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INCREMENTAL RETROFITTING AND MATERIAL - SPACE ADAPTATION IN PLANTATION LINE HOUSING: EVIDENCE FROM A WET-ZONE SETTLEMENT IN SRI LANKA

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ABSTRACT

Plantation line housing represents a distinctive residential typology developed during the colonial plantation economy in Sri Lanka. These dwellings were originally constructed using simple material systems granite foundations, brick masonry walls, and clay tile roofing and designed to accommodate small worker households with limited spatial flexibility. However, contemporary plantation communities experience changing household structures, environmental pressures, and socio-economic transitions that require these rigid housing units to adapt over time. This study investigates material–space adaptation and incremental retrofitting in plantation line housing through a case study of a wet-zone settlement in the Kegalle District, Sri Lanka. It aims to examine how residents modify spatial arrangements and construction materials in response to environmental and spatial constraints, addressing the questions of how these adaptations occur and how they contribute to spatial resilience. Field observations, measured drawings, and resident narratives were used to document transformations in construction materials, interior partitions, and spatial organization. The findings reveal recurring spatial adaptation patterns, including rear-oriented extensions for cooking, vertical storage practices, and the use of lightweight partitions to reorganize interior space. Environmental pressures, particularly heavy rainfall and clay roof tiles damage caused by monkeys have also encouraged the replacement of traditional roofing with metal and asbestos sheets, producing hybrid material systems. The study demonstrates how resident-driven modifications enable plantation housing to remain functional despite spatial and environmental constraints. These insights highlight the importance of incremental and flexible retrofit strategies for improving low-income housing in resource-constrained contexts.

Keywords: *Incremental housing; Low-income housing; Material adaptation; Plantation housing; Spatial resilience*

1. INTRODUCTION

Housing plays a fundamental role in shaping social wellbeing, spatial functionality, and everyday living practices within the built environment. In many developing countries,

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however, large segments of the population continue to occupy housing environments originally designed for different socio-economic conditions and household structures. As household sizes increase and domestic practices evolve, such housing environments often become spatially constrained, requiring residents to adapt and reorganize their living spaces (Tipple, 2000; UN-Habitat, 2011).

Plantation line housing in Sri Lanka represents a historically significant housing typology developed during the colonial plantation economy to accommodate plantation workers in compact and standardized residential units. These dwellings, commonly known as line houses, typically consist of narrow rectangular units arranged in linear rows with minimal internal spaces and limited spatial flexibility (Peebles, 2001). While this configuration initially served the functional needs of plantation communities, contemporary household structures and living practices have significantly changed.

Increasing family sizes and evolving domestic activities have placed considerable pressure on these spatially constrained housing units, leading residents to modify and reorganize their interior spaces to accommodate changing needs (Perera, 2016; Tipple & Speak, 2009). Within housing studies, such transformations are commonly explained through the concept of incremental housing, which emphasizes how residents gradually adapt and extend their dwellings over time in response to spatial limitations (Turner, 1976; Hamdi, 2004).

More recently, the concept of spatial resilience has been used to describe the capacity of spatial systems to adapt and reorganize in response to social and environmental pressures while maintaining functional living conditions (Holling, 1973; Meerow et al., 2016). In the context of low-income housing, spatial resilience often emerges through resident-driven spatial adaptations that allow housing environments to remain functional despite spatial constraints.

Despite the widespread presence of plantation line settlements in Sri Lanka, limited research has examined the interior spatial transformations occurring within these housing units. This study therefore investigates how residents incrementally transform interior spaces in plantation line housing settlements in the Kegalle District of Sri Lanka. By examining these adaptations, the research aims to contribute to a better understanding of spatial resilience and resident-driven housing transformation in spatially constrained residential environments.

