ECO RESILIENT COMMUNITIES

Housing for Landslide-Prone Precipitous Terrain in Bogotá's Informal Settlements

Daniela Diaz Avila | 5901553

Housing for Vulnerable Communities in Bogotá's Periphery: A Resilient Approach to Landslide Mitigation

Daniela Diaz Avila | 5901553

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Research mentor: Mo Smit

Design Mentor: Yannick Warmerdam

Building Technology Mentor: Paddy Tomesen

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Abstract

This paper examines the causes of landslides and the resilient architectural strategies employed in three vernacular case studies from the Inca Empire, Sherpa communities in Nepal, and the Eastern Black Sea region of Turkey. It explores how their architecture integrated climate-responsive techniques, local materials, and structural systems built to withstand natural disasters such as earthquakes and landslides. The analysis highlights the significance of settlement layouts, passive design strategies, structural foundations, wall systems, and roofing methods that harmonize with the steep terrain and minimal environmental impacts, offering valuable insights for current sustainable and resilient design approaches for social housing in Bogota's periphery in steep terrain.

Keywords:

Landslide mitigation, Vernacular Architecture, Climate-Responsiveness, Resilient Design, Mountains, Social Housing

Table of Contents

Acknowledgments

Abstract

1. Research Plan 9.

2. Research 21.

3. Site Analysis 47.

4. Dwelling & Anthropologic Research 55.

5. System Proposal 69.

6. Dwelling Proposal 95.

7. Project Management Structure 115.

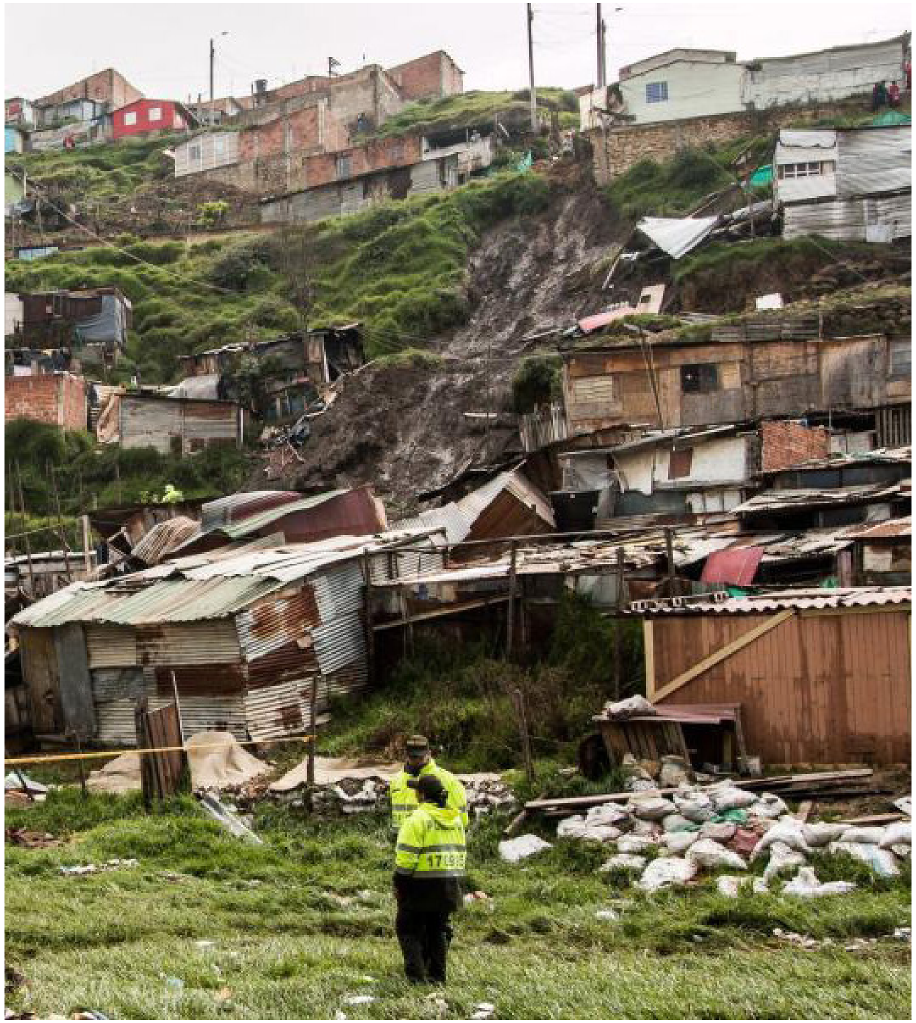


Image Mauricio León from El Tiempo Newspaper

1
Research Plan

INTRODUCTION

Landslides pose a significant global challenge, causing substantial damage and loss of life, especially on steep terrains. Between 1900 and 2018, Colombia experienced 30,730 documented landslides, resulting in the loss of 34,198 lives [1], and devastating entire communities. According to the landslide susceptibility map, 78% of Colombia's regions are classified as high-risk[2]. This threat highlights the vulnerability of areas prone to natural disasters triggered by heavy precipitation, steep topography, deforestation, and human intervention.

Many residents of Colombia's informal settlements are victims of forced displacement due to ongoing armed conflict, often instigated by outlaw groups. This conflict has led to the exodus of 13% of Colombia's population, reaching 6.8 million by the end of 2022[3], The influx of rural residents into urban areas exacerbates poverty cycles, worsened by limited government support and resources, which hinder communities from mitigating risks and perpetuate socioeconomic disparities.

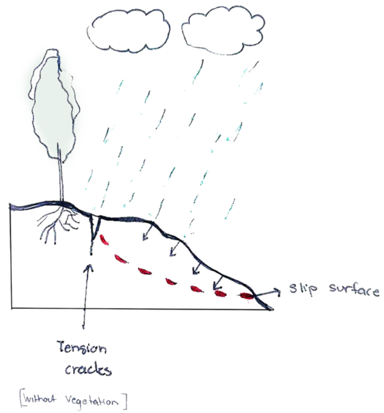
PROBLEM STATEMENT

Displaced individuals resort to constructing their dwellings and settling wherever possible, often driven by necessity. According to Martin-Molano, more than 50% of Bogotá has grown from informal settlements. Furthermore, socioeconomic limitations hinder access to adequate infrastructure and materials, resulting in detrimental effects. Lacking technical expertise, they excavate and build structures with little to no structural integrity, utilizing scavenged materials such as plastic, sticks, wood planks, asphalt screens, and zinc tiles. These inadequate practices facilitate water flow through the mountain system, leading to ground fissures and increasing the risk of landslides, perpetuating recurring devastation despite continuous, albeit erroneous, reconstruction efforts[4].

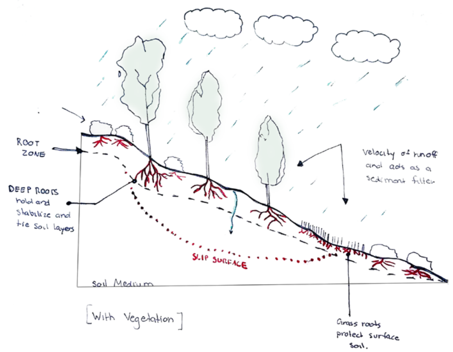
1. Gómez, Derly & García, Edwin & Aristizábal, Edier. Spatial and temporal patterns of fatal landslides in Colombia. 2021.
2. GFDRR. Think Hazard. Colombia 2020
3 .Colombia Situation. The United Nations High Commissioner for Refugees (UNHCR). 2024
4. Diaz, D. (2024). Learning from Vernacular Architecture to Develop Potential Methods in the Colombian Periphery to mitigate the housing crisis in Landslide prone topography. Delft

Landslide Inducing Factors- Rain, Deforestation, and Wildfires

During Bogotá's monsoon season, heavy rainfall saturates the ground from June to November, increasing the risk of landslides. Insufficient drainage systems in informal settlements exacerbate water accumulation and slope instability.



Deforestation and vegetation clearance further contribute to soil erosion, making slopes highly vulnerable to landslides during intense rainfall. Nelson Grima's study, conducted under the International Union of Forest Research Organizations, found that landslides are six times more likely to occur in non-forested areas compared to forested regions in Colombia[5]. Deforestation and wildfires amplify vulnerability to landslides by inducing soil hydrophobicity, disrupting the natural binding effect of soil roots, vital for soil cohesion and stability. In 2017, IDEAM classified the Andean region of Colombia as the second most deforested area in the country, following the Amazon,[6] as in the last two decades, Colombia has experienced a loss of 5.7% of its tree cover, about 4.7 million hectares, particularly affecting informal settlement areas mainly located in Bogota's periphery.



5. Grima, N. et al Landslides in the Andes: Forests can provide cost-effective landslide regulation services. International Union of Forest Research Organization.
6. Garcia-Delgado et al. (2022)

Uncontrolled Anthropogenic Interventions

While climate change continues to play a significant role in deforestation, so does rapid demographic growth and migration to Urban Centers as found in a study conducted by Ojeda and Donelly.[7] In Bogotá, the spatial redistribution of displaced rural populations has occurred in localities such as San Cristobal, Ciudad Bolívar, and Usme. The influx of residents relocating to informal settlements around the periphery[8], coupled with uncontrolled and uninformed anthropogenic interventions and migration, is directly linked to an increase in shallow landslide activity. [9]

In the majority of Bogotá's informal settlements, residents construct their own homes using subpar materials and methods unsuited for the steep terrain, increasing the risk of landslides. These dwellings often feature unreinforced masonry, adobe bricks, and recycled metal sheets. Due to their informal status, these settlements lack proper foundations and adherence to building codes and are not part of formal urban planning. Without engineering oversight, these construction methods and materials make structures highly susceptible to landslides and other natural disasters, increasing the likelihood of collapse or severe damage.

Image by Daniela Diaz- Soacha, Los Frutales comuna 2024

"We're still to some extent sleepwalking our way into disasters for the future which we know are going to happen, and not enough is being done to mitigate the damage."
—John Holmes, UN Under-Secretary General for Humanitarian Affairs (Lynn 2009)

The Impact of Earthquakes: Seismic-Induced Landslides

Throughout Colombia's history, landslides triggered by seismic activities have been a recurring challenge. The ongoing interaction among the Nazca, South America, and Cocos tectonic plates, uplifts mountain systems and sustains seismic activity. Historically, landslides in Colombia coincide with seismic events of at least a 5.0 magnitude, though occurrences at lower intensities have also been documented. Pérez-Consuegra's research highlights the significant impact of tectonic forces on slope dynamics in the Eastern Cordillera region, where Bogotá lies, intensifying landslide risks beyond rainfall's influence.

Research Objective

The primary objective of this research is to analyze the resilience of vernacular architecture in regions susceptible to landslides and earthquakes and to identify aspects that can be adapted and combined with modern technology to inform the design of housing typologies for the informal settlement Los Ceresos in Bogota's Periphery. Furthermore, developing a methodology for introducing construction techniques using locally available and upcycled resources, aiming to empower residents in constructing their dwellings with accessible building methods suitable for non-skilled labor, addressing housing shortages and vulnerability to landslides in peripheral areas.

The research will examine three vernacular case studies: Peru, Nepal, and Turkey with comparable topography, altitude, and materiality. Despite their commonalities, each case study will present unique cultural needs, climatic conditions, and challenges, providing comprehensive insights into the adaptability and efficacy of vernacular architectural strategies across varying environmental parameters.

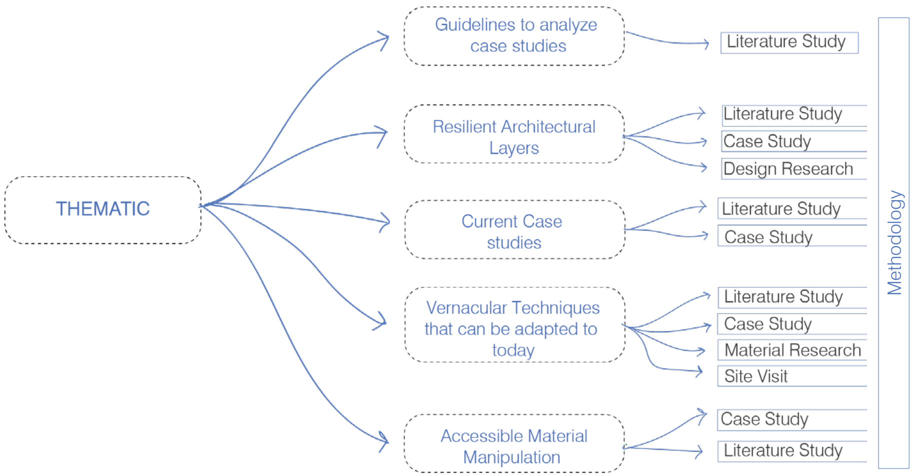
How can vernacular architecture and construction techniques used in steep/ mountainous terrains susceptible to landslides and earthquakes be adapted with modern technology and locally sourced biobased and upcycled materials to address inadequate/housing shortages and landslide vulnerability in peripheral areas?

Subquestions:

- What are the key characteristics of resilient vernacular construction techniques in steep/mountainous terrains prone to natural disasters?
- How can these vernacular techniques be reinterpreted and adapted to today?
- How can ensuring that these techniques are designed for ease of construction by unskilled labour and are readily replicable be achieved?

7. Ojeda J, Donnelly L (2006) Landslides in Colombia and their impact on towns and cities.

8. Lambin EF, Geist HJ (2003) Regional differences in tropical deforestation.
9. Glade T (2003) Landslide occurrence as a response to land use change



Thematic research diagram. - Drawing by author.

Design Objective

The overall design objective of the graduation project is to *revitalize a block within the Soacha slum, via the introduction of housing typologies and a communal space.* Soachal is situated in the mountainous periphery of Bogotá, where the constant threat of landslides poses a challenge. Through this project, I intend to *showcase a set of passive housing designs featuring diverse spatial characteristics* tailored to accommodate families of different sizes and needs, alongside communal or shared spaces. Moreover, these designs will be *informed by vernacular architectural engineering techniques*, prioritizing *structural stability, sustainability, and constructability*, including the utilization of *biobased and upcycled materials*. Presenting a vision for the community, I aim to demonstrate how their neighborhood can evolve sustainably while meeting their diverse needs.

This entails addressing the immediate need for safe housing and harmonizing with the local environment and cultural context. Recognizing and addressing the community's needs is a fundamental aspect of the research. Incorporating a social/communal space into the design is particularly intriguing, as a key strategy of the Bogotá Humana Development Plan[10] focuses on improving recreational spaces as part of crime prevention and urban security, emphasizing inclusivity by addressing diverse social groups needs, particularly in vulnerable areas resulting in lower crime rates in parks and the surrounding neighborhoods.

