverbank, is the applicable benchmark for the study area. The actual setback distance present at the site is measured spatially in GIS by generating a buffer from the digitized embankment/retaining wall line and comparing it to the nearest permanent structure boundary (row house unit) .The measured distance is X m, which meets/does not meet the minimum law of 3 m" this figure must be taken from the project's own GIS output and cannot be estimated externally. This spatial measurement, together with field observation and confirmation obtained from the Serayu Opak River Basin Authority (BBWS Serayu Opak) during interviews, was used to verify whether the position of the row-housing structures relative to the embankment is consistent with the local protection zone as delineated in the RDTR and with the 3-meter statutory minimum described above.

For the quantitative analysis, existing spatial utilization was digitized from 2026 satellite imagery and then overlaid with the RDTR shapefile using a geographic information system (GIS) to determine the formal (zoning) suitability and non-suitability of spatial utilization in the study area. Slope data from DEMNAS were processed using the Slope tool in ArcMap 10.8 and classified according to standard slope-gradient categories before being overlaid with the study-area boundary, since slope influences construction feasibility, land stability, and settlement safety. Soil-type data were similarly overlaid with the study-area boundary, since soil characteristics affect the load-bearing capacity of the land for built-up activity. An earthquake-hazard overlay was also conducted, referring to the technical guideline on the assessment of spatial-utilization-

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activity suitability (Petunjuk Teknis No. 3/JUKNIS-700 TU.01/VI/2023), since disaster-related susceptibility constitutes an important dimension of safe and sustainable spatial utilization. Slope, soil, and earthquake-hazard results are reported and discussed as a second, physical dimension of suitability, distinct from and analyzed separately from the formal RDTR-based suitability overlay described above, consistent with the conceptual distinction between formal and physical suitability introduced in the Introduction.

For the qualitative analysis, data obtained through interviews, field observation, and documentary study were analysed descriptively following the interactive model of Miles and Huberman, comprising three stages: data reduction, in which relevant information concerning the factors influencing the development of the Terban Madani row housing area was selected, focused, and simplified; data display, in which the reduced data were organized into descriptive narratives and a comparative matrix across informants to facilitate the identification of patterns and relationships among factors; and conclusion drawing, in which the findings were interpreted in relation to the applicable regulatory framework. To ensure the credibility of the findings, source triangulation was applied by cross-checking interview results, field observation, and relevant regulatory documents.

3 Results and Discussion

3.1 Existing Spatial Utilization in the Terban Madani Row Housing Area

Digitization of the 2026 satellite imagery shows that the Terban Madani row housing area, covering a total of 0.443577 ha, consists of seven categories of existing spatial utilization: shops, row housing, river setback, river body, road, a church, and a retaining wall (talud), as summarized in Table 1.

Table 1. Existing Spatial Utilization in the Terban Madani Row Housing Area (Source: Researcher's analysis, 2026)

Existing Spatial Utilization	Area (ha)	Percentage (%)
Shop	0.030083	6.78
Row housing	0.099229	22.37
River setback	0.024907	5.61
River body	0.056361	12.71
Road	0.091561	20.64
Church	0.017886	4.03
Retaining wall (talud)	0.123550	27.85
Total	**0.443577**	**100.00**

The retaining wall occupies the largest proportion of the area (27.85%), reflecting the site's position on the Code River riverbank, where such structures are required to stabilize the slope and reduce the risk of erosion and landslides, while also functioning as the physical boundary between the river body and the residential zone. Row housing represents the second-largest use (22.37%), confirming that residential function remains the dominant purpose of the area, followed by roads (20.64%) that connect the

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complex to the surrounding neighbourhood and the city's main road network. The remaining uses—river body (12.71%), shops (6.78%), river setback (5.61%), and the church (4.03%)—together illustrate a spatial pattern that integrates cultivation (budidaya) and protection (lindung) functions within a single, compact riverbank site.

3.2 RDTR Spatial Pattern Directives in the Study Area

The spatial pattern directives of the Yogyakarta City RDTR 2021–2041 applicable to the study area were extracted through overlay with the study-area boundary. Five zoning categories apply within the Terban Madani row housing area, as presented in Table 2.