Accordingly, the objective of this study is to investigate how residents incrementally adapt plantation line housing through material and spatial transformations in response to changing household needs, environmental pressures, and spatial constraints. The study addresses the following research questions: (1) How do residents modify and reorganise interior spaces within plantation line housing units over time? (2) What material transformations occur in response to environmental pressures in wet-zone plantation settlements? and (3) How do these adaptations contribute to spatial resilience within spatially constrained housing environments?

2. LITERATURE REVIEW

2.1 INCREMENTAL HOUSING AND RESIDENT-DRIVEN TRANSFORMATION

Housing in many low-income settlements evolves through gradual processes of adaptation rather than through fixed architectural design. The concept of incremental

housing highlights how residents progressively modify and extend their dwellings in response to spatial constraints and socio-economic needs. Turner (1976) argued that housing should be understood as a dynamic process shaped by residents rather than a completed product delivered by formal planning systems. This perspective emphasizes the agency of residents as active participants in shaping their living environments.

Subsequent studies demonstrate that incremental housing transformations commonly occur in standardized or spatially constrained housing environments where formal design solutions fail to accommodate changing household needs. Recent studies continue to emphasise incremental housing as an effective approach for accommodating changing household needs in resource-constrained contexts, particularly within rapidly urbanising regions of South Asia (Batra, 2021; Wakely & Riley, 2005.). Hamdi (2004) notes that residents frequently introduce extensions, internal partitions, and multifunctional spaces as adaptive responses to limited space and evolving domestic practices. Similarly, Tipple (2000) observes that user-initiated transformations allow households to gradually improve the functionality and usability of their dwellings despite limited financial resources.

These incremental processes can also be understood through the perspective of Open Building theory, which distinguishes between the permanent structural "support" of a building and the adaptable "infill" elements controlled by occupants (Habraken, 1972). Within this framework, the structural shell of a dwelling remains relatively stable, while interior spatial elements evolve through resident-driven modifications. Such a distinction is particularly relevant in plantation housing settlements where the original masonry structures function as long-term supports, while interior partitions and extensions introduced by residents operate as flexible infill systems that adapt to changing household needs.

In plantation housing settlements, similar incremental processes have been observed as residents adapt colonial-era housing units to contemporary living conditions. Plantation line houses were originally designed as compact and repetitive housing units with minimal spatial flexibility (Peebles, 2001). As household sizes increase and domestic practices evolve, residents often introduce informal spatial modifications that enable these housing units to remain functional despite their rigid original design (Perera, 2016). The adaptive nature of incremental housing has also been highlighted through case studies that demonstrate how households progressively expand and modify their dwellings using affordable and locally available resources (SPARC, 2013; Balestra & Göransson, 2009).

2.2 SPATIAL ADAPTATION IN LOW-INCOME HOUSING

Spatial adaptation refers to the processes through which occupants modify and reorganize built environments in response to changing functional and social requirements. Within domestic environments, adaptation frequently occurs through interior reconfiguration, temporary partitions, and multifunctional use of limited spaces. Brand (1994) highlights that buildings naturally evolve over time as occupants modify spatial arrangements to accommodate changing needs, suggesting that built environments should be understood as continuously transforming systems.

In low-income housing contexts, spatial adaptation plays a critical role in enabling households to cope with spatial limitations and limited resources. Studies of informal settlements demonstrate that residents often convert single rooms into multifunctional

environments that accommodate sleeping, social interaction, and domestic activities simultaneously (Tipple & Speak, 2009; Hamdi, 2004). Such practices illustrate how spatial flexibility emerges through everyday domestic routines rather than through predetermined architectural design.

Within constrained housing environments, this flexibility can also be understood as a form of spatial elasticity, where a single interior space expands or contracts functionally to accommodate different domestic activities at different times of the day. Through such adaptive practices, limited domestic spaces are capable of supporting multiple household functions without requiring permanent architectural alterations.