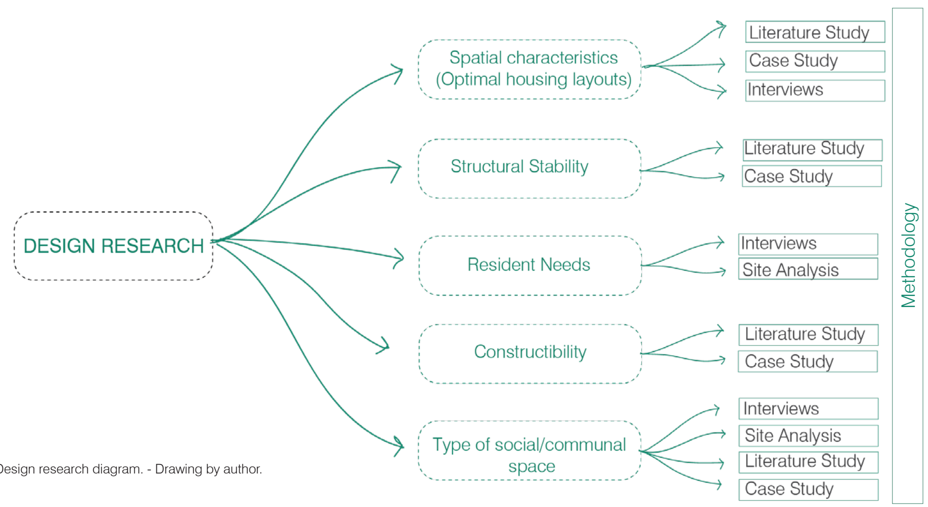
Moreover, I aim to design climate-responsive housing that ensures residents enjoy comfortable living conditions regardless of extreme temperatures. Alongside structural stability, the focus is on incorporating passive systems to enhance sustainability and resilience. These include elements such as rainwater harvesting systems, effective sun protection mechanisms, and natural ventilation strategies, all aimed at optimizing the environmental performance of the housing units while fostering a healthier and more livable environment for the occupants.

How can resilient, passive, and culturally sensitive housing, informed by vernacular practices, be designed with today's technology for a vulnerable community in Bogota's mountainous periphery, prone to landslides?

Subquestions:

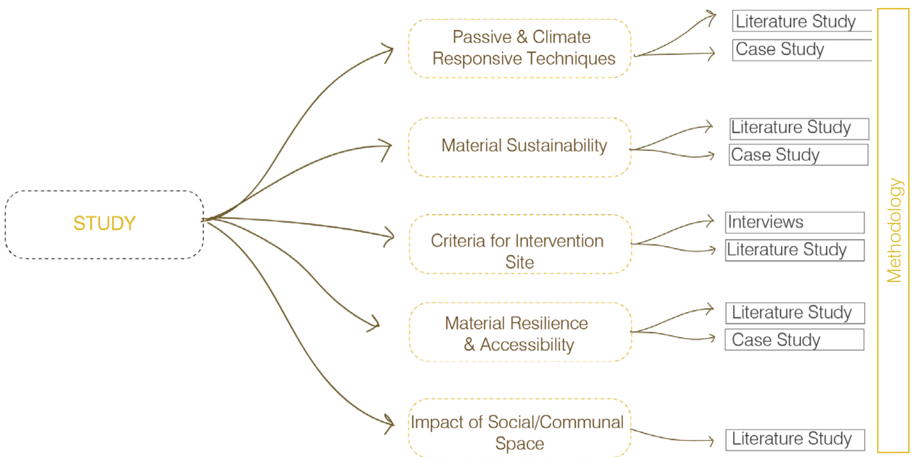
» How can comfort in extreme climates with passive systems like rainwater harvesting and natural ventilation be ensured? Offering not just housing, but a holistic vision for sustainable community development.

» What criteria guide the selection of intervention locations for effective landslide mitigation?



Design research diagram. - Drawing by author.

10. Secretaría Distrital de Planeación., Plan de desarrollo 2012-2016: Bogotá Humana 1–489 (2012). Bogotá; Alcaldía Mayor



Study research diagram. - Drawing by author.

In addition to the thematic research, I conducted several smaller studies that will inform the design process, though they are not directly tied to the main research theme. The first study focuses on determining the criteria for site selection and the type of intervention. This will be done through interviews, literature reviews, and a site visit. The study will also assess the impact of creating a social or communal space based on community needs, drawing insights from both the literature review and the site visit. It will be interesting to explore what facilities the community could share, with a communal garden being a potential option, given that many residents come from farming backgrounds.

The studies will also focus on climate-responsive and passive housing techniques. These will help me design an optimal cross-ventilation system and incorporate rainwater harvesting strategies. Additionally, I will examine the sun path to ensure the best possible placement of functions according to solar and heat retention principles.

Material selection will be another important aspect of these studies, which I will approach through literature reviews and case studies. This is crucial because of the limited availability of building materials and the community's scarce economic resources. The materials must also be easy to work with, as the houses will likely be constructed by the community itself.

Relevance

The decline of traditional building methods has led to construction practices that often overlook environmental factors and climate adaptability. Embracing these traditional techniques can make construction more accessible for everyone and better withstand natural disasters.
The project aims to support communities living in Bogota's mountainous areas, where they face unique challenges. Limited access to construction materials due to economic factors has inspired the exploration of alternative options like repurposed materials such as tires and resilient natural materials like bamboo. This not only addresses their structural needs but also promotes sustainability.

According to the Technical Document of Support to the Territorial Order Plan of Bogotá, many areas on the city's outskirts are at risk of landslides. While the focus is on San Cristobal, similar areas like Usme and Ciudad Bolivar share common geological features, making them vulnerable to landslides as well. Efforts in San Cristobal can serve as a model for addressing similar challenges in these areas.

Methodology

The chosen methods are mixed- both qualitative and quantitative
My methodology begins with investigation and data collection on vernacular architectural practices in mountainous regions faced with landslide and earthquake challenges, primarily via case studies through literature. Subsequently, I will construct a guideline to systematically analyze and contrast various case studies, considering factors such as altitude, morphology, climate patterns, and materials utilized. Furthermore key architectural layers will also be analyzed such as foundations, walls, landscape interventions and roofs. This analysis aims to discern landslide resilient approaches and identify shortcomings. Concurrently, I will investigate current case studies addressing landslide challenges in different countries, seeking commonalities in the methods and materials employed.

With the selection of Soacha as the intervention site, comprehensive research is necessary to identify locally available biobased and upcycled materials and assess their accessibility. Additionally, smaller studies that will inform the design process will be conducted, such as the potential passive design strategies both from findings of vernacular and modern case studies.

The next step involves pinpointing two potential site locations through an examination of the locality's development plans, expansion areas, protected zones, projected neighborhood growth, and susceptibility to landslides. Furthermore, a detailed site analysis will be conducted, considering factors such as climate patterns, solar orientation, historical context, and the demographic and socioeconomic characteristics of the residents.

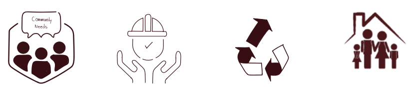
Research Trip:

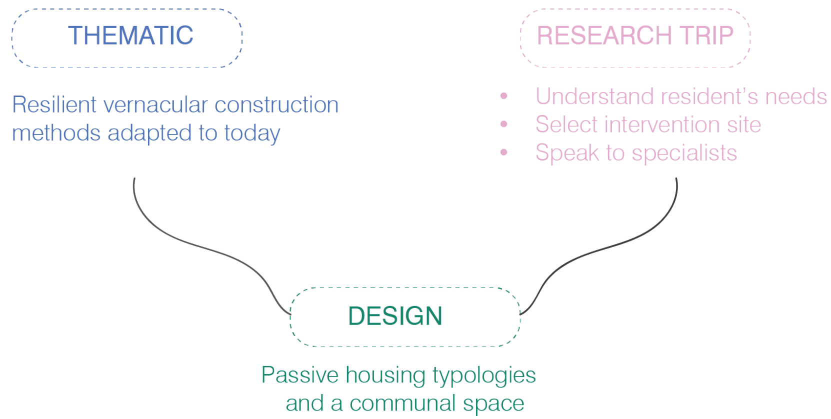
During the research trip, I will visit the site to document and evaluate its existing conditions, (housing structures and layouts, vegetation, road networks, family demographics, and prevalent building materials). Additionally, I will also interview the residents to gather insights into their perceptions of landslide risks, including any undocumented occurrences, and cross-reference this information with the technical documentation from the 2019 Plan of Territorial Order in Bogota. Furthermore, I will inquire about the community's spatial needs to inform future design decisions. Establishing communication with the Local Administrative Board (JAL) and the community Action team is crucial in order to understand their priorities and assess the feasibility of the proposed design.

As upcycled tires and bamboo are identified as ideal materials thus far, I plan to interview architects specializing in bamboo construction techniques, as well as environmentalist Alexandra Posada, who focuses on passive design strategies and building using tires. These interviews will provide valuable insights into the practicalities and challenges associated with working with these materials.

Expected Result Of Thematic Research And Design Implementation

From the thematic research and vernacular architecture case studies conducted via literature study, I intend to identify overarching construction component and materials that were resilient against landslides. I will then contrast and compare these methods with modern day case studies and current site conditions. The aim is that the result obtained from this study will inform the design, construction techniques and materials chosen that will be suitable for housing construction, while optimizing environmental suitability.





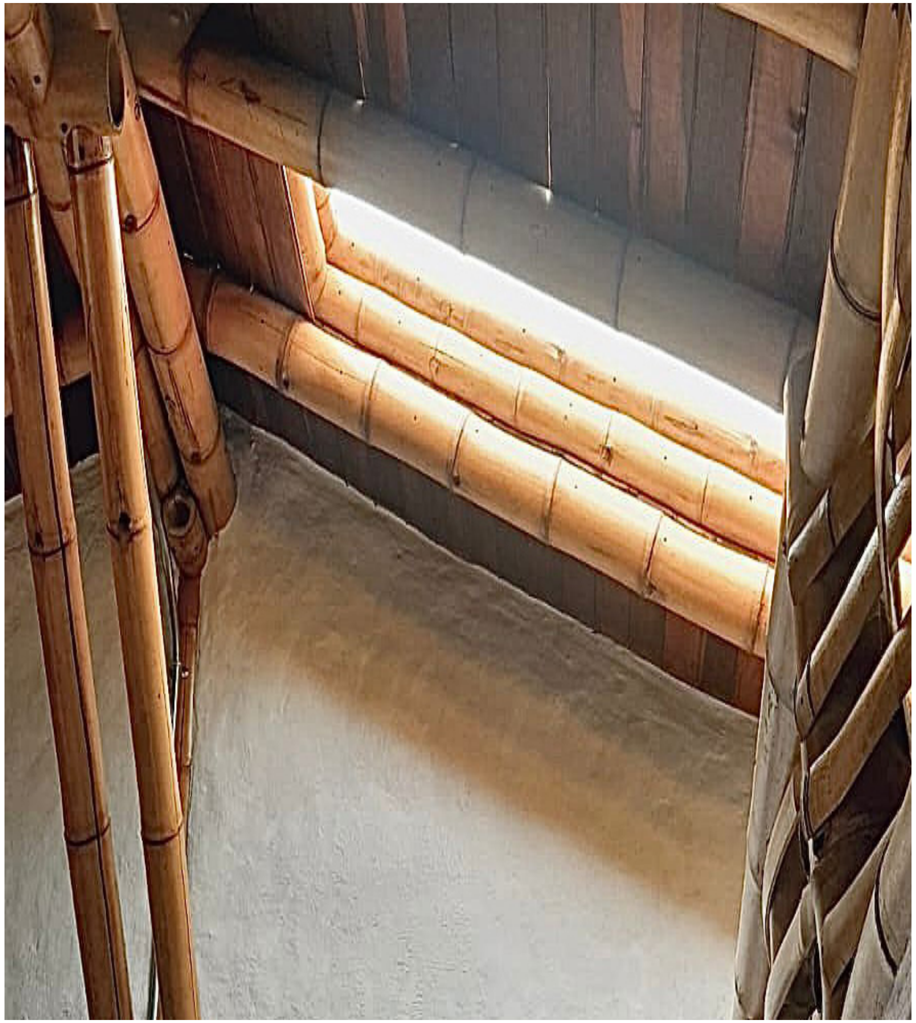


Image by Daniela Diaz- Medellin Colombia 2024

2
Research

Glossary

Akapana: Stone blocks in the base of a structure in the form of a parallelepiped with smooth surfaces and perfect joining.

Artuma: Porch-like/balcony structures in the Eastern Black Sea region in Turkey.

Cordillera: Mountain Range

Depression: In geomorphology, a depression is an area of the Earth's relief located at a lower elevation than the surrounding regions.

Gompa: Shrine/religious buildings for Buddhists found in Sherpa Vernacular settlements.

Göz Dolmasi: a rectangular cell infill wall system.

Kallanka: Large unpartitioned hall with wooden pillars to support the roof. Served as temporary lodging for individuals rather than families.

Kancha: Group of several housing units. Two Kanchas would make an 'apple'.

Kara Saçak: Rain-shielding eaves that can reach up to 2.5m in the Eastern Black Sea region in Turkey.

Kara boğaz: an interlocking technique with logs used in the Eastern Black Sea region in Turkey

Kurt boğaz technique: an interlocking technique with wood planks in Vernacular Turkish architecture.

Qollqa: Storage units also called Deposits in Peru.

Informal Settlements: Refers to housing arrangements where residents lack legal land ownership and operate outside government regulations

Muska Dolgu: a triangular cell infill wall system.

Tampu: Rest stations in the Inca empire. There was a tampu in the road at the end of each day's travel.

Slum: According to UN-Habitat, 'slums' are characterized by a lack of essential amenities such as durable housing, clean water, improved sanitation, adequate living space, and secure tenure.

Surrender: Traditional Turkish granary or storage building.

Suyu: Quarter (in the sense of a region).

Usnu: A stepped structure, a platform, the base of a throne, a place intended for high-ranking personages. May also be an altar in the Inca empire

Vernacular Architecture: A Paradigm For Resilient And Sustainable Design

The concept of Vernacular Architecture encompasses a diverse range of definitions and interpretations, spanning from ancient to simple, and Indigenous traditional structures[11]. This approach has often been categorized as crafted or reared at home[12], in contrast to the formal, “scholarly” architecture associated with professional design and academia. Amos Rapoport, in House, Form, and Culture, underscored the importance of understanding vernacular architecture through anthropological and cultural lenses. He emphasized that the study of such architecture goes beyond mere construction, intertwining with the social, environmental, and cultural contexts of the people who build and inhabit these structures.