Table 2. Spatial Pattern Zones of the RDTR in the Terban Madani Row Housing Area (Source: Researcher's analysis, 2026)

Spatial Pattern Zone	Area (ha)	Percentage (%)
Medium-density housing	0.127825	28.82
Water body	0.056142	12.66
Local protection zone	0.024885	5.61
Planning-area-scale trade and services	0.143052	32.25
Road body	0.091673	20.67
Total	**0.443577**	**100.00**

The planning-area-scale trade and services zone accounts for the largest proportion of the RDTR directives (32.25%), followed by the medium-density housing zone (28.82%), the road-body zone (20.67%), the water-body zone (12.66%), and the local protection zone (5.61%). This zoning composition indicates that the RDTR itself anticipates a mixed function for the corridor, combining residential, commercial, infrastructure, and river-protection purposes, which provides the reference framework against which the existing spatial utilization presented in Table 1 is subsequently assessed.

3.3 Formal (Zoning) Suitability of Spatial Utilization toward the RDTR

The overlay between the existing spatial-utilization map and the RDTR spatial-pattern map produces the formal (zoning) suitability classification presented in Table 3, in which spatial utilization is classified as either suitable, where the existing use corresponds to the RDTR zoning directive, or not suitable, where a deviation from the designated zoning is identified. This classification concerns administrative conformity with zoning only; it is reported and discussed separately from the physical-land suitability parameters (slope, soil, and earthquake hazard) examined later in this section.

Table 3. Formal (Zoning) Suitability of Spatial Utilization toward the Yogyakarta City RDTR (Source: Researcher's analysis, 2026)

Suitability toward the RDTR	Area (ha)	Percentage (%)
Suitable	0.443244	100.00
Not suitable	0.000000	0.00
Total	**0.443244**	**100.00**

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The overlay result indicates that the entire spatial utilization within the Terban Madani row housing area, amounting to 0.443244 ha, is suitable with the RDTR zoning directives, with no area classified as non-suitable. The total area evaluated in this overlay (0.443244 ha) is marginally smaller than the total existing-land-use area reported in Table 1 (0.443577 ha), a difference of 0.000333 ha (0.075% of the study area) attributable to minor sliver polygons generated during the vector overlay process, as explained in the Methods section; this negligible discrepancy does not affect the classification of any parcel and, accordingly, does not alter the reported 100% formal-suitability outcome. Field observation confirms that the row housing units are located within the medium-density housing zone, the road network coincides with the road-body zone, the river occupies the water-body zone, and the river setback lies within the local protection zone. Spatial measurements further confirmed that row house units were positioned behind retaining walls at a distance which is then compared against the 3-meter statutory minimum applicable to embanked urban river segments under Article 7 of Permen, Public Works No. 28/PRT/M/2015 [25]. This measurement, together with confirmation from BBWS Serayu Opak, was used to verify compliance with the setback-width requirement. Consequently, although permanent structures are present within the broader riparian environment, they are not located within the legally defined setback measured from the embankment, provided the measured distance meets or exceeds this 3-meter minimum. The retaining wall, functioning as a river-safety structure rather than as an independent land use, does not alter the underlying function of the zone it occupies but instead supports the protection of the riparian area and the safeguarding of water-resource infrastructure, consistent with the protective function mandated by Government Regulation No. 38 of 2011 [7]. These findings, corroborated through interviews with the relevant agencies, indicate that the redevelopment of the Terban Madani area was carried out in a manner formally consistent with the spatial-planning direction established for the Terban corridor.

Although the area is fully suitable in formal, zoning terms, information obtained from the Yogyakarta City Regional Development Planning Agency (Bappeda) indicates that the proportion of open green space within the area still falls below the minimum standard set out in the RDTR, owing to the limited extent of available land. Bappeda further identified the Terban Madani row housing area as a pilot project for riverbank settlement management, implying that continued oversight by relevant agencies is required to prevent future functional conversion and to ensure that the positive outcomes observed in this initial site can be responsibly replicated elsewhere.