In plantation line settlements, the rigid spatial configuration of the original housing design often necessitates internal spatial modifications. Previous research indicates that residents commonly subdivide bedrooms, convert living spaces into sleeping areas, or construct small extensions to accommodate growing household structures (Perera & Nilsson, 2013). Such spatial adaptations illustrate the dynamic relationship between domestic practices and housing environments within spatially constrained residential settings.

2.3 SPATIAL RESILIENCE IN THE BUILT ENVIRONMENT

The concept of resilience has become increasingly important in studies of urban systems and the built environment. Initially developed in ecological research, resilience refers to the capacity of a system to absorb disturbances while maintaining its core functions (Holling, 1973). In urban and spatial contexts, resilience is understood as the ability of built environments to adapt to social, economic, and environmental changes (Meerow et al., 2016).

In architectural discourse, spatial resilience refers to the capacity of spatial systems to accommodate evolving user needs while maintaining functionality and habitability. Built environments that support flexibility and incremental transformation are considered more resilient because they allow spaces to adapt to changing social conditions over time (Sharifi & Yamagata, 2016). Similarly, Brand (1994) argues that buildings capable of continuous adaptation achieve greater long-term sustainability.

In highly dense domestic environments, spatial resilience is often closely linked to strategies of territorial regulation and privacy management. Altman (1975) argues that occupants use physical or symbolic boundaries to regulate social interaction and psychological density within shared environments. In constrained housing settings, such boundaries may take the form of lightweight or temporary partitions that allow households to manage privacy without permanently altering the spatial structure of the dwelling.

In low-income housing environments, spatial resilience often emerges through informal and resident-driven spatial practices rather than formal design interventions. Residents introduce incremental spatial modifications to support changing household activities and spatial needs (Hamdi, 2004; Tipple & Speak, 2009). Despite the relevance of spatial resilience to housing environments, limited research has examined how such resilience manifests through interior spatial transformations within plantation housing settlements (Peebles, 2001; Perera, 2016).

2.4 RESEARCH GAP

Although existing literature provides valuable insights into incremental housing, spatial adaptation, and resilience in the built environment, limited research specifically examines interior spatial transformations within plantation line housing settlements. Most studies emphasize socio-economic conditions, labor histories, and settlement development patterns rather than the micro-scale spatial adaptations occurring within individual housing units.

This study addresses this gap by examining how residents in plantation line housing settlements incrementally modify their interior environments in response to changing household needs. By mapping spatial transformations and analyzing adaptation patterns within selected case studies, the research aims to reveal how spatial resilience emerges through resident-driven incremental adaptations in spatially constrained housing environments.

3. METHODOLOGY

3.1 RESEARCH APPROACH

This study adopts a qualitative case study approach to investigate spatial resilience in plantation line housing through resident-driven spatial transformations. Case study methodology is widely used in built environment research to examine spatial phenomena within real-life contexts (Yin, 2018). The study focuses on documenting incremental interior transformations occurring within plantation line housing units and identifying recurring spatial adaptation patterns that enable households to maintain functional living environments within constrained architectural structures.

3.2 CASE STUDY SELECTION

Two plantation line housing clusters located in the Beligala area of the Kegalle District, Sri Lanka, were selected as case studies. The settlements lie within the wet-zone climatic region, which significantly influences material and spatial adaptation practices.

A total of 12 housing units were documented across the two clusters, locally known as '*Udaha Laima'* and '*Pahala Laima'.* The housing units were selected through purposive sampling to capture variations in resident-driven modifications while maintaining consistency in housing typology and settlement context.

Linear row housing arrangement

- Identical repetitive housing units
- Limited floor area
- Rigid spatial configurations

Despite their similar original layouts, the housing units demonstrate varying degrees of spatial modification introduced by residents over time. The selection of these two case studies therefore allows a comparative spatial analysis of different adaptation strategies occurring within similar architectural frameworks.