Rapoport proposed a two-phase model for studying vernacular architecture:

1. Natural history stage: describing, documenting, and classifying the vernacular buildings.

2. The problem-solving phase: comparative and comprehensive studies, leading to the development of theories and concepts.[13]

Building on Rapoport’s approach, this dissertation takes a practical and technical view of vernacular architecture, focusing not only on its cultural significance but also on the functional principles and construction techniques that underpin these traditional structures. By analyzing how these buildings are adapted to local conditions—whether in terms of climate, available materials, or social practices—this study aims to uncover how vernacular methods can offer valuable insights for contemporary architectural practice.
Particular attention will be given to the adaptability, sustainability, and efficiency of vernacular designs, especially in relation to resource-constrained environments. These insights have the potential to inform modern architectural solutions that prioritize environmental responsiveness and community participation, bridging the gap between tradition and innovation.

11 Vernacular Architecture. Oxford Reference. Retrieved Feb. 2024, from https://www.oxfordreference.com/view/10.1093/oi/authority.20110803115517898.

12 Frey, P. (2010). Learning from vernacular towards a new vernacular architecture. Actes Sud.
13 Rapoport, Amos, Vivienda y cultura, G.Gili, Barcelona, 1972

Unraveling Complexity: Three Resilient Vernacular Case

The three vernacular case studies chosen exhibit remarkable resilience against earthquakes and landslides. Despite their varying climates, available local materials, and distinct cultural influences shaping their designs, they share a common steep topography. This shared geographical feature adds an intriguing dimension to the analysis, highlighting how diverse environmental factors can influence architectural resilience. Moreover, their locations on different continents offer a unique opportunity to explore strategies across distant regions, providing valuable insights for the conclusion. The introduction of each case study will involve contextualizing its prominent features, including geographical and climate context, settlement layouts, climate responsiveness, and an in-depth analysis of the structural integrity.

3.1 The Inca Resilience: Engineering In The Andes Mountains

This section will explore Incan methodologies, from Ollantaytambo, Pisaq, and Machu Picchu. The Incan civilization thrived from the thirteenth to sixteenth centuries, showing adaptability across diverse landscapes. Nestled amidst the Andean peaks, Incan cities showcased architectural ingenuity and urban planning, crafted to withstand seismic activity and landslides while prioritizing sustainability. Terracing supported both construction and agriculture, seamlessly blending with natural contours. Ceremonial spaces and royal residences were meticulously aligned with astronomical movements, reflecting a connection between culture and landscape.

Housing And Settlement Layouts

In Incan urban planning, complexes were arranged into distinct sectors, often featuring two plazas and spacious vestibules. In Ollantaytambo, Kancha, a system organizing quadrilateral buildings into functional complexes, were enclosed areas with four residential buildings bordering a central courtyard, each accessible from the central street. Buildings followed a north-south axis layout, with plazas facilitating communal interaction. While most houses were single-story, some featured high gable roofs, suggesting additional levels. Multi-level houses included shelves in their rear walls to support upper-floor construction. The structured organization of administrative centers, plazas, and Kanchas was foundational to Incan cities, facilitating governance and community engagement. The strategic placement of residential units and city structures integrated with the natural topography exhibited resilience against landslides.

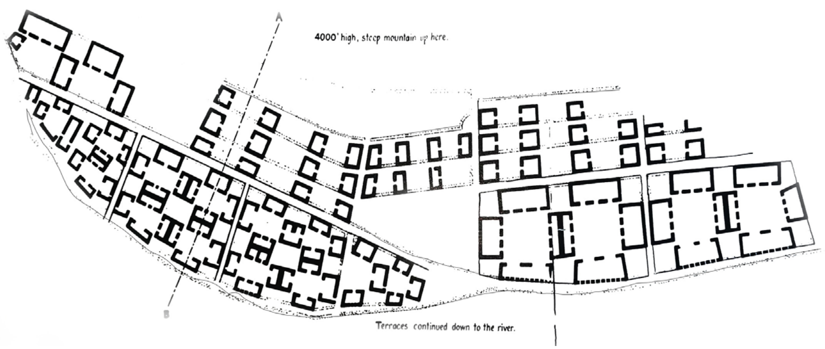


Fig. 1- A plan of kancha and other buildings following the natural contours of a mountain. Image drafted by Hiram Bingham in 1911.

Climate-Responsive And Adaptive Architecture

The Incas employed design strategies that embraced climate-responsive and adaptable architecture, as evidenced by stepped terracing and close arrangement of buildings which provided aerodynamic benefits, effectively deflecting strong winds. Negative pressure zones formed between the roofs and the rear portions of the highest buildings. Model tests and qualitative analysis conducted by Jean-Pierre Protzen revealed that smoke near lower buildings would be drawn in and promptly expelled through rear windows, preventing smoke from reaching central buildings.[14] This was facilitated by strategically positioned windows in a cross-ventilation system.

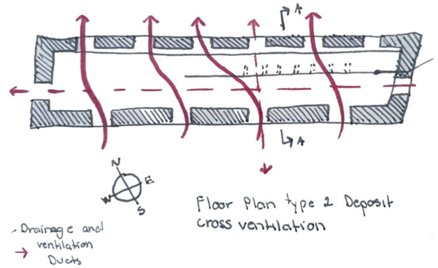


Fig. 2 - A plan of a rectangular type two qollqa in Ollantaytambo Highlighting the cross ventilation and ducts. Drawing and annotation by the author, (redrawn from Jean-Pierre Protzen 2005, fig 5.19)

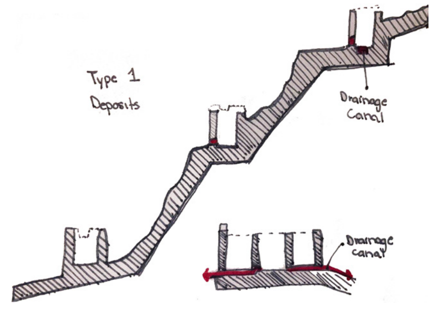


Fig. 3- The drawing demonstrates a transversal section of the deposit type one structures, highlighting the drainage and ventilation canals. Drawing and annotation by the author (redrawn from Jean-Pierre Protzen 2005, fig 5.5)

Furthermore, the Callejón in Ollantaytambo situated between one to six meters below the terrace surface and spanning approximately sixty meters in width, creates a unique microclimate protected by lateral retention walls. Fostering a conducive environment for crops and enhancing urban integration. The walls absorb and gradually release solar radiation, promoting warmth and facilitating the growth of crops adapted to warmer climates. The air temperature within the lower part of the depression is consistently two to three degrees Celsius higher than that of the tallest terraces, as the area benefits from significant protection against strong evening winds that traverse the Alluvial fan.[15]

14. Diaz, D. (2024). Learning from Vernacular Architecture to Develop Potential Methods in the Colombian Periphery to mitigate the housing crisis in Landslide prone topography. Delft.

15. Protzen,P. (2005). Arquitectura y Construcción Incas en Ollantaytambo.Pontificia Universidad Catolica del Peru.

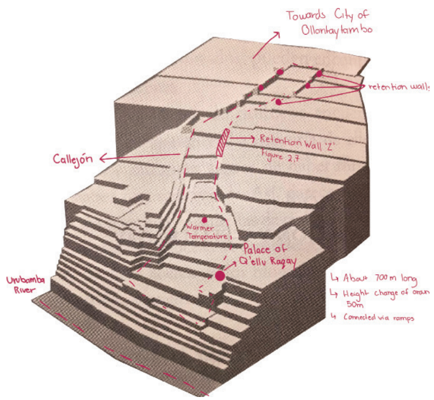


Fig. 4- 3D model of terraces by Jean-Pierre Protzen annotated by Author.

Structural System and Foundations

Most of the Inca structures were built on solid rock or large stone foundations, ensuring stability and evenly distributing the weight of the buildings. Utilizing locally sourced materials in their architecture the Inca relied predominantly on rocks such as rhyolite, tuff, rhyolite breccia, limestone, granite, and ignimbrite. In areas that seemed to be less stable, the Incas constructed raised platforms or used deep foundational stones. The stones were meticulously fitted together without mortar in a masonry technique called ashlar, relying on the precise cutting and shaping of each block resulting in highly stable structures and resistance against earthquakes.

Additionally, as the Incas followed natural contours, they also incorporated natural bedrock outcroppings into the foundations for extra stability. The largest and flattest stones are laid at the bottom to create a level base in trenches dug into the ground, with smaller stones used for the upper courses. This method enabled resiliency, capable of enduring the test of time and natural forces.

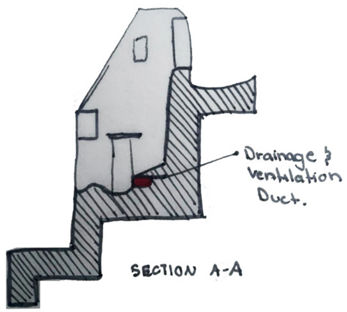


Fig. 5 - The drawing shows a cross-section of a wall structure, highlighting drainage and ventilation canals. Drawn and annotated by the author, based on Jean-Pierre Protzen (2005, fig 5.5).

Walls

The cities were surrounded by large contention walls that would protect them from possible avalanches and landslides. The process of stone extraction was meticulous and had to be carefully planned, as the extraction sites had to be protected at strategic locations with retention walls. The walls, in most cases, were a continuation of the stacked stones from the foundation without the use of mortar. The wall was able to stand due to an interlocking mechanism via "T-shape' and 'U-shape' notches employed on one side of the stones. The interlocking system allows walls to slightly move during an earthquake and resettle, enhancing the structural integrity by eliminating weak stress points and vibrations due to the tight connections between the stones. Then, the inferior part of the wall would also incline at a 10% average per meter in height toward the mountain's slope to form a trapezoidal form, acting as a retention wall, supporting the pushback of the slope. Often, the retention walls were built with two or more layers anchored together in a staggering manner depending on the height, protruding stones from the lower layer would interlock with the next.

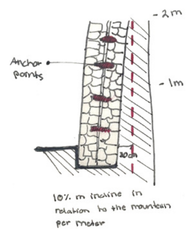


Fig. 6- Incline towards the mountain with anchor points highlighted. Drawing by the author.

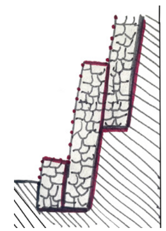


Fig. 7- Staggered walls for greater stability. Drawing by the Author.

In many housing units, the use of Nichos was incorporated as a practical characteristic, and aesthetic as well. The walls were generally thicker and heavier at the bottom, and lighter at the top. In some cases, if the wall was to be high, the Inca would use adobe.

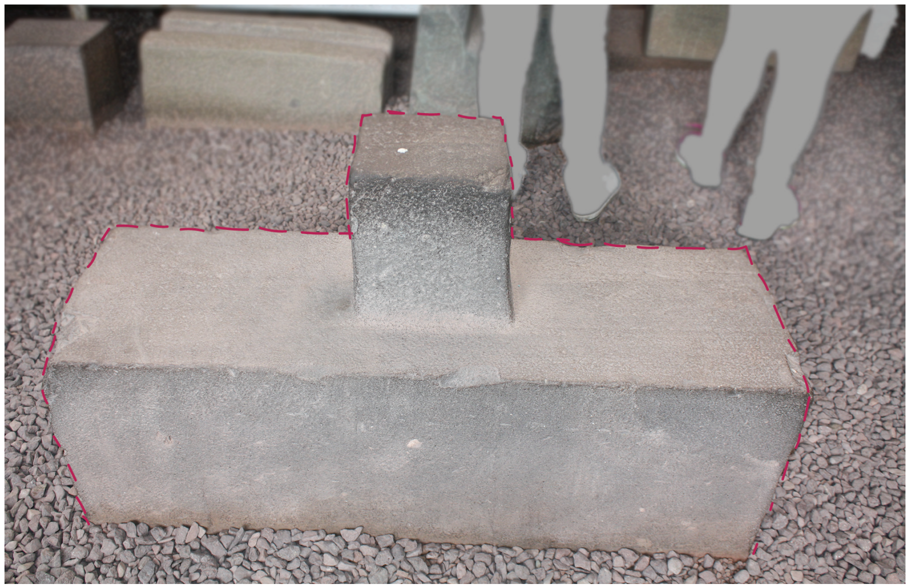
Fig. 8- Image of Inca ruins in Pisaq, Peru. Image by the author.

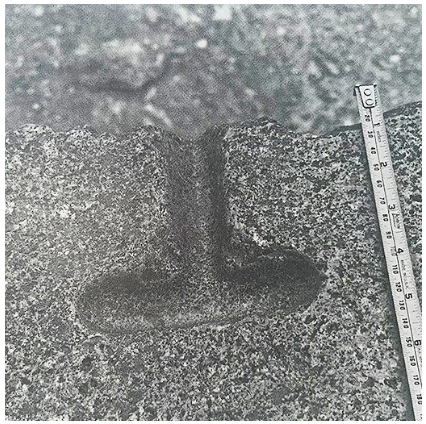
Roofs

Incan roofs, evidenced by remaining gables, were steeply pitched, generally around 60 degrees, with some variation. Despite covering smaller areas, larger structures like expansive halls are indicated by discovered ridge beams positioned approximately 10 meters above the eaves. These beams were supported by beams extending up to 12 meters long.

Inca carpenters likely employed braces for structural reinforcement against lateral forces in expansive structures. Agurto's calculations suggest that the weight and angle of longitudinal walls resisted thrust forces. Steeply pitched Inca roofs aimed to counter thrust forces but increased vulnerability to

Wall Technology





The Incas showcased advanced rock manipulation by creating “T-shape” and “U-shape” notches for interlocking stones, akin to modern Lego designs. This method enhanced structural integrity, allowing walls to move slightly during earthquakes and resettle without collapsing, while tight stone connections minimized vibrations and stress points.

wind loads. Wind passing over the roof could create low-pressure zones, potentially causing uplift surpassing the roof's weight, requiring secure attachment methods. Therefore, to secure mats over joists, tie down forks were strategically placed for stability in adverse weather conditions, while exterior nails acted as anchors, safeguarding against wind damage.

In the Punkuyoq Mountains, a distinctive architectural style emerged, featuring gable bases notched at every corner and sloping walls that created interior shelves. These gables, embellished with mooring forks and horizontal stone nails, utilized notches as joist supports and Nichos for rounded wood tripods. Tie-down forks secured mats over joists for stability in harsh weather, while exterior nails acted as anchors, protecting against wind damage. At Inkwazi, the ledge on longitudinal walls and anchored ridge beams likely prevented roof detachment effectively.