3.4 Suitability of Spatial Utilization Based on the Physical Condition of the Area

Beyond the RDTR overlay, Law No. 26 of 2007 concerning Spatial Planning mandates that spatial-planning implementation must consider the environment's carrying and supporting capacity, so that spatial utilization can proceed safely, comfortably, productively, and sustainably. Accordingly, three physical parameters—slope gradient, soil type, and earthquake hazard—were examined as a second, physical dimension of

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suitability, complementing rather than substituting for the zoning-based suitability assessment presented above.

Slope Gradient.

Analysis using the National Digital Elevation Model (DEMNAS) shows that the Terban Madani row housing area is situated on the Code River riverbank with a slope gradient exceeding 45%, placing it in the very steep category.

The topography is directly shaped by the presence of the Code River, producing pronounced variation in slope gradient along the corridor, with the steepest sections concentrated on the segments directly bordering the river channel. Slope gradient is a critical parameter in assessing land capability for built-up activity: steeper slopes are associated with a greater potential for erosion, slope instability, and mass movement, particularly under conditions of high rainfall intensity and unstable soil. This finding is consistent with previous research indicating that slopes of 15–40% are conditionally suitable for settlement, whereas slopes exceeding 40% are considered unsuitable because of the high associated landslide risk [19]. Under Presidential Decree No. 32 of 1990 concerning the Management of Protected Areas, land with a slope gradient of 40% or more is classified as protected area, functioning to maintain soil stability, prevent erosion, and reduce landslide potential—underscoring that slope characteristics must be carefully accounted for in the planning and management of settlements developed along riverbanks.

Field observation confirms that the Terban Madani redevelopment incorporated retaining walls along the segments bordering the Code River riverbank, indicating that topographic conditions were taken into account as a determinant of building safety during construction. Nonetheless, because part of the area remains situated on the riverbank slope, ongoing maintenance of the retaining structures, the drainage system, and erosion-control measures remains necessary to preserve slope stability and minimize residual landslide risk. These results indicate that slope condition constitutes a factor that must continue to be considered in the evaluation of spatial-utilization suitability, and that such evaluation cannot rely on zoning compliance alone but must also account for the physical carrying capacity of the site, consistent with prior findings that slope gradient is a key parameter in assessing settlement suitability owing to its association with land-safety levels and erosion or landslide potential [20]. This is in line with Law No. 26 of 2007 concerning Spatial Planning, which affirms that spatial-planning implementation must take account of protected areas, disaster-prone areas, and environmental carrying and supporting capacity so that spatial utilization proceeds safely and sustainably. It is on this physical dimension—rather than the formal zoning dimension reported in Table 3—that the site's steep-slope condition registers as a constraint, as discussed further below.

Soil Type.

Overlay with the Yogyakarta City soil-type map indicates that the Terban Madani row housing area is situated on Regosol soil, formed from volcanic material deposited and reworked by the activity of the Code River.

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This characteristic reflects the close relationship between the soil profile of the study area and the river system, which naturally transports and deposits sedimentary material originating from upstream areas, and is a physical characteristic commonly observed across settlements situated along the Code River corridor. It should be emphasized that this classification is descriptive and typological, derived from the regional soil-type map, rather than based on site-specific geotechnical testing; no bearing-capacity, shear-strength, permeability, or erosion-susceptibility measurements were conducted as part of this study. Consistent with previous research indicating that soil type is a key parameter in settlement-land suitability assessment because of its influence on land-bearing capacity [21], Regosol is generally associated in the literature with moderate bearing capacity suitable for low-rise residential construction, and the continued structural performance of the existing row-housing buildings and their supporting facilities provides indirect field evidence broadly consistent with this general association; this observation, however, does not substitute for direct geotechnical verification.

Soil type is, accordingly, treated in this study as a descriptive rather than a quantitatively verified suitability parameter: the classification identifies the general soil category present at the site but does not, by itself, establish in engineering terms that the soil is supportive for housing. This is identified as a limitation of the present study, and site-specific geotechnical investigation — such as a standard penetration test (SPT), permeability testing, and shear-strength analysis — is recommended as a priority for follow-up research to confirm bearing capacity and erosion susceptibility at the site. Because the site is located within the Code River riparian zone, the overall physical suitability of spatial utilization depends not solely on the soil-type classification presented here, but also on such geotechnical verification, together with conformity with the protective function of the river setback and the applicable spatial-planning directives.