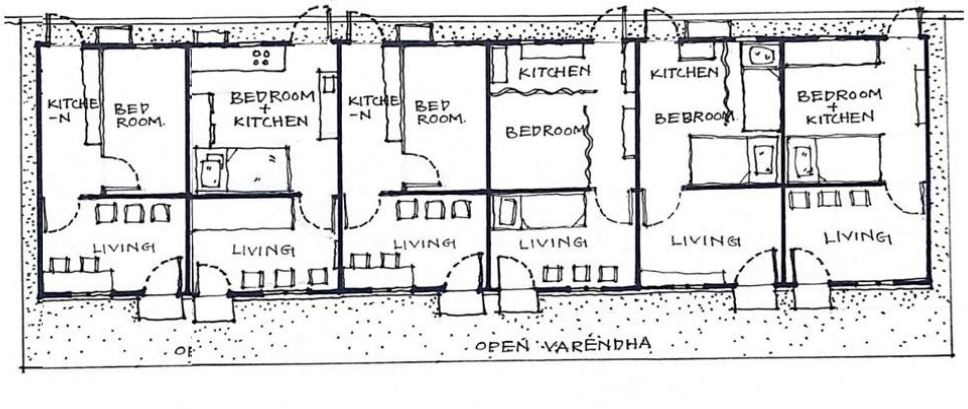

Figure 1: Typical plantation line housing arrangement showing repetitive linear housing units -Case study 01

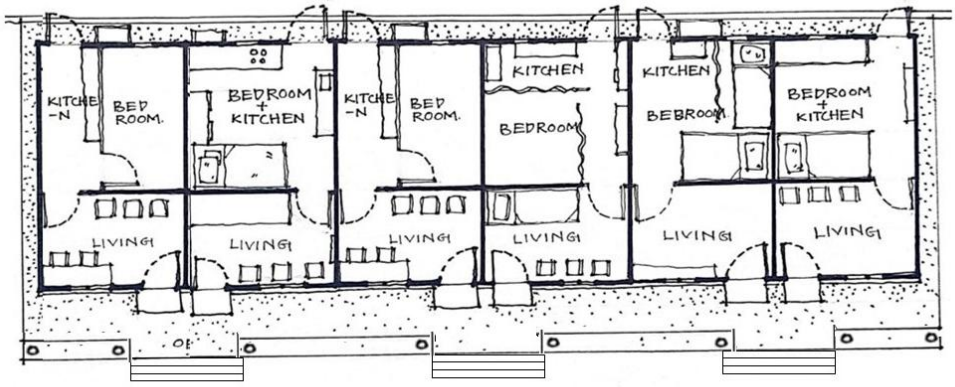

Figure 2: Typical plantation line housing arrangement showing repetitive linear housing units -Case study 02

3.3 SPATIAL DOCUMENTATION

Field-based spatial documentation was conducted to record both the original spatial configuration of plantation line housing units and the subsequent spatial transformations introduced by residents. Measured sketches and observational drawings were used to document the interior layout of selected housing units. The documentation process involved:

1. Recording spatial dimensions of housing units
2. Identifying functional spaces within the house
3. Mapping interior partitions and modifications
4. Documenting extensions and additional spaces

This process allowed the development of detailed plan drawings representing the existing spatial configuration of the housing units. The collected sketches were later converted into analytical diagrams to facilitate spatial analysis and comparison between the original and modified layouts. Resident narratives were collected through informal conversations conducted during field visits. Notes were recorded to document residents' explanations

regarding spatial modifications, material substitutions, and household practices. Verbal consent was obtained prior to observations and spatial documentation.

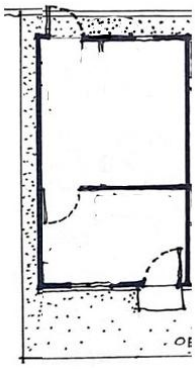

Figure 3: Original spatial configuration of a plantation line housing unit.