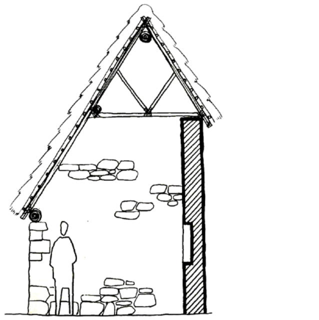


Fig. 9- Drawing of roof slopes and lengths by Gasparini & Margolies

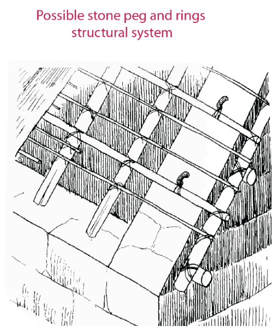


Fig. 10- Drawing by Gasparini & Margolies annotation by the author.

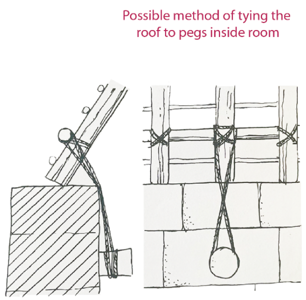


Fig. 11- Drawing by Gasparini & Margolies, annotated by the author.

3.2 Nepal- Sherpa architecture

The second case study explores the Khumbu region in Nepal, where Sherpa villages are nestled in the Himalayan mountain range bordering Tibet. Buildings in this area face diverse geomorphology and altitudes over 3,000 meters. They must endure heavy rains and hazards associated with the Himalayan fault line, including a high risk of earthquakes, landslides, and avalanches. A study by Nripal Adhikary documented that vernacular houses and modern buildings incorporating traditional materials like bamboo and rammed earth survived the catastrophic 2015 earthquake[16].

Housing and Settlement Layouts

In the Khumbu Region, settlements are typically found in the alluvial fan, between the mountainside and river gorges. Villages incorporate a uniform layout, with dwellings grouped in small clusters, terraced on slopes forming a semicircle similar to an amphitheater surrounded by cultivated land, incorporating an open space or yard in front of the house, serving both as a social space and a landslide mitigation measure. Furthermore, Sherpa communities, deeply religious and nature-respecting, incorporate a Gompa at the settlement center. Their reverence for nature extends to climate-responsive strategies integrated into their architectural practices.

Fig. 12- The Namche Bazaar in the Khumbu region. Images courtesy of Sherpa Village Lodge Trek.

Climate-Responsive and Adaptive Architecture

Sherpa houses employ various climate-responsive techniques, such as maximizing sun exposure, promoting cross-ventilation, and using local materials thoughtfully. Construction is a deliberate equilibrium between wood and stone, fostering environmental harmony. Strategically positioned on a southeast axis, doors and windows enhance solar heating exposure and natural lighting, particularly advantageous during the extended winter. This integration and features like thick insulating walls and flooring create more comfortable living spaces. In the summer months from June to September, natural ventilation avoids overheating. Wood, brick, and stone

16. Adhikary, N. (2016). Vernacular architecture in post-earthquake Nepal. International Journal of Environmental Studies, 73(4), 533–540.

are employed for their weather-resistant capabilities.

Structural System and Foundations

Sherpa houses, similar to those of the Inca Empire, feature a rectangular form parallel to the slope and are elongated to integrate into the terrain. These structures are occasionally two storeys high, with the ground floor used for cattle storage during the cold months and the upper floor serving as the living area. Additionally, some L-shaped houses incorporating private worship spaces have also been documented.

Sherpa houses utilize two main structural components and materials. The foundation, embedded into the ground and constructed from large rocks, integrates the hillside into the ground floor.[17] The inner framework comprises wooden pillars, and beams, while the outer structure features large stone walls. Additionally to support the floor above a rectangular wooden joists system is atop the main framework of beams. Windows are framed with tenons or projecting tongues of wood, assembled without nails, and seamlessly integrated into the stone walls.

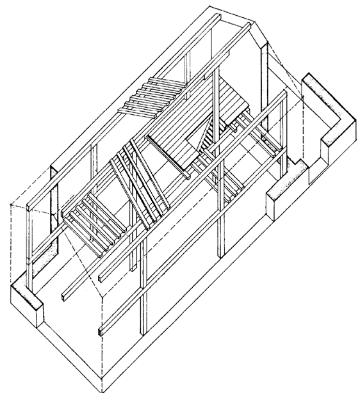


Fig. 13- Axonometric of Sherpa dwelling. Drawing by Valerio Sestini and Enzo Somigli.

Walls

The walls are made from large, locally sourced stones up to one meter thick, are load-bearing, and are crucial for withstanding wind and earthquake forces. These stone walls are bound with rudimentary mortar or clay, with more evenly shaped stones reinforcing corners, doorways, edges, and windows. The walls are often plastered with clayed earth for weatherproofing. Finely carved wooden windows and doors, featuring graceful lines and vivid colors, enhance the aesthetic appeal.

17. Khadka, S. S., Acharya, S., Acharya, A., & Veletzos, M. J. (2023). Enhancement of Himalayan irregular stone masonry buildings for resilient seismic design. Frontiers in Built Environment, 9, 1086008. https://doi.org/10.3389/fbuil.2023.1086008

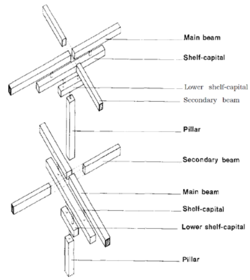
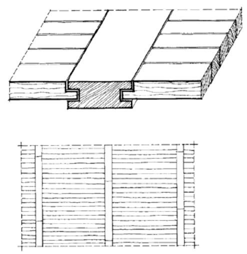


Fig. 14- An axonometric of the main beams and shelfcapitals in a gompa.



The interlocking system employed for the floors. Diagrams by Valerio Sestini and Enzo Somigli.

Roofs

In the Khumbu mountains, local architecture is designed to withstand heavy rainfall and strong monsoon winds that could lift lighter materials. Houses typically have ridge or sloping roofs, often constructed from heavy stone slabs for added durability. The roof's supporting framework consists of closely spaced rafters resting on main beams. Simple eaves are created by extending the roofing material slightly beyond the walls, reflecting practical adaptations to the region's challenging weather conditions.

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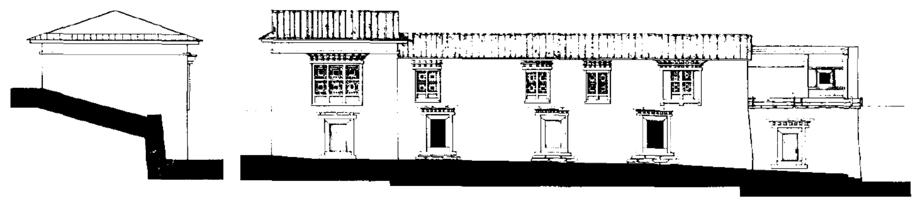


Fig. 15- Elevations of a dwelling-house at Phortse. Drawings by Valerio Sestini and Enzo Somigli.

3. 4 Turkey- Eastern Black Sea Region

The third case study, located in the steep mountains of Turkey's Eastern Black Sea region, showcases a vernacular settlement shaped by physical and cultural factors. Generational knowledge allows for optimal use of local materials[18], resulting in architecture that reflects the relationship between users and consciousness of the environment.[19] Due to the region's topography, buildings are constructed parallel to the slopes and are spaced apart to adapt to the uneven terrain. Furthermore, the climate is characterized by high moisture levels and frequent rainy seasons receiving around 2309 mm annually compared to Turkey's 615.6mm average. [20]

Housing and Settlement Layouts

A characteristic of the black sea region settlements is scattered clusters of housing built into the mountain slope following its natural contours, favoring rockier ground as it proves to be more stable terrain during the rainy season. They are often classified as compact scattered or rose settlements. To encourage social connections, the houses are close together, forming small streets and neighbourhood units, facing the valley and arranged in a repeating pattern of one house and one serender. [21] As an ecological strategy to combat soil erosion and prevent landslides, each house is surrounded by tea gardens with zigzag terraced rows and the community prioritizes planting trees in settlement areas. The region's architecture aligns with nature with minimal land alteration, blending into the terrain.

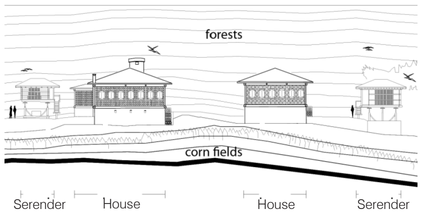


Fig. 16- Elevations of a dwelling-house at Phortse.
Drawings by Valerio Sestini and Enzo Somigli.

Climate-Responsive and Adaptive Architecture

Rather than treating nature as an obstacle, the vernacular architecture in the Black Sea Region challenges the mountainous topography leading to self-sufficient housing units through effectively utilizing local biobased resources such as stones and wood. Furthermore, the passive systems employed consider the climatic conditions such as the wind, rain, and sun[22], addressing the well-being of the occupants, protecting them from harsh weather, and minimizing heat loss in cold months.

Practical orientation and land-use strategies are employed to achieve cross-ventilation techniques utilizing the natural airflow through calculated openness ratios on walls via windows and ventilation gaps. The large eaves like the Kara Saçak act as rain-shielding elements for the building. Furthermore, the design encourages natural light and features adaptable interiors with wooden dividers, allowing for versatile space utilization.

The design and ability of disassembly and reassembly of Serenders is particularly innovative in vernacular architecture, allowing the structures to be temporary, portable, or moved to another place. Furthermore, the Serenders also incorporate local and recycled materials, which reduces waste and promotes circular design.

Structural System and Foundations

Most houses incorporate two levels with the first level serving as a warehouse barn, aligning the structure with the landscape. The second level is for the residents. The main construction material is timber due to its insulation capabilities and resistance against humidity. Two timber structural systems are common:

1. The Timber Masonry system employs overlapping and interlocking mechanisms, eliminating the need for nails or mortar. The rectangular structure features square cross-section support columns placed at regular intervals. Both interior and exterior walls are constructed simultaneously using notched and neck joints, with timber elements extending 20-30 cm from jointing points for support.

2. The Timber Frame System features load-bearing elements standing vertically on stone foundations. Basement joists, set at 15x15 cm intervals, utilize interlocking neck joints for strength. The posts above these joists determine each floor's height, with ceiling joists positioned over the corner and middle posts, resulting in a lightweight structure with a flexible floor plan.

The timber structures are supported by masonry foundations integrated into the

18. Karahan and Davardoust, 2020

19. Senosiain, 2003
20. Turkish State Meteorological Service, 2021
21. Özen, Keleş and Engin. Journal of Civil Engineering and Architecture, Vernacular Building Heritage in the Eastern Black Sea Region in Turkey. 2012.

22. Oktay, 2010

land, following its contours. Some houses partially bury the foundation for insulation and humidity protection, using locally sourced granite.

Walls

The subsequent analysis pertains to the structural composition and components of the walls. The Kurt boğaz and Kara boğaz techniques align with the timber masonry system and function as load-bearing connections. In addition, two primary façade systems are prevalent: Göz Dolmasi, a rectangular cell infill system, and Muska Dolgu, a triangular cell infill system.

The Göz Dolmasi integrates stone and timber elements. Initially, joists are positioned above the stone walls, followed by timber posts at intervals. Each segment is filled with wooden pieces creating rectangular cells horizontally and vertically. These cells are then filled with stones and other regional materials, with leftover spaces filled using clay or lime mortar. Typically, 20-25 cm wide plates are placed between pillars both internally and externally[23], facilitating the creation of window and door gaps, and ensuring secure fixation through an interlocking method.

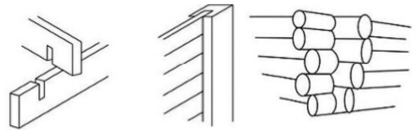


Fig. 17- The different types of structural interlocking systems. Retrieved from Elif Berna Var.

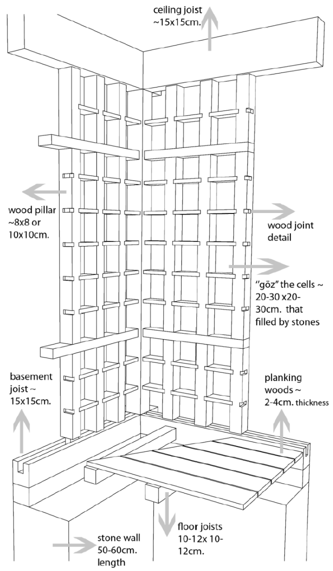


Fig. 18- Perspective drawing of the construction of a timber frame structure with cell infilling system (Güler, 2013)

The Muska Dolgu wall system uses similar components and incorporates metal binding elements instead of timber joints. Diagonal supports between the posts create triangular divisions, filled with small stones. While nails expedite construction, they affect the structure's demountability.

Both techniques often feature interior walls lathed with plaster or timber veneer. Over time, the elements darken, creating a contrast with the stones. Artuma, porch-like/balcony structures around the building, were made of timber frames resting on the masonry foundation, accessible from bedrooms and protecting lower floor openings.

Fig. 19- Wall cell infill system. Image by Hamiyet Özen

Fig. 20- Wall cell infill system. Image by Hamiyet Özen

Roof

The vernacular roof types prevalent in the Eastern Black Sea Region primarily feature steep-hipped designs, which are subdivided into three main variations: double-pitched, triple-pitched, and quadruple-pitched. These variations are determined based on factors such as the required space and the climatic conditions of the region, particularly focusing on efficient water drainage with exterior and wall protection. The roofs also doubled as functional storage units, with height directly correlating to increased storage capacity.
The region is recognized for the Kara Saçak cantilevered eaves extending up to 2.5m in length[24] and are about 80-180 cm in width. The timber truss system is then constructed according to the roof's desired height, pitch, and slope. The shingles were predominantly made out of wood (chestnut) or thatch (straw or reed), as these biobased materials are moisture-resistant and durable.

23. Construction Techniques of the Vernacular Architecture of the Eastern Black Sea Region. 2013.

24. Şen, Necati. 1967. Rize'de Beş Ev. İstanbul: Technical University Publishing.

4. Case Study Conclusions

Comparing Incan architecture in the Andes, Sherpa architecture in Nepal's Khumbu region, and Turkey's Eastern Black Sea region reveals the resilience of vernacular engineering's resilience over time. These cases showcase how vernacular architecture, molded by both physical and cultural elements, embodies an understanding of steep terrain, local materials, and climate-responsive techniques, offering lessons adaptable to modern sustainable, and resilient designs.