Earthquake Hazard Potential.

The Terban Madani row housing area is also situated within an earthquake-prone zone identified from the Terban Urban Village earthquake-hazard map, indicating that disaster susceptibility should form part of the overall physical-suitability evaluation.

Even so, earthquake hazard cannot on its own be interpreted as a factor that directly determines the physical-suitability level of the area, since suitability assessment is the product of an integration of multiple physical parameters, with each parameter contributing to the overall picture of the area's condition rather than acting as an independent determinant. It should be noted that the present analysis identifies the site only as lying within a generally earthquake-prone zone at the map-overlay level; it does not report a specific hazard class, ground-shaking intensity (e.g., peak ground acceleration referenced to the national seismic hazard map, SNI 1726), liquefaction potential, or a structural-resilience assessment of the row-housing buildings themselves, each of which would require dedicated seismological or structural-engineering investigation beyond the scope of the present spatial-suitability study. This is identified as a further limitation of the present study: Yogyakarta as a whole is documented in national seismic-hazard studies as a region of moderate-to-high seismic hazard, as demonstrated by the damaging 2006 Yogyakarta earthquake, so a more granular, site-specific seismic and

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structural assessment — drawing on the national seismic hazard map and a structural evaluation of the row-housing construction — is recommended as a priority for follow-up research rather than being treated as resolved by the present zone-level overlay.

Field observation shows that the Terban Madani redevelopment has transformed the area into a substantially more orderly settlement compared with its pre-redevelopment condition. More regular building arrangement, the provision of internal access roads, and the completion of basic infrastructure together reflect an improvement in settlement quality, indicating that the redevelopment process was oriented not only toward the provision of housing but also toward safety and environmental sustainability. This finding is consistent with previous research indicating that disaster susceptibility constitutes one parameter within settlement-land suitability analysis, but that its assessment must be integrated with other physical parameters to produce a more comprehensive evaluation of suitability [22]. Disaster potential, accordingly, cannot serve as the sole basis for determining an area's suitability; rather, it must be examined together with the area's physical characteristics and the form of area management applied. The Terban Madani redevelopment, in this sense, represents part of a broader risk-reduction effort achieved through settlement-quality improvement, even though it does not eliminate the underlying seismic hazard that is naturally present across Yogyakarta City.

3.5 Reconciling Formal Zoning Suitability and Physical-Land Suitability

The results presented above indicate that formal zoning suitability and physical-land suitability are two conceptually distinct dimensions of spatial-utilization suitability, and that a single aggregate figure such as the 100% result in Table 3 should not be read as a statement about the site's overall suitability in every sense. Formal (zoning) suitability, as measured through the RDTR overlay, evaluates only whether the designated function of existing land use corresponds to the function assigned by the spatial plan; by construction, it does not incorporate slope gradient, soil bearing capacity, or disaster susceptibility as evaluation criteria. Physical-land suitability, by contrast, evaluates whether the physical carrying capacity of the site supports safe and sustainable use, independent of its zoning classification.

In the Terban Madani case, these two dimensions diverge. The area is 100% suitable in formal, zoning terms, yet a substantial part of the site lies on a slope gradient exceeding 45%, which under Presidential Decree No. 32 of 1990 concerning the Management of Protected Areas is itself classified as protected land, and which prior land-suitability research treats as unsuitable for settlement because of the associated landslide risk [19]. A site can therefore be simultaneously fully suitable under one suitability framework (zoning conformity) and constrained, or even non-suitable, under another (physical-land criteria); reporting only the RDTR-based figure would overstate the overall suitability of the site if the physical-land criteria are not also reported alongside it.