3.4 ADAPTATION MAPPING

To analyse the spatial transformations occurring within the housing units, an adaptation mapping method was employed. Adaptation mapping is a spatial analysis technique used to identify and visualize modifications introduced to build environments over time. In this study, the adaptation mapping process involved comparing the original housing layout with the current spatial configuration observed in the case study units. Spatial modifications were categorized into three primary types:

1. Interior partitioning – introduction of temporary or permanent partitions to divide spaces
2. Functional transformation – changes in the use of existing spaces
3. Incremental extensions – addition of new spaces outside the original housing footprint

These spatial transformations were illustrated through analytical diagrams that highlight the differences between the original and modified layouts.

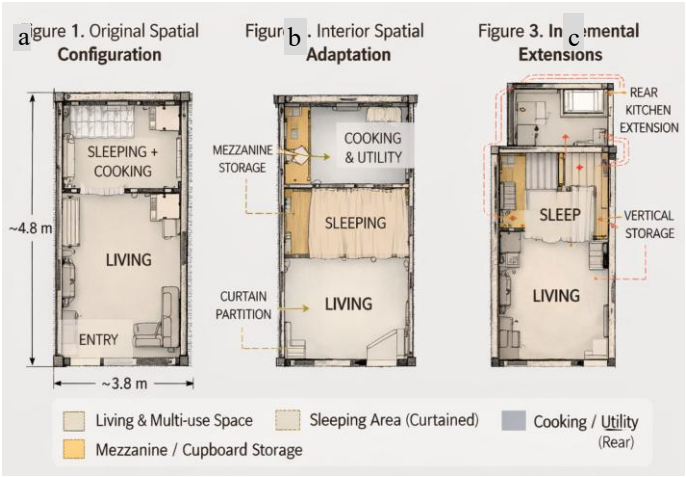

Figure 4: Interior spatial adaptation mapping showing resident-driven modifications within the housing unit

3.5 INCREMENTAL TRANSFORMATION ANALYSIS

To understand the process through which spatial modifications evolve over time, the study developed an incremental transformation map that illustrates the sequence of spatial adaptations occurring within the housing units. This diagram represents the gradual transformation of the original housing layout through successive modifications introduced by residents.

The analysis focuses on identifying patterns in spatial transformations, including:
• subdivision of interior spaces
• multifunctional use of limited spaces
• incremental rear extensions for cooking or storage

By mapping these transformations, the study examines how spatial modifications contribute to the emergence of spatial resilience within constrained housing environments.

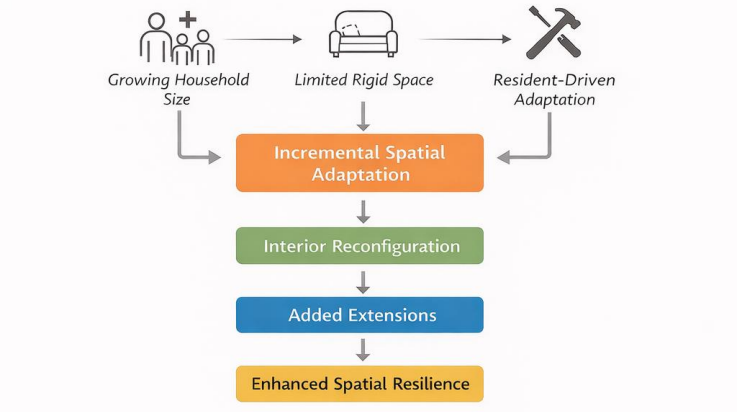

Figure 5: Spatial adaptation Framework

3.6 COMPARATIVE SPATIAL ANALYSIS

A comparative analysis was conducted between the two selected case studies identify common patterns of spatial adaptation. The analysis focused on comparing:

- types of interior modifications
- patterns of spatial extensions
- functional transformations of interior spaces

This comparison enabled the identification of recurring adaptation strategies used by residents to overcome spatial limitations within plantation housing units.

Table 1: Comparative analysis of spatial adaptation patterns observed in the selected case studies.