In settlement layouts, these cases integrate with natural contours, minimizing ecosystem impact through terracing techniques for mountain construction. Clustered formations optimize resource utilization and support networks for swift crisis response, while cultural features like courtyards, plazas, and gardens foster community bonds and unique identities.

For contemporary designs, incorporating vernacular techniques such as passive cooling through cross-ventilation and strategic window placement is crucial for promoting natural airflow and cooling within buildings. Solar orientation ensures maximum exposure to sunlight for heating and lighting, especially during winter. Insulation and thermal mass, facilitated by thick walls, regulate indoor temperature and humidity. Rainwater management, including steep roofs and terracing, efficiently directs runoff to protect structures from moisture damage. Vernacular designs emphasize the use of local and durable materials, simple structures, and open-plan layouts.

Analyzing the structural systems and foundations is critical to understanding which elements and techniques rendered vernacular architecture resilient against landslides. Interestingly, none of the vernacular structures were raised on stilts, as seen in some current constructions in various slums in Bogota to avoid flooding. Instead, these structures are embedded into the landscape, following the contours of the land. To address flooding, Inca vernacular techniques involved canalizing rainwater and rerouting it through small channels underneath the houses for cooling. Additionally, both the Sherpa and Black Sea regions utilize terraced gardens and plantations to mitigate runoff water. These strategies could be incorporated into the housing design.

Moreover, two out of the three vernacular cases employed interlocking structural and wall techniques, utilizing either large stones arranged in lego-like or wooden interlocking joint mechanisms. While only one of these cases incorporated an inclination of the walls towards the mountain, all of them adopted a rectangular shape for the buildings, aligning them parallel to the slope. Therefore, when designing in steep terrain prone to landslides, it is essential to consider strategies such as mitigating runoff rain, integrating thick retention walls into the mountain slope, and assessing potential interlocking mechanisms to enhance construction accessibility and building flexibility.

The vernacular studies revealed that steep-hipped roofs were the most efficient in terms of structural integrity and water drainage, with larger eaves providing wall protection. Each case study employed bio-based structures and coverings like thatch. Notably, in the Eastern Black Sea Region, some houses merged into the ground with grass serving as a natural roof covering, resembling a green roof design.

Finally, the only case study that employed a 'future-proof' strategy was the Eastern Black Sea Region through modular techniques, recycled materials, and design for disassembly, which is an aspect that should be considered when designing social housing in Bogota's periiphery.

5. Stilt Foundation Case studies

To further explore vernacular architecture and its resilience against natural disasters, particularly in steep mountainous terrain prone to landslides, this research phase focuses specifically on structures with stilt foundations from various regions aroundworldwide. While previous case studies included different structural elements, they all shared one common feature: foundations embedded directly into the mountainside. In contrast, this segment examines only stilt foundations, intentionally excluding other components like roofs and walls, which were analyzed earlier in the study.

The selected case studies include the Toraja people in Indonesia, the Miao people in China, and the Arunachal Pradesh community in India. These communities were intentionally chosen for their geographic diversity, representing distinct climatic and topographical conditions. Other potential case studies, primarily located in Southeast Asia—such as in the Philippines, Vietnam, and Laos—were excluded to avoid overrepresentation of similar environmental factors and to ensure a broader comparative analysis.

5.1 Indonesia- Toraja Community

The Toraja community is settled in the mountains of Sulawesi at elevations varying from more than 1000m asl, surrounded by tropical forests, rice paddies, and coffee plantations. The climatic conditions of this region are humid year-round with high temperatures. It constantly rains and the air is perceived as muggy.

The Toraja traditional houses are known as *tongkonan* and are boat-shaped houses built with two main types of raised foundations:

The *log house* construction stands on four cornerstones made of mountain stone to prevent termite damage and decay from groundwater. Round beams are stacked and interlocked at right angles using slots. The *pile-house* construction uses four or more posts arranged in grid-like formation each made from locally sourced palm tree trunks and an approximate diameter of 25cm, set on base stones and connected by cross-beams for stability. The beams, transfer loads from the upper to the substructure. A central post, known as *ariri posi*, serves as the main support.

The elevation primarily allows for airflow, cooling, and protection from the humidity on the ground, however, it also minimizes land excavation and preserves the natural landscapes. Furthermore, as Indonesia is prone to earthquakes, the stilts enhance the structural resilience of the homes by allowing shear flexibility and even distribution on the ground, absorbing the seismic shocks offering greater stability compared to rigid foundations. The space beneath the *tongkonan* is often adapted for practical use, serving either as a communal gathering area or for housing livestock.

Fig. 21- Pile-house stilts. Image by Lilianny Siegit Arifin.

5.2 China- The Miao Community

The Miao people live in the steep, uneven mountainous regions of Southwest China, where they have developed unique architectural solutions suited to the challenging terrain. One such structure is the *diaojiaolou*, which translates to "hanging feet buildings." These homes, typically two to three stories tall, are rectangular and elevated on stilts and wooden columns, supported by stone blocks at their bases. Their construction relies on grooves and joints rather than nails or glue mediums.

The elevation of the *diaojiaolou* serves practical purposes. The stilts help protect against the region's high humidity, especially during the summer, and guard against frequent floods, earthquakes, and even venomous snakes. This innovative design ensures the homes are equipped for the environmental challenges the Miao people face year-round.

Fig. 22- Basha Miao Village. Image by Discover China Tours.

Fig. 23- Basha Miao Village traditional house. Image by Discover China Tours.

5.3 India- The Arunachal Pradesh Region

Arunachal Pradesh, with its mostly hilly terrain, features both mountainous and sub-mountainous regions. Homes, like the Assam-type and stilt houses (Chang Ghar), are built to suit this challenging landscape. These houses are typically elevated between 1.2 and 3 meters off the ground. This design helps protect them from flooding during the monsoon season and wild animals.

Bamboo is commonly used for stilts due to its strength, flexibility, and resistance to water, while mud and salwood are also important materials. The light weight of these building materials makes the homes more resistant to earthquakes. Additionally, the space beneath the stilt houses allows for better air circulation, naturally improving ventilation and keeping the interior cooler.

Fig. 23- Traditional House. Image by WordPress

Fig. 24- Journal of Social Sciences Institute, Volume 28, Issue 1, 2019, Page 92-103

5.2 Conclusion Foundations Stilts vs Embedded

This research phase examined the use of stilt foundations in vernacular architecture on steep terrain, focusing on the Toraja in Indonesia, the Miao in China, and communities in Arunachal Pradesh, India. These case studies highlight the adaptability of stilt structures in addressing environmental challenges such as seismic activity, landslides, and uneven ground. While materials and designs vary—from the palm trunks used in the Toraja tongkonan to the bamboo stilts of Arunachal Pradesh and the Miao *diaojiaolou*—the common feature is the use of stilts in flood-prone areas for protection and ventilation.

The research shows that the choice between stilt or mountain-integrated foundations depends on local environmental and topographic conditions. Stilt foundations are favoured in humid and frequent flooding areas, while mountain-integrated homes are favoured in rockier and drier regions.

In the context of Bogotá's mountainous periphery, it is recommended to shift from stilt foundations to mountain-integrated designs. This approach better adapts to the steep terrain, providing greater stability. Given Bogotá's relatively cold, dry climate, integrating homes into the mountain would improve insulation and offer added protection against landslides through the use of retaining walls.

Considering the self-built aspect of the housing design, a combination of embedded and stilt foundations is more practical. Embedding the foundation at the rear provides greater stability, while using stilts at the front allows for easier adaptation to the terrain, reducing the need for extensive digging by the residents.

3

Site Analysis

Location and Geography

Colombia, situated in the northwest corner of South America, is characterized by its diverse geography, climates, and topography, making it one of the most ecologically rich countries globally. The Andes mountain range shapes its climate, ecology, and urban development. Bogotá, the capital, sits at 2,640 meters above sea level and is a major urban hub.

In Bogotá's periphery, Soacha is rapidly expanding as more people arrive seeking better opportunities. This growth brings challenges like inadequate infrastructure and limited access to services. The steep slopes increase landslide risks, especially in informal settlements, where many residents live in poor housing conditions.

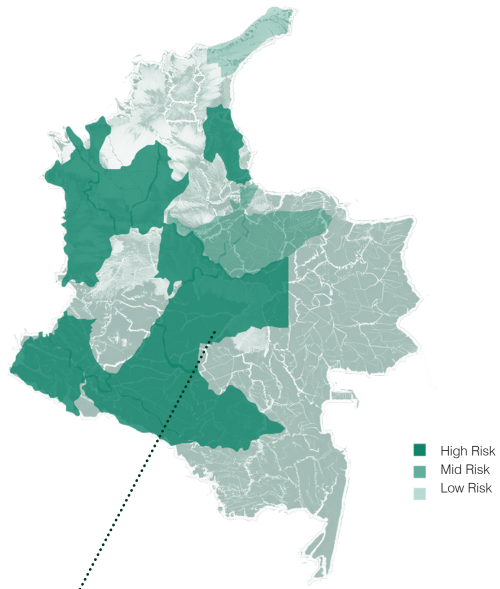


Image by Daniela Diaz- Brick factory located below the residential area right beside the Coal Factory. Causing air pollution.

Precipitation

Rainy days fluctuate significantly throughout the year, with the wet season encompassing April, May, and September to December. In contrast, the dry season is from January, February, July, and August—according to IDEAM. The highest rainfall occurs in April with a maximum amount of 200mm, while January tends to have the least precipitation.

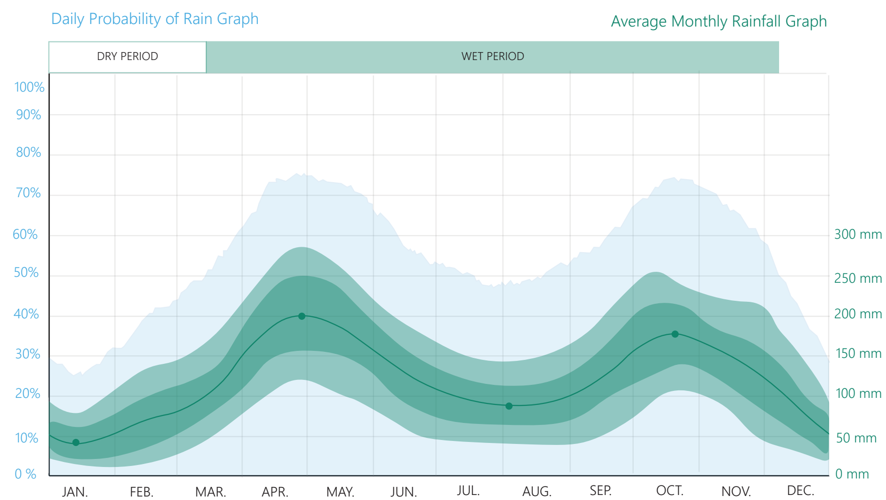


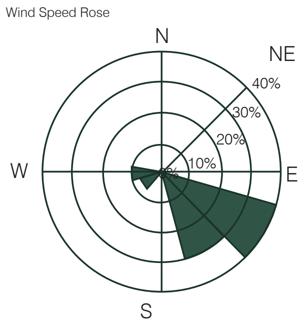
Fig. 26- Traditional House. Image by WordPress

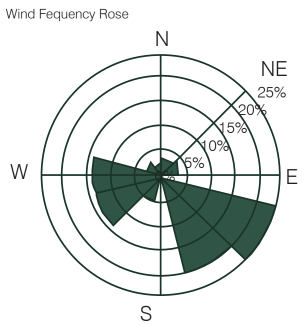
Climate

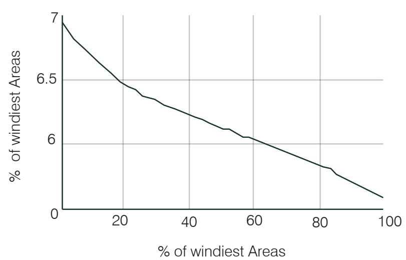
IDEAM reports Bogotá's climate is changing, with shifts in rainfall and shorter temperature fluctuations. The city has a temperate highland climate, averaging 13.1°C. Daytime highs range from 18-20°C, and nighttime lows from 7-10°C. The coldest months, June to August, see lows around 7°C, while the warmer season, December to April, reaches up to 24°C. Climate change may raise temperatures by 1.4°C by 2070 and 2.2°C by 2100, with altered rainfall. The city's high altitude intensifies sunlight and limits vegetation.

Wind

The wind analysis for the indicates that the majority of days throughout the year have low wind speeds, mainly ranging from 2 to 5 km/h. Only a few days reach wind speeds of 5 to 10 km/h, particularly evident in March and April. This data reveals a consistent pattern of low wind speeds, contributing to a generally calm atmosphere in Soacha. Additionally, occurrences of wind speeds in the 10 to 20 km/h range are infrequent. However, up in the mountains, where the site is located, wind speeds change and become stronger, as the flow of air is free to move more quickly at very high altitudes. The wind rose diagrams explain that the most constant wind comes from the South-East.







Environmental and Biodiversity

The area has experienced severe environmental degradation from illegal mining, deforestation, and open-air carbon factories, causing erosion, frequent landslides, and air pollution. A UNDP and UNIMINUTO report highlights urban agriculture efforts in a nearby neighborhood, supported by the FAO, to improve food security through community gardens. However, discussions on broader sustainable agricultural practices have yet to result in concrete action.

Image by Daniela Diaz- One of the few remaining patches of vegetation in the area, which was once densely forested.

Historical and Socio-Economic Context

Los Frutales is a sector with neighborhoods named after fruits, including Los Cerezos (The Cherry Trees), an informal settlement that began in the 1990s as people fled violence and displacement from Colombia's internal conflict. The population has grown over time, driven by the need for affordable housing, often acquired through questionable deals that have led to ongoing legal issues around land ownership. The community has long suffered from a lack of basic services like water, electricity, and education infrastructure. Today, it is primarily home to single mothers with young children and elderly people—some of the most vulnerable groups.

Employment is limited, with many relying on informal work in construction, recycling, or street vending. While crime, such as drug trafficking, is a concern in some areas, the site visited, which is newer, hasn't reported any safety threats. However, physical safety is a concern due to poor housing, lack of services, and no street lighting, making the dark, uneven terrain hazardous at night.

Transportation

Transportation is a major challenge for residents. Without access to public transit, many walk over an hour to reach a bus stop, while some ride bicycles once the terrain allows. Others use an informal minivan service run by a community member, but those living higher up often have to trek down on foot as the van can't reach them.

During interviews with some children in the community, they expressed their love for school. Higher education seemed out of reach to them, as many of their family members hadn't completed high school. When asked how often they attend school, they responded with laughter:

"Oh yeah, we can't go to school if it rains. No one can make it down the mountain because it gets so muddy. So, we just stay home trying to catch up."