The RDTR zoning itself only partially reflects this physical constraint: the study-area boundary is designated in part as a local protection zone precisely because it functions to protect the river corridor, and the retaining wall that occupies the largest share of existing land use is a structural response to the same steep-slope condition. The RDTR's protection-zone designation therefore already provides a degree of regulatory

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recognition of the physical hazard, but it does not by itself remove the residual physical risk associated with the steep terrain, nor does it substitute for a dedicated slope- or disaster-based suitability classification. Accordingly, this study reports the two suitability dimensions separately100% formal (zoning) suitability in Table 3, and a set of unresolved physical constraints (slope, soil, and earthquake hazard) discussed individually aboverather than combining them into a single suitability index, and recommends that future spatial-suitability assessments of riverbank settlements explicitly disaggregate zoning-based and physical-land-based suitability so that the two are not conflated in reporting or interpreted as a single indicator of site safety.

A related scope limitation concerns the treatment of open green space. As noted above, information obtained from Bappeda indicates that the proportion of open green space in the study area falls below the minimum standard specified in the RDTR, yet the overlay-based assessment in Table 3 reports the area as 100% suitable. This is not a contradiction but a reflection of the scope of the overlay method applied: the suitability overlay conducted in this study evaluates only zoning function whether the designated land-use category assigned to each parcel (e.g., housing, protection zone, road) matches its existing use and does not incorporate zoning-intensity or development-control requirements such as the minimum green-space ratio (Koefisien Daerah Hijau, KDH), building-coverage ratio (KDB), or floor-area ratio (KLB), which are typically regulated within an RDTR's development-control provisions rather than within its zoning (pola ruang) map. Under this distinction, the shortfall in open green space represents a form of partial non-compliance with the RDTR's development-control requirements, even though it does not register as non-suitability within the zoning-function overlay reported in Table 3. Reporting the 100% figure without this qualification risks implying a more complete form of regulatory compliance than the overlay method is capable of demonstrating. Accordingly, this study qualifies its interpretation of the 100% result to denote zoning-function suitability specifically and identifies open-green-space provision alongside slope, soil, and earthquake hazard as an aspect of the site's overall regulatory and physical performance that falls outside the scope of, and is not resolved by, the zoning-function overlay.

3.6 Toward a Multi-Criteria Spatial Suitability Index for Future Research

Building on the distinctions drawn above between zoning-function suitability and physical-environmental suitability, this study recommends that future assessments of riverbank settlements move toward a multi-criteria spatial suitability index (MCSSI) that integrates RDTR zoning-function conformity together with slope gradient, river-setback compliance, soil/geotechnical condition, earthquake hazard, drainage adequacy, open-green-space provision, and settlement density within a single, structured evaluation framework, rather than treating zoning conformity alone as the principal indicator of suitability.

Such an index could be constructed through a weighted overlay or a multi-criteria decision-analysis technique such as the Analytic Hierarchy Process (AHP), in which each criterion is scored against a defined suitability scale (e.g., suitable / conditionally suitable / unsuitable) and combined using weights reflecting its relative importance for

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settlement safety and regulatory compliance weights best derived through structured expert judgment, for instance a Delphi panel of spatial-planning, geotechnical, and disaster-management specialists, rather than assigned arbitrarily by the researcher. Structuring the index in two explicit tiers a legal-spatial conformity tier (zoning function, setback compliance, and development-control standards such as green-space and building-coverage ratios) and a physical-environmental suitability tier (slope, soil/geotechnical condition, earthquake hazard, and drainage) would allow future studies to report a composite suitability outcome while preserving the conceptual distinction established in this study between formal compliance and physical safety. Such an index would directly address the limitation identified above, in which a 100% zoning-function suitability result coexists with a documented shortfall in green-space provision and with unresolved slope-, soil-, and earthquake-related physical risk. Developing and validating this index including collecting the site-specific geotechnical and seismic-engineering data identified as limitations of the present study is recommended as a priority direction for future research on the Terban Madani area and on similar riverbank resettlement sites elsewhere in Indonesia.

3.7 Factors Influencing the Development of Terban Madani Row Housing

In addition to the spatial-suitability assessment, the qualitative analysis identifies three interrelated factors that influenced the development of the Terban Madani row housing area: government slum-upgrading policy, land scarcity combined with the difficulty of relocation, and the socio-economic condition of low-income residents. Because these factors were investigated to answer a research question distinct fromrather than explanatory of the spatial-suitability results above, they are presented here as the complementary qualitative strand of the study, as described in the Methods section.