Spatial Adaptation Strategy	*"Udaha Laima"*	*"Pahala Laima"*	Spatial Function
Interior partitioning	Frequently observed	Frequently observed	Creation of additional sleeping areas and privacy
Kitchen extension	Common rear extensions	Common rear extensions	Expansion of cooking space and improved ventilation
Storage addition	Present in several units	Rarely observed	Additional storage for household items

Spatial Adaptation Strategy	*"Udaha Laima"*	*"Pahala Laima"*	Spatial Function
Multifunctional living space	Widely practiced	Widely practiced	Daytime social space converted to sleeping area
Temporary partitions	Fabric/plywood partitions used	Fabric partitions occasionally used	Flexible spatial subdivision
Rear utility extensions	Cooking and washing areas added	Limited rear extensions	Support domestic activities outside main unit

4. RESEARCH FINDINGS

4.1 STRUCTURAL CONSTRAINTS AND THE ORIGINAL SPATIAL FRAMEWORK

The Field documentation of the case study units indicates that plantation line houses were originally designed as compact linear domestic structures organized along a front-to-rear spatial sequence. Each unit typically consists of a living space at the front, a sleeping area in the middle, and a small cooking zone toward the rear. Domestic activities such as circulation, resting, cooking, and social interaction occur within a highly compressed spatial environment where functional boundaries are weakly defined.

The linear row configuration of plantation housing clusters imposes a significant structural constraint on spatial transformation. Because housing units share continuous party walls, lateral expansion toward the sides is structurally impossible. The original construction technology of plantation line housing, characterised by granite foundations, load-bearing brick masonry walls, and continuous party-wall construction, provides a durable structural framework but limits opportunities for major spatial reconfiguration. While the masonry shell constrains lateral expansion and structural alterations, lightweight retrofit materials such as fabric partitions, plywood panels, corrugated metal sheets, and reused materials enable residents to introduce flexible extensions and interior modifications. Consequently, spatial adaptation primarily occurs through adaptable infill elements rather than changes to the permanent structural system. This spatial rigidity establishes the underlying framework within which subsequent resident-driven adaptations occur.

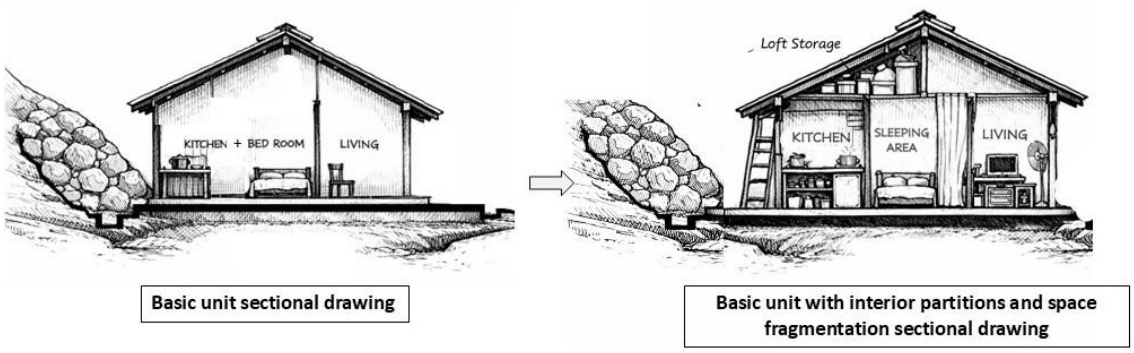

Figure 6: Transformation and adaptation of spaces in typical unit – sectional drawing

4.2 PATTERN IDENTIFICATION IN SPATIAL ADAPTATION

Comparative analysis of the documented housing units revealed that spatial transformations do not occur randomly but follow recurring patterns shaped by structural constraints, environmental pressures, and everyday domestic practices. Three dominant spatial patterns were identified across the case study settlements.