I also inquired about the location of their school and how long it took them to get there. Standing at the top of the mountain, they pointed to a pair of buildings far in the distance and said their school was nearby, but it took at least an hour to reach on a good day. When I asked if there was a closer school, they mentioned there was, but it was in such poor condition that their mothers feared it might collapse. They laughed again, seemingly unaware of the gravity of their situation, or perhaps because it's simply part of their everyday life.

Image by Daniela Diaz- Resident with his bike.

Image by Daniela Diaz- A young resident holding his stuffed elephant as he shares his experiences about school.

4

Dwellings and Anthropologic Research

Dwelling evaluation and Anthropologic Research

Structural Integrity

Upon arriving at the site, it was immediately apparent that none of the houses had structural integrity. While a few seemed slightly more stable than others, most appeared on the verge of collapse. Many were constructed from large sticks tied together with scrap materials and wire. In some cases, additional smaller sticks had been added over time to reinforce the structures, but these makeshift efforts offered little reassurance.

Residents confirmed they had built the houses themselves, with some expressing embarrassment over the condition of their homes. Most of the houses were single-story and packed closely together, creating a serious risk of a domino effect in the event of a natural disaster.

The primary building materials consisted of wood, rocks, a few bricks, and occasional steel poles. Roofs were mostly made of zinc sheets, many of which were riddled with holes and weighed down by bricks. In some instances, the roofs were attached to internal structures with wire. The typical house plot measured about 12 by 6 meters.

Interiors

The living conditions at the site were marked by several challenges. The homes were poorly lit, with no windows to provide natural light or ventilation, making the space hot and stuffy. Unpleasant odors lingered in the air, with multiple people often sharing small, overcrowded rooms. Many homes lacked sufficient space to hang clothes, and most of the bathrooms were located outside.

The roofs frequently had holes, offering little protection from the elements. Inside, the floors varied—some were bare mud, others had uneven concrete, or scattered tiles. In some homes, planks were laid over uneven areas to create a walkable path.

Living spaces were generally defined by function, although a few homes had been divided into makeshift studio apartments for up to three people. In many cases, layers of tarp were used to partition rooms or even serve as exterior walls. The primary construction materials included tarp, plastic, corrugated metal sheets, plywood, wooden slats, and cardboard, which was mostly used as insulation on the floors. Most homes were equipped with gas stoves, with the gas cylinder attached.

Water Management

Bogotá is facing a water shortage with cuts lasting 24 to 30 hours every other week. However, this neighborhood struggles even more, as the government-installed water tank remains empty due to trucks being unable to access the unpaved roads. Residents are told to pave the roads first, creating a cycle where their basic needs are overlooked despite road infrastructure being a government responsibility.

Image by Daniela Diaz- Image of homes in the neighbourhood, constructed by Residents.

Image by Daniela Diaz- Image of homes in the neighbourhood, constructed by Residents.

Image by Daniela Diaz- Improvised water management systems constructed by Residents.

Image by Daniela Diaz- Resident-constructed drainage canal, currently clogged with garbage and characterized by strong odors and mosquito infestations.

When asked about collecting rainwater, residents said they had considered it but never implemented the idea. Buckets are mainly used to catch leaks from their roofs, and larger bins are impractical since they can't transport them when full, relying instead on smaller containers.

People

Many families in Los Frutales, along with their cats and dogs, live together in cramped conditions. Despite the limited space, family bonds are notably strong, with siblings supporting one another closely. Often, the eldest child assumes a parental role, taking on responsibilities such as cooking and cleaning while their parents are at work.

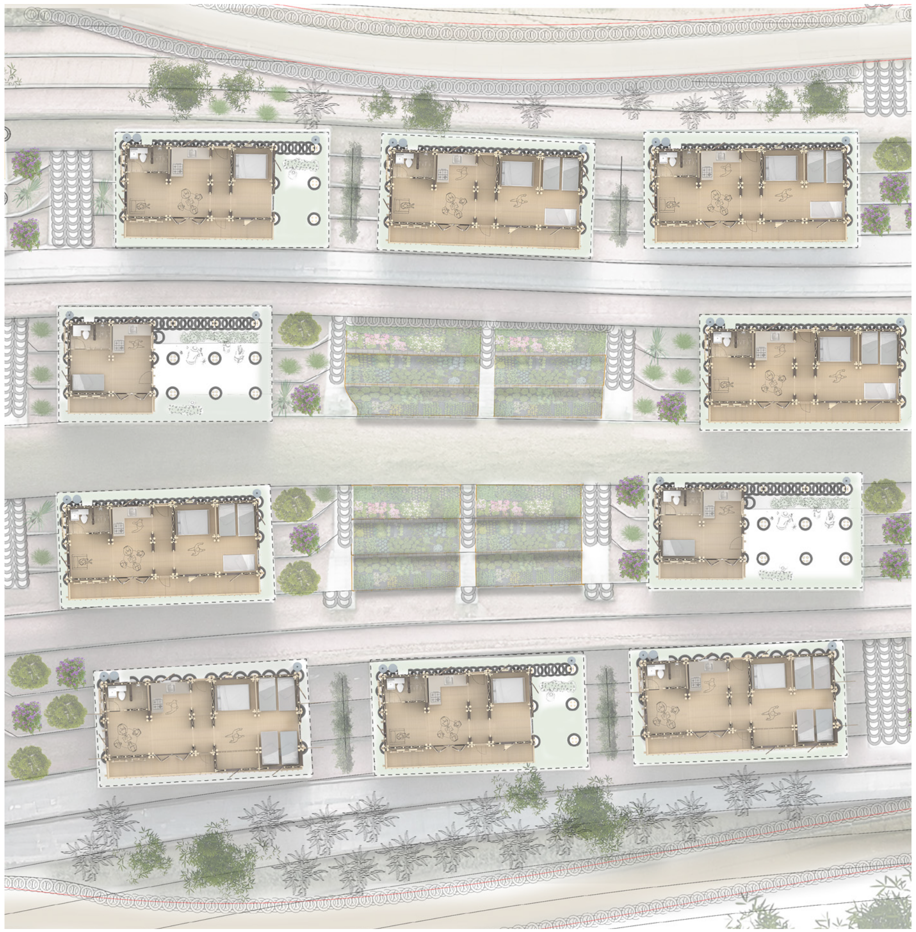
Resource scarcity forces residents to keep everything, leading to cluttered and dusty homes. With no designated laundry area, clothes are washed by hand in outdoor sinks, adding to the sense of overcrowding. Surprisingly, there are no plants, and residents seem unaware of the benefits, like how tree roots help stabilize the soil

Through interviews and observations, it became clear that the community's development is closely linked to their experiences of forced migration from Colombia's armed conflict. In Los Frutales, residents have created new identities and social structures, shaped by collective memories of displacement and marginalization.

Image by Daniela Diaz- Young Resident sitting on the empty government-installed water tank.

The informal settlement process reflects both physical and social transformation, as residents develop creative strategies to cope with their environment, showing resilience as they rebuild their lives and strengthen community ties, despite the lack of infrastructure and state support.

Image by Daniela Diaz- Single mother with her two children accompanied by a community leader.



5
System Proposal

Design Principles Diagram

Design Principles

Resilient Housing for Community:

The design emphasizes resilient housing that reflects community strength and adaptability. It incorporates long-term landslide mitigation and climate change strategies, using biotechnical slope stabilization with native plants. Durable, bio-based, and sustainable materials ensure weather resistance, and environmental harmony.

Community Shared Spaces:

Central designated social areas promote inclusivity and community cohesion. These spaces include a community garden, a workshop for prefabricating housing components and hosting skill-building workshops, a children's playground, and an outdoor lounge area.

Vernacular Architectural techniques:

Combining vernacular construction techniques with modern technology and locally available materials enables more accessible, community-led building. These vernacular methods have proven their resilience, enduring centuries of weather and environmental challenges.

Community Empowerment:

This design empowers the community by enabling residents to collaborate with the architect to express their needs. Flexible house designs accommodate their abilities and budgets, fostering ownership. Collaborative spaces and community gardens promote active participation, self-sufficiency, and stronger social ties.

Modularity:

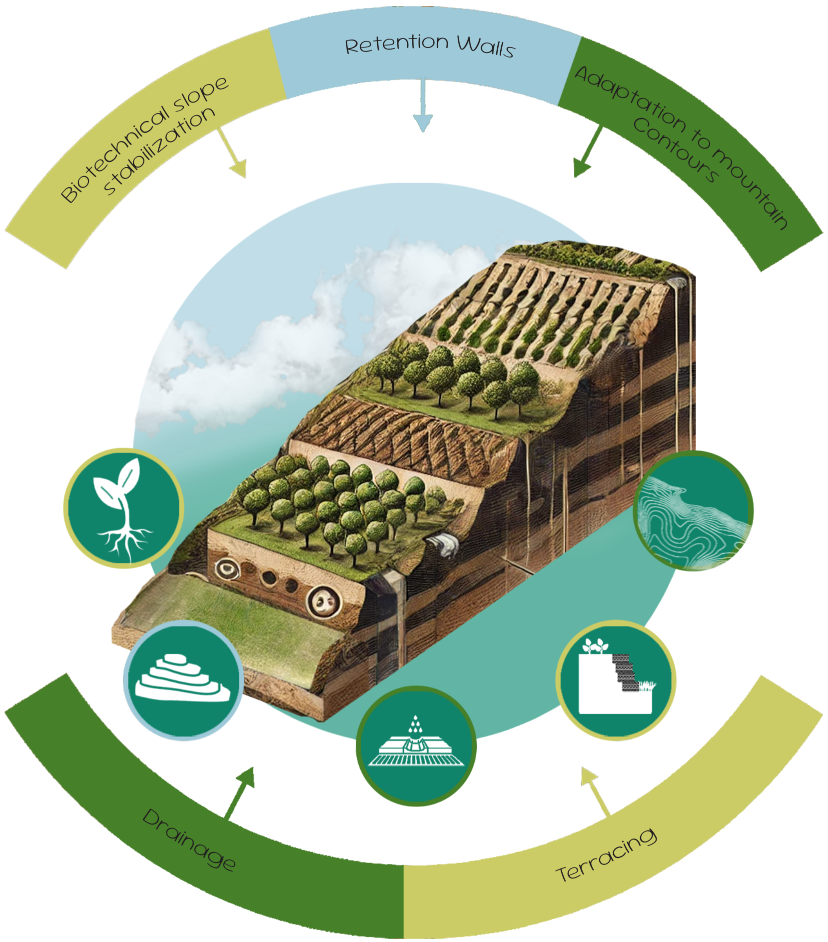
Incorporating modularity into the design provides greater flexibility and enables a faster construction process, facilitating future expansions and scalability.

Sustainable

The community design uses bio-based and recycled materials to reduce its carbon footprint and restore native mountain vegetation. It also employs passive design techniques and includes spaces for community-led food cultivation to promote self-reliance.

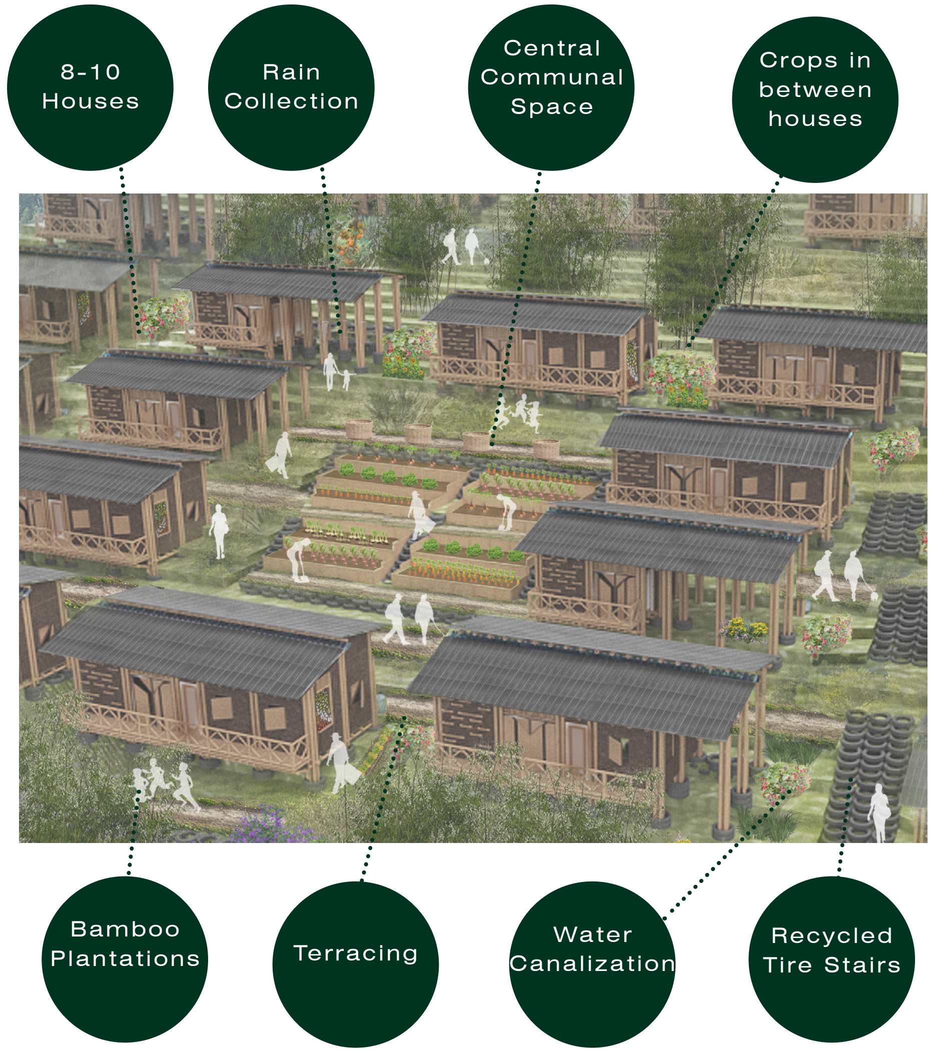
Landslide Mitigation Techniques Derrived from Vernacular Engineering

T hese landslide mitigation techniques are effective due to their adaptability, functionality, and cost-efficiency. Biotechnical slope stabilization combines vegetation and engineering to reinforce soil, reduce erosion, and enhance slope stability naturally. Drainage systems prevent water accumulation by redirecting excess water, reducing soil weakening and landslide risks. Terracing decreases slope steepness, distributes weight, and minimizes soil movement, making it ideal for steep terrains. Retention walls, especially those made from repurposed tires, provide strong, durable, and economical structural support while promoting sustainability. Finally, adapting to natural contours minimizes environmental disruption, maintains slope stability, and reduces destabilization risks.