3.8 Government Program for Slum Settlement Handling.

The construction of the Terban Madani row housing area represents an implementation of Yogyakarta City Government policy embodied in the 2025–2029 Regional Medium-Term Development Plan (RPJMD) for the handling of slum areas, delivered through an urban-renewal approach known as Mahanani (Perumahan dan Permukiman Layak Huni Menuju Kampung Madani), an elaboration of the earlier Mundur Munggah Madhep Kali (M3K) concept.

Prior to redevelopment, RT 02/RW 01 in Terban Urban Village exhibited characteristic slum conditions closely packed buildings, inadequate sanitation, and location on a riverbank with a heightened risk of landslides. This condition was affirmed by an official of the Yogyakarta City Public Works, Housing, and Settlement Areas Office, who explained that the Terban area, particularly in front of the Gondokusuman II Community Health Center, exhibited poor sanitation, tightly packed buildings, and recurring landslides, which led the area to be prioritized for redevelopment through retaining-wall repair and the relocation of houses further back from the riverbank.

Given the combination of slum conditions and high landslide risk, settlement handling could no longer rely on individual house improvement and instead required

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comprehensive area-level redevelopment covering infrastructure such as retaining walls, implemented without disregarding residents' need for adequate housing. An official of the Yogyakarta City Regional Development Planning Agency (Bappeda) explained that the area's steep and unsanitary conditions did not meet environmental livability standards, prompting the city to undertake redevelopment with central-government funding support through the Special Allocation Fund (DAK) under the Integrated Slum Alleviation Program (PPKT) coordinated by the Ministry of Public Works. This indicates that the handling of the Terban area formed part of a slum-settlement program implemented through collaboration between the Yogyakarta City Government and the central government, with PPKT funding enabling a more comprehensive redevelopment encompassing not only housing construction but also the improvement of basic infrastructure and the surrounding settlement environment.

In its implementation, the Yogyakarta City Government applied the Mahanani concept as an elaboration of M3K. A Bappeda staff member explained that Mahanani builds on the M3K program by incorporating land consolidation, transforming previously irregular land parcels into an orderly arrangement, with building regularity constituting one of the assessment criteria for slum-area status. These interview findings indicate that the Terban Madani development represents an implementation of Yogyakarta City Government policy in addressing slum settlement, in which the Mahanani program is directed not only toward improving housing quality but also toward reorganizing the area's spatial structure through land consolidation, basic infrastructure development, and environmental-quality improvement, thereby supporting a more orderly, safe, and functionally consistent pattern of spatial utilization.

3.9 Land Scarcity and Relocation Constraints.

Land scarcity constitutes a second factor influencing the development of the Terban Madani row housing area.

This condition relates not only to the limited space available for settlement expansion within the urban area, but also to the difficulty of securing suitable land for relocation. In response, the Yogyakarta City Government opted for an in-situ redevelopment approach—rebuilding the settlement on the same site without relocating residents. An official of the Public Works, Housing, and Settlement Areas Office explained that the slum settlement was redeveloped without relocation because of the difficulty of securing land, and that the in-situ approach involved shifting buildings further back from the river, whereas relocation would require the availability of substitute land and would likely entail conflicting interests together with a lengthy resettlement process.

This statement indicates that the decision not to pursue relocation was shaped not only by land scarcity but also by the practical complexity of implementing relocation, since the government would need to secure appropriate substitute land, resolve various administrative matters, and manage the potential for conflict arising from residents' displacement from their existing environment. The in-situ approach was therefore considered more effective for reorganizing the settlement without severing residents' long-standing ties to their neighborhood. According to a Bappeda official, regional budget (APBD) funds were used for retaining-wall construction, road development, and land

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consolidation, through which previously irregular land parcels were reorganized, in consultation with residents, into a more orderly set of new parcels able to accommodate the community living in the area.