- Pattern 1 – Rear-ward drift
- Pattern 2 – Vertical storage adaptation
- Pattern 3 – Soft partition logic and ventilation

4.2.1 Pattern 1 – Rear-ward Drift: Linear Push of Domestic Functions

One of the most prominent spatial patterns identified is the rear-ward drift of domestic functions, where spatial adaptation occurs along the longitudinal axis due to the constraint of shared party walls preventing lateral expansion. As household sizes increase, interior space becomes increasingly compressed, leading residents to relocate cooking activities to small rear extensions constructed with lightweight or reused materials. Although detailed socio-economic data were not collected, field observations suggest that households with larger family structures tended to introduce more extensive spatial modifications, including partitions and rear extensions, to accommodate increasing domestic demands. This process allows the kitchen to gradually "escape" the interior space, creating additional room for sleeping and domestic activities while generating a progressive outward shift of service functions toward the rear of the dwelling.

This adaptation demonstrates spatial elasticity; whereby domestic functions are reorganised and redistributed beyond the original housing footprint to accommodate changing household needs. The relocation of cooking activities to rear extensions enables the limited interior space to support multiple functions while maintaining the usability of the dwelling.

4.2.2 Pattern 2 – Vertical Storage Adaptation: Storage Practices in Constrained Interiors

Another key spatial pattern identified is vertical storage adaptation, where storage functions shift upward due to the extremely limited floor area and absence of designated storage spaces in plantation line houses. Residents commonly use cupboard tops, roof rafters, and upper wall areas to store household items, effectively transforming the upper spatial volume of the house into an informal storage zone. This upward redistribution of storage demonstrates how households adapt vertically within constrained interiors, suggesting that future plantation housing design should consider higher ceiling heights or integrated vertical storage strategies. The upward redistribution of storage functions illustrates spatial resilience within constrained housing environments. By utilizing vertical space, residents adapt existing spatial resources without requiring significant structural alterations, enabling the dwelling to remain functional despite increasing household demands.

4.2.3 Pattern 3 – Soft Partition Logic and Ventilation-Based Spatial Boundaries

Material transformations in plantation line housing are strongly influenced by environmental pressures in the wet-zone climate. The humid climatic conditions of the wet zone also influence interior spatial adaptations. Residents frequently prefer

lightweight fabric partitions over rigid walls, as these maintain cross-ventilation and reduce heat and moisture accumulation within the compact housing units Heavy rainfall and damage caused by monkeys often affect traditional clay tile roofs, leading many households to replace them with corrugated metal or asbestos sheets. In this context, frequent roof damage caused by monkeys acts as a biological stressor, encouraging the adoption of more durable and easily repairable roofing materials. These material substitutions also shape spatial adaptation by enabling lightweight partitions, rear extensions, and vertical storage practices, gradually producing hybrid construction systems that combine original colonial structures with resident-driven retrofit elements. The use of fabric curtains and lightweight partitions reflects a form of territorial regulation and privacy management within highly compressed domestic environments. These flexible boundaries allow residents to create temporary private zones for sleeping and personal activities while maintaining airflow and visual connectivity within the dwelling. This adaptation enhances both spatial resilience and spatial elasticity by enabling spaces to accommodate changing functional requirements throughout the day.

Table 2: Identified spatial adaptation patterns in plantation line housing

Spatial Pattern	Spatial Driver / Constraint	Observed Adaptation Strategy	Spatial Outcome	Design Implication
Rear-ward Drift (Linear Push)	Continuous party walls restrict lateral expansion	Cooking activities relocated to rear through small kitchen extensions using lightweight or reused materials	Progressive outward movement of service spaces toward the rear of the dwelling	Future plantation housing should allow flexible rear expansion zones to accommodate inevitable service space growth
Vertical Sequestration	Limited floor area and absence of dedicated storage spaces	Use of cupboard tops, roof rafters, and upper wall areas for storing household items	Transformation of upper spatial volume into an informal storage infrastructure	Housing design should incorporate higher ceiling heights and integrated vertical storage systems
Soft Partition Logic & Ventilation Adaptation	Humid wet-zone climate and need for cross-ventilation	Use of fabric curtains and lightweight partitions instead of rigid walls	Flexible interior subdivision while maintaining airflow and thermal comfort	Interior layouts should support breathable partitions and adaptable spatial boundaries suited to humid climates