Components of Cluster system

The cluster system consists of 8-10 houses designed to foster collaboration during construction while maintaining manageable density. Smaller clusters improve disaster response, allowing for quicker evacuations. Each cluster is surrounded by bamboo plantations for slope stabilization, water absorption, and material resources. The terraced clusters feature a central community space and a 3-meter distance between houses, with fruit plants in between to enhance the environment.



Agricultural Potential and Biotechnical Slope Stabilization

As the Cerrezos neighborhood in Soacha is located at a high altitude in the Andean region, it experiences a cool climate with average temperatures ranging from 10-16°C and abundant rainfall. These conditions, typical of Colombia's montane ecosystems, provide an ideal environment for a wide variety of native and cultivated plants adapted to such climates. Through research, site analysis, and consultations with locals, it has been determined that the following plants, vegetables, and fruits can be successfully grown and harvested in this region.

Native Plants

Chusquea - Andean Bamboo

This native bamboo is excellent for the climate and height due to its adaptability to wet and cool conditions. Its dense root system stabilizes soil and prevents erosion. Efficient in absorbing water and releasing it slowly into the environment. Furthermore, it acts as a natural windbreak.

Giant cabuyá (Furcraea andina)

Native to Colombia's Andean region, known for its long, fibrous leaves and deep root system. Its extensive roots help stabilize soil, prevent erosion, and reduce the risk of landslides in steep, mountainous areas.

Yarumo (Cecropia spp.)

A fast-growing tree that tolerates high rainfall and cooler temperatures. It plays a role in improving soil quality and biodiversity.

Encenillo (Weinmannia tomentosa)

A hardy tree that thrives in high-altitude, wet environments. Its presence supports native ecosystems by providing shelter and preventing soil erosion. In terms of water, it prefers consistent moisture but is drought-tolerant once established.

Fruits

Uchuva (Physalis)
-Vine plant

Blackberries (Rubus glaucus)
-Vine plant

Lulo (Solanum quitoense)

Curuba (Passiflora tripartita)
-Vine plant

Tomato

Vegetables

Potatoes (Solanum tuberosum)

Carrots (Daucus carota)

Vegetables

Beets

Cabbage (Brassica spp.)

Onion

Lettuce

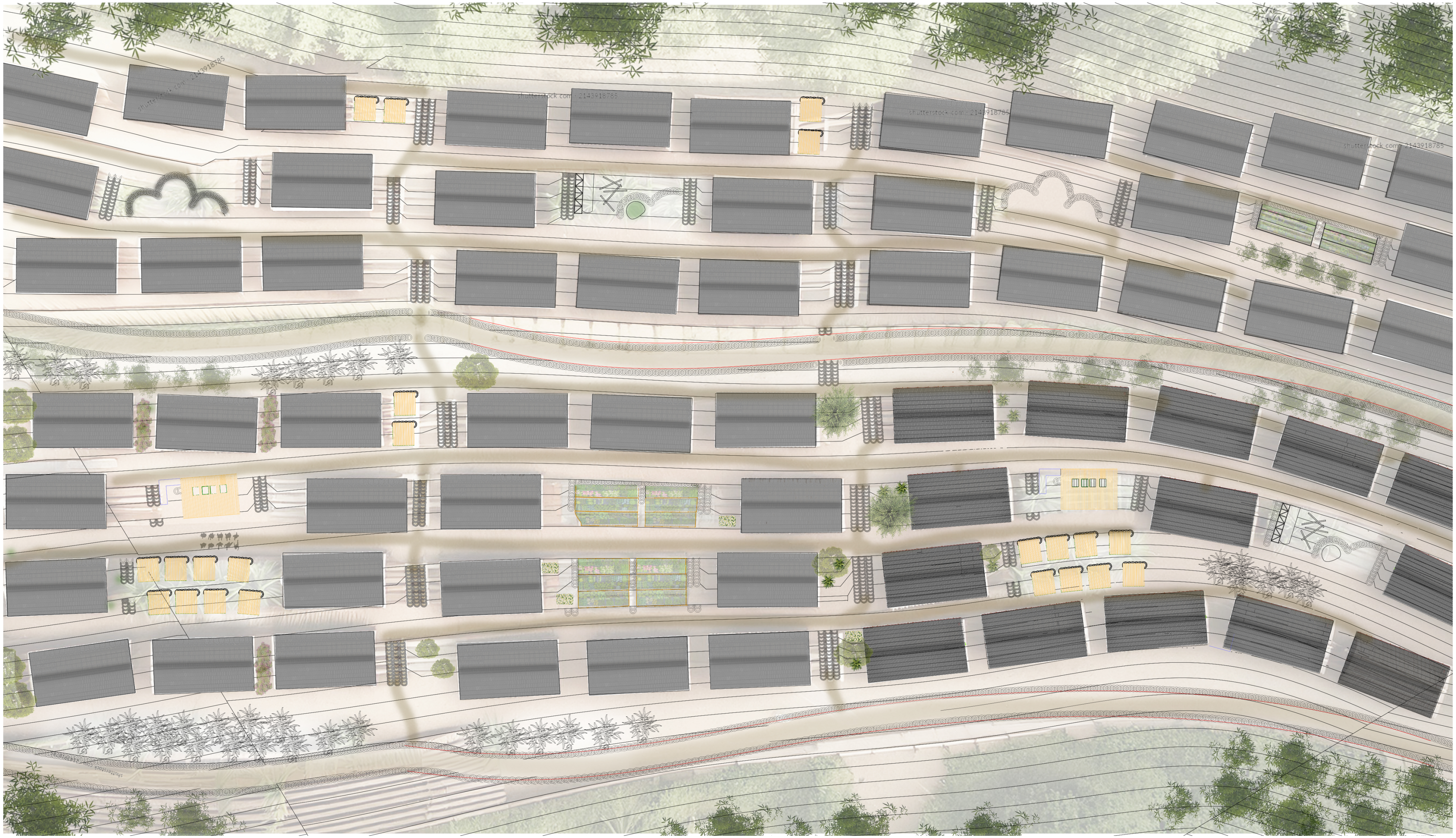
Coriander- Cilantro

Cammomile

Lemon Grass

Master Site Plan 1:600

The master site plan features a total of 63 houses, complemented by 8 communal spaces, including gardens, workshops, storage areas, an outdoor lounge, and a children's playground. Each cluster is surrounded by bamboo plantations and integrates terracing, pathways, water management systems, rainwater collection, and stairways made from recycled tires. The plan illustrates smaller clusters with the potential for continuous growth, promoting community connectivity and sustainability.

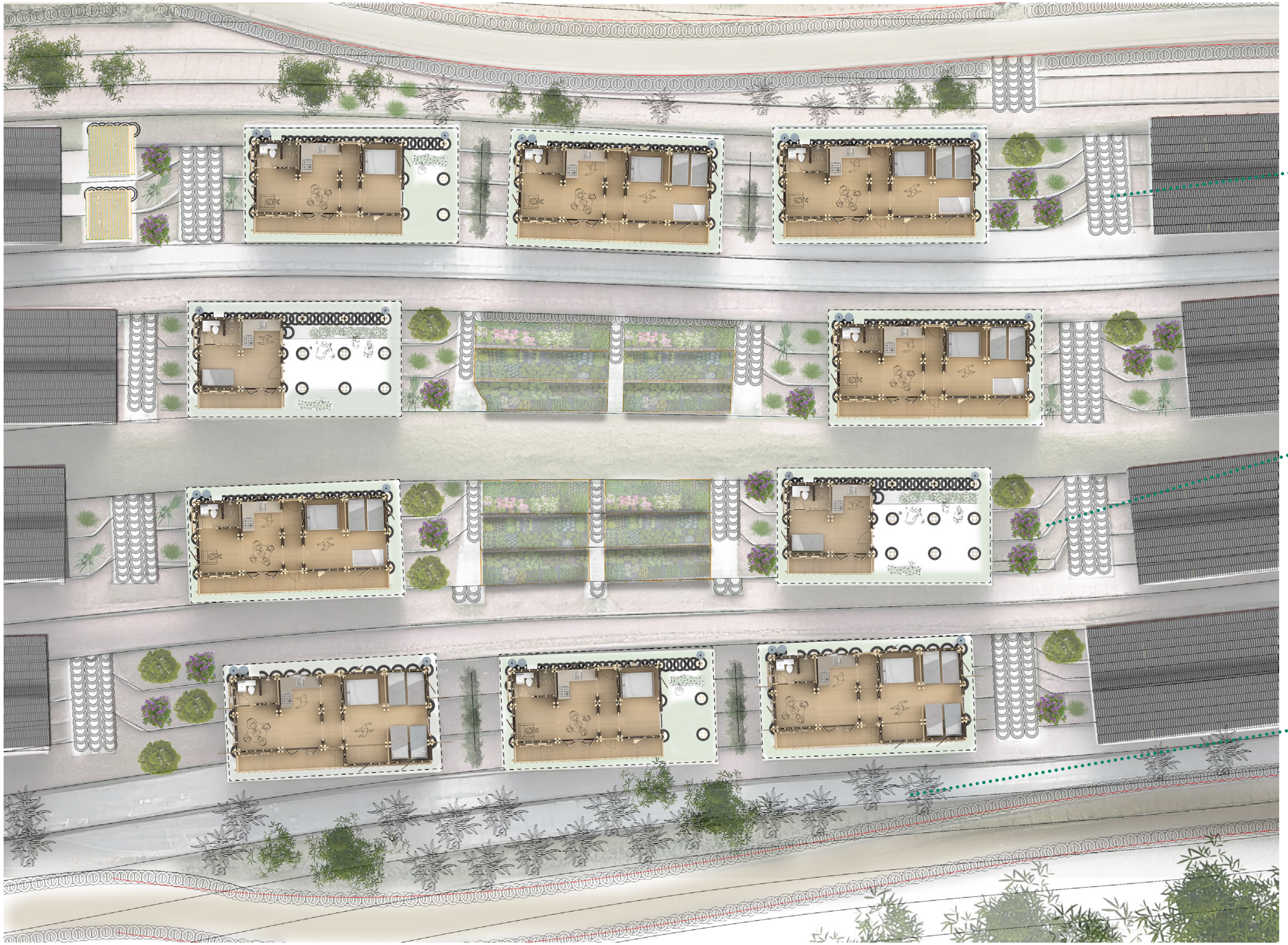


Water Management Paths

The water paths are depicted in blue, while the green circles represent trees that collect excess water, preventing potential impacts on the houses.

Garden Cluster 1:300

In the garden cluster of 10 houses, the various construction stages and flexible spatial organizations are illustrated. The spaces in between highlight how the houses integrate into the community, along with landslide mitigation techniques. Additionally, on the far left, two storage units have been constructed, demonstrating the adaptability of the space, as these units could easily be transformed into local shops that residents can utilize as needed



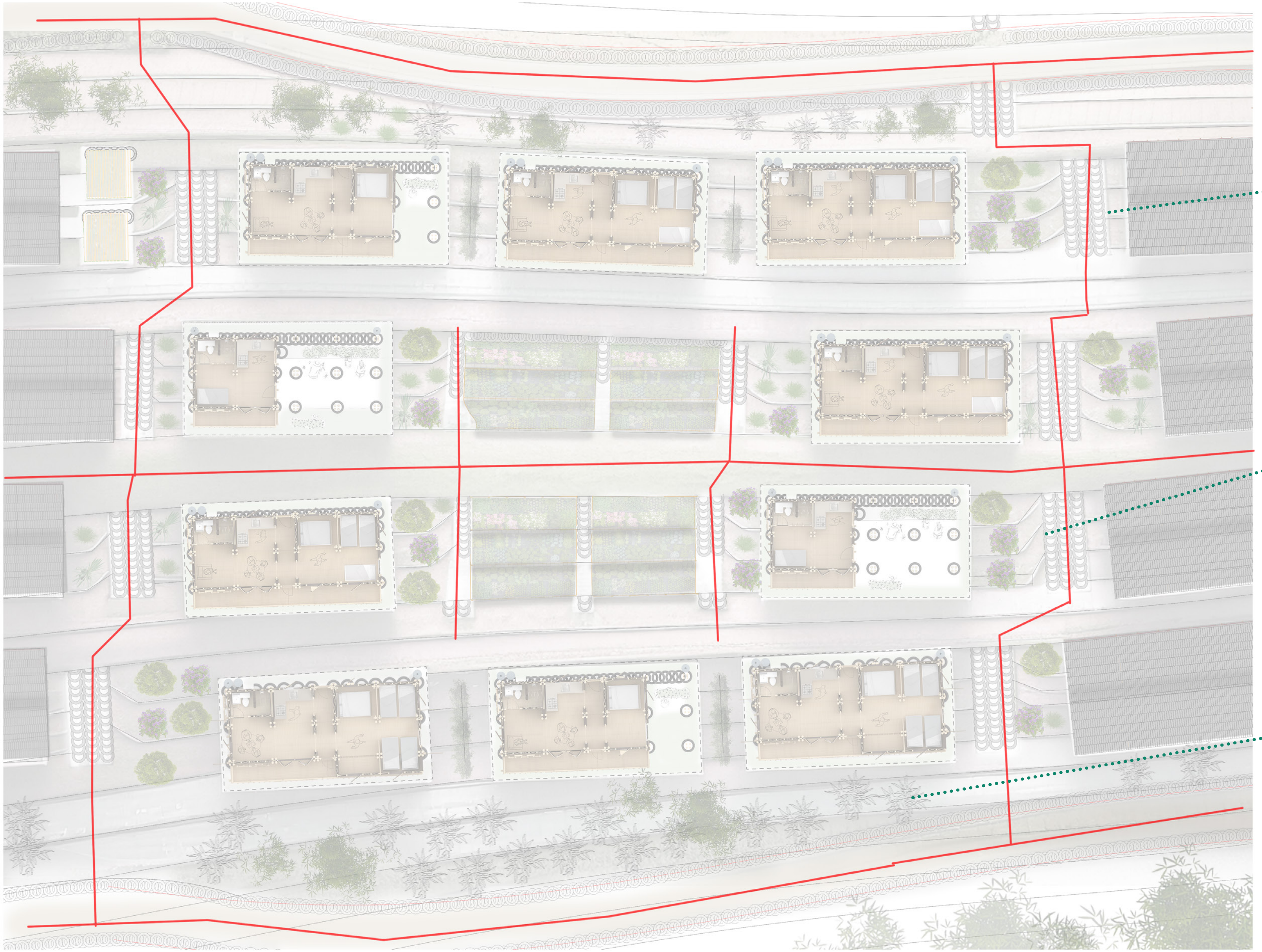
Recycled Tire Stairs

Terracing plantations

Chusquea Guadua Plantations

Cluster Main Circulation 1:300

The red paths represent the primary circulation routes within and around the cluster, indicating the main pathways residents will likely use for daily travel down the mountain.