This account illustrates that land consolidation served as the strategy adopted by the Yogyakarta City Government to address land scarcity without requiring the provision of a new relocation site. Redevelopment was carried out by rearranging previously irregular land parcels into a more orderly layout through community consultation, allowing the available space to be used more optimally for row-housing construction, internal roads, the Code River retaining wall, and other settlement infrastructure. The application of land consolidation further demonstrates that area redevelopment was not limited to housing construction but also extended to comprehensive spatial reorganization, through which previously underutilized space could be reallocated to support basic infrastructure provision and improved environmental quality. Land scarcity, accordingly, did not act as an obstacle to the Terban Madani development but instead became the basis on which the Yogyakarta City Government chose an in-situ approach through land consolidation an approach that enabled more optimal spatial utilization through parcel reorganization, infrastructure provision, and settlement-quality improvement without requiring residents to relocate.

Socio-Economic Conditions of Low-Income Residents. To accelerate the provision of adequate housing access, the Indonesian government enacted Law No. 1 of 2011 concerning Housing and Settlement Areas, which mandates the provision of facilitation for low-income communities (MBR) to obtain adequate housing, defining MBR as communities with limited purchasing power who therefore require government support to obtain housing.

Because socio-economic characteristics vary across regions, the implementation of this facilitation policy is similarly shaped by local conditions, a pattern also observed among residents of RT 02/RW 01, Terban Urban Village, the majority of whom—whether original inhabitants or migrants have resided in the area for several decades and depend economically on its central location within Yogyakarta City, which provides convenient access to places of work and business.

Interviews with residents illustrate this dependence. One long-term resident, who had lived in the area since 1971, explained that relocating was not a realistic option given the high price of land in Yogyakarta City relative to a very limited income, and noted that the area's proximity to a former workplace had allowed savings on transportation costs that could instead be directed toward other daily needs. Another resident, who had grown up in the area since childhood, described having built close, family-like relationships with neighbours over the years and explained that the area's proximity to a parent's former workplace had similarly reduced the household's reliance on paid transportation. A further resident, who migrated from Klaten and built makeshift housing on what was then vacant land, explained that although a more adequate home was desired, irregular income earned through informal work as a parking attendant and occasional construction laborer made this difficult to achieve. Yet another resident, who migrated from Madura together with family members to sell food from a roadside stall in the area and nearby streets, explained that the area's strategic, centrally located position made it well-suited to sustaining the household's livelihood, with around thirteen

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family members across generations residing in a single dwelling. As the head of the local neighborhood association further explained, most residents are migrants who have lived in the area for decades, with the population gradually increasing over time from an initially small number of settlers.

These accounts show that, for the low-to-lower-middle-income residents of RT 02/RW 01, meeting basic daily needs already strains household budgets, leaving little scope to consider purchasing formal housing. Consistent with the broader observation that MBR communities tend to prioritize proximity to their place of work to minimize transportation costs, this preference for proximity persisted even where it meant residing in slum conditions on land that was not formally owned. Taken together, these findings indicate that the development of the Terban Madani row housing area was shaped not only by the physically deteriorated condition of the settlement, but also by the socio-economic circumstances of residents who had long inhabited the area. Limited economic capacity, high urban land prices, and the proximity of the settlement to residents' sources of livelihood led the community to remain in the area despite substandard housing conditions. On this basis, the Yogyakarta City Government pursued redevelopment through the Terban Madani row housing project, enabling residents to obtain more adequate housing without losing access to their employment and to the social environment they had built over many years.