4.3 MATERIAL ADAPTATION AND BIOLOGICAL ENVIRONMENTAL PRESSURES

Spatial transformations within plantation line housing are closely linked with material adaptation processes influenced by environmental pressures in the wet-zone climate. Residents reported that heavy rainfall and frequent monkey activity often damage traditional clay tile roofing systems, leading many households to replace them with corrugated metal sheets or asbestos roofing materials.

In this context, monkey interference acts as a biological stressor affecting the durability of the original roofing system. The adoption of metal sheet roofing represents a practical response to this environmental condition, providing a more durable and easily repairable alternative.

Material substitutions also influence spatial organization within the housing units. Lightweight roofing systems enable residents to use roof structures for vertical storage, while lightweight construction materials facilitate the installation of temporary partitions and rear extensions. As a result, plantation line houses gradually evolve into hybrid material systems that combine colonial masonry structures with resident-driven retrofit elements.

4.4 SYSTEMATIC ADAPTATION PATTERNS ACROSS CASE STUDY SETTLEMENTS

Comparative analysis of the two case study settlements *Udaha Laima* and *Palleha Laima* reveals a strong convergence in spatial adaptation practices. Despite minor variations in the scale of modifications, the transformation processes observed across both settlements follow the same underlying logic of adaptation.

The spatial patterns identified in this study rear-ward drift, vertical sequestration, and soft partition logic illustrate how plantation housing residents systematically reorganize domestic environments in response to spatial constraints, environmental pressures, and changing household structures.

These patterns demonstrate that spatial transformation in plantation line housing is not the result of isolated household modifications but rather a collective adaptation process shaped by the structural conditions of the housing typology and the everyday practices of its occupants.

5. CONCLUSIONS AND RECOMMENDATIONS

This study examined material - space adaptation in plantation line housing through spatial documentation and comparative analysis of two wet-zone settlements in the Kegalle District of Sri Lanka. The findings show that although plantation line houses were originally designed as rigid and spatially minimal worker dwellings, they have evolved into adaptable domestic environments through incremental, resident-driven transformations. Lightweight partitions, multifunctional living spaces, and rear-oriented extensions enable households to reorganize limited interior areas and accommodate changing family structures, reflecting broader patterns of incremental housing adaptation. Environmental pressures in the wet-zone climate have also encouraged material substitutions, particularly the replacement of clay tile roofs with metal sheets, resulting in hybrid construction systems that combine original colonial structures with improvised retrofit elements.

These findings highlight the need for incremental and flexible housing strategies in plantation communities. Future housing design should support adaptable interior layouts, allow rear service extensions, incorporate breathable partition systems for ventilation, and provide sufficient ceiling heights for vertical storage practices observed in existing houses. Recognizing these resident-driven adaptations can help architects develop more resilient and context-responsive plantation housing solutions that enhance spatial flexibility while responding to local environmental conditions The identified adaptation

patterns also demonstrate how spatial resilience emerges through resident-driven modifications. Rear-oriented extensions illustrate spatial elasticity by enabling domestic functions to expand beyond the original housing footprint, while vertical storage practices maximise limited spatial resources within constrained interiors. Similarly, lightweight partitions function as mechanisms of territorial regulation and privacy management, allowing households to negotiate personal space without compromising ventilation. Together, these adaptations highlight the capacity of plantation housing residents to continuously reorganise and transform their living environments in response to changing social and environmental conditions.

The findings suggest that future housing policies should move beyond rigid standardisation and support incremental, adaptable housing models that enhance resilience, affordability, and long-term spatial flexibility.

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