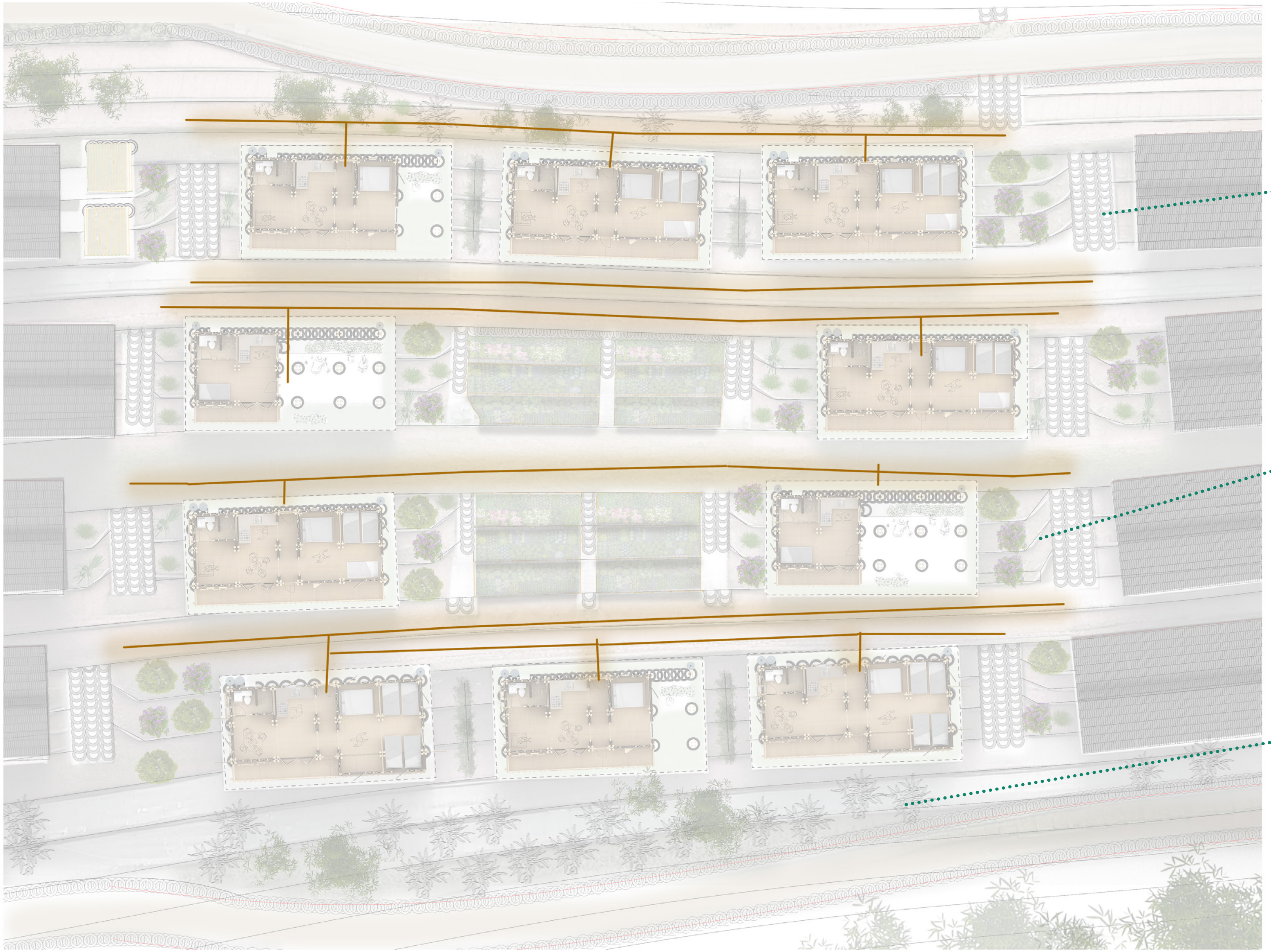
Recycled Tire Stairs

Terracing plantations

Chusquea Guadua Plantations

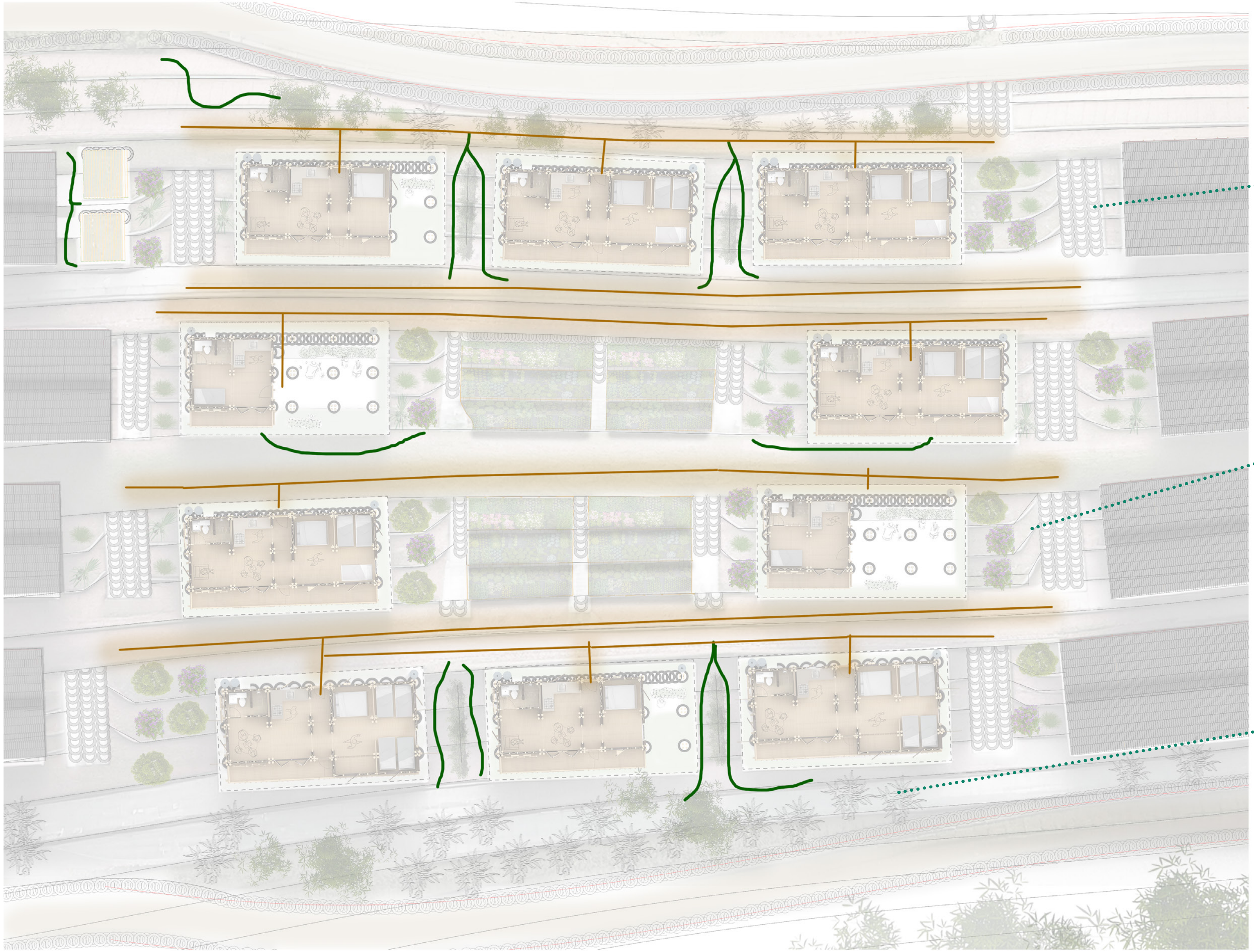
Cluster Level Circulation 1:300

The brown lines illustrate circulation at the cluster level, showing how residents navigate the paths to access their homes and visit their neighbours.



Informal Circulation 1:300

The green paths represent informal routes that residents use to navigate around the mountain and access the fruit plantations situated between the houses.



Recycled Tire Stairs

Terracing plantations

Chusquea Guadua Plantations

Section in Perspective | Garden Cluster

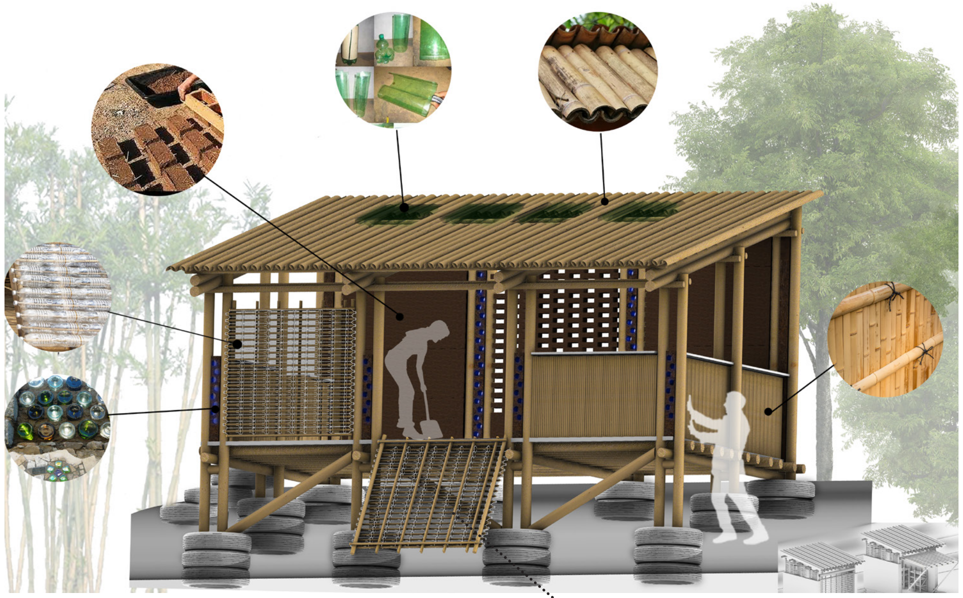
The section through the garden cluster highlights the significance of terraced leveling and the plants, whose roots provide biotechnical stabilization to help mitigate landslides both short- and long-term. Additionally, the spaces in between the houses show how residents utilize them, while the central garden serves as a focal point that fosters community togetherness. This design encourages interaction between neighbors, promoting closer connections

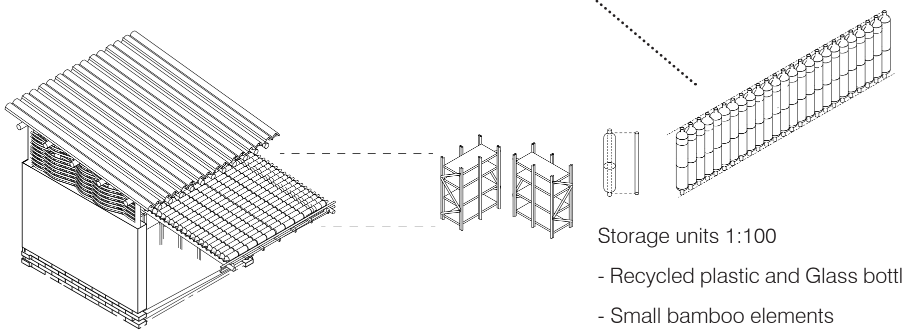
Workshop Cluster 1:350

This drawing showcases two cluster examples, featuring 14 houses and a workshop space with 8 storage units and a children's park. Surrounded by bamboo plantations, the design incorporates landslide mitigation elements to enhance safety and sustainability. This integrated approach combines residential, communal, and protective features

Workshop Design

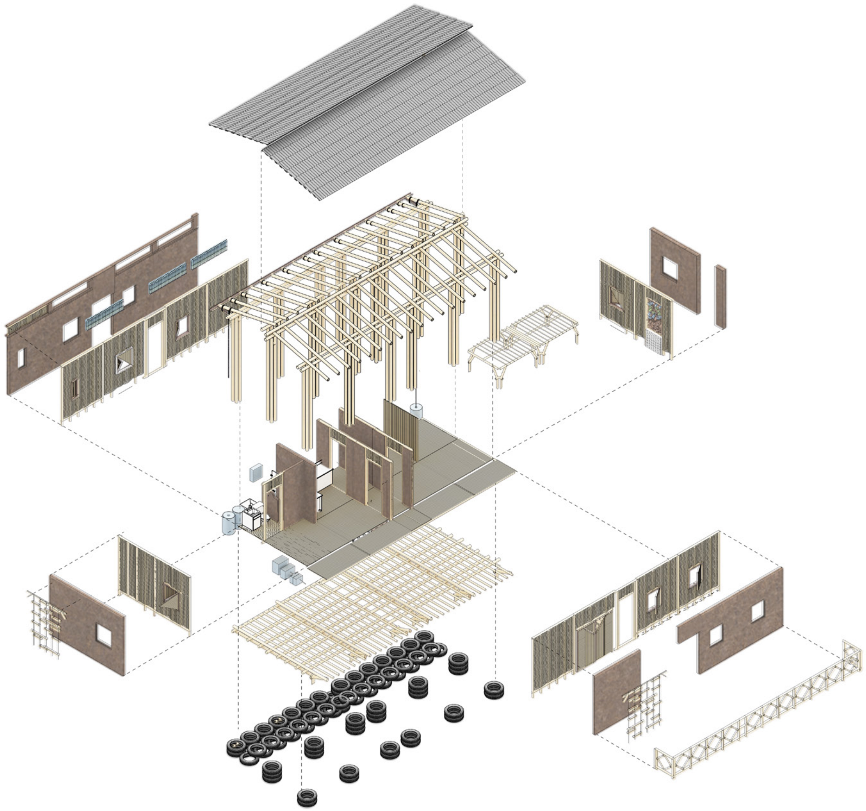
The workshop serves multiple purposes: it enables the prefabrication of house elements, such as walls and woven bamboo components, while also providing shelter from rain or adverse weather conditions. The open design of the space facilitates mixing adobe by ensuring ample ventilation. Additionally, the workshop features doors that double as walls, constructed with bamboo frames and recycled plastic bottles. These lightweight materials allow the doors to be lowered, making it easy to remove large construction elements.





Storage units 1:100

- Recycled plastic and Glass bottles
- Small bamboo elements