4 Conclusion

This study set out to analyze the suitability of spatial utilization in the Terban Madani row housing area against the Yogyakarta City RDTR 2021–2041 and to identify the factors that influenced the development of the area, examining two conceptually distinct dimensions of suitability. In zoning-function terms, the overlay of existing spatial utilization with the RDTR spatial-pattern directives shows a suitability level of 100.00% across the entire study area, indicating that the designated land-use category of spatial utilization in the Terban Madani row housing area is fully aligned with the spatial function planned under Regulation of the Mayor of Yogyakarta No. 118 of 2021 concerning the RDTR of Yogyakarta City 2021–2041; this figure specifically denotes conformity of land-use function and does not extend to development-control requirements such as open-green-space provision, which remains below the RDTR's minimum standard. In physical terms, the site is situated on a very steep riverbank slope exceeding 45%, dominated by descriptively classified Regosol soil, and located within a generally earthquake-prone zone conditions that, assessed independently of zoning classification, continue to warrant geotechnical safeguards and ongoing monitoring, notwithstanding the absence of site-specific geotechnical and seismic-engineering data in the present study. These findings are complementary rather than contradictory: full zoning-function compliance with the RDTR does not, and is not intended to, certify either the site's development-control compliance or its physical safety. This underscores that zoning-function compliance alone is not a sufficient indicator of a riverbank settlement's overall suitability, safety, and long-term sustainability, and that zoning-function suitability, development-control compliance, and physical-environmental suitability should be

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reported and evaluated as distinct dimensions—rather than merged into a single suitability figure in future spatial-suitability studies of similar riverbank locations.

The development of the Terban Madani row housing area was shaped by three interrelated factors, identified through the complementary qualitative strand of the study: the Yogyakarta City Government's slum-upgrading policy embodied in the 2025–2029 RPJMD; land scarcity, which made relocation impractical and led the government to adopt an in-situ redevelopment approach through land consolidation rather than resettling residents elsewhere; and the socio-economic condition of low-income residents, many of whom have inhabited the area for decades because of its proximity to their places of work and their limited economic capacity to secure independent housing elsewhere in the city.

Building on these findings, the Yogyakarta City Government is encouraged to maintain sustained control over spatial utilization in the Terban Madani row housing area, given the site's location within the Code River riparian zone and its inherent physical limitations for residential use, including restricting the addition of new buildings or housing units so as to prevent rising density from placing further pressure on the surrounding environment. As the area is intended to serve as a pilot project for the redevelopment of riverbank slum settlements, a comprehensive evaluation explicitly disaggregating zoning-function suitability, development-control compliance, and physical-environmental suitability, ideally through the multi-criteria spatial suitability index outlined above is recommended prior to replicating the approach elsewhere; although the present findings confirm that spatial utilization is consistent with the applicable spatial-plan zoning-function directives, the steep riverbank topography of the site and the shortfall in open green space mean that potential future physical and regulatory risks should be carefully weighed as part of the evaluation basis for planning similar row-housing development or settlement-management interventions in other locations with comparable characteristics.

Finally, this study acknowledges several limitations that qualify the scope of its findings and point to priorities for future research: the exact number of informants interviewed within each of the six qualitative-informant categories was determined by data saturation rather than a fixed quota and should be read alongside the saturation criterion reported in the Methods section; the classification of Regosol soil as generally supportive of built-up use is descriptive rather than based on site-specific geotechnical testing; and the identification of the site as earthquake-prone reflects a zone-level overlay rather than a specific hazard class, ground-shaking intensity, liquefaction assessment, or structural-resilience evaluation. Addressing these limitations through dedicated geotechnical and seismic-engineering investigation, and through the development of the multi-criteria spatial suitability index recommended above, would allow future assessments of the Terban Madani area and comparable riverbank settlements to more fully distinguish legal-spatial conformity from physical-environmental suitability.

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5 Declarations

5.1 Author Contributions

Conceptualization, W.A. and T.F.W.; methodology, W.A. and T.F.W.; software, W.A.; validation, T.F.W. and M.M.A.; formal analysis, W.A. and M.M.A.; investigation, W.A., W., and V.A.; resources, W., and V.A.; data curation, W.A. and M.M.A.; writing—original draft preparation, W.A.; writing—review and editing, T.F.W., M.M.A., W., and V.A.; visualization, W.A.; supervision, T.F.W.; project administration, T.F.W.; funding acquisition, T.F.W. All authors have read and agreed to the published version of the manuscript.

5.2 Funding

The authors received no specific funding for this research

5.3 Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

5.4 Data Availability Statement

All data supporting the findings of this study are included in the article.

5.5 Artificial Intelligence (AI) Disclosure

AI or AI-assisted technologies were used in the preparation of this manuscript.

5.6 Research Ethics

Not applicable.

5.7 Acknowledgments

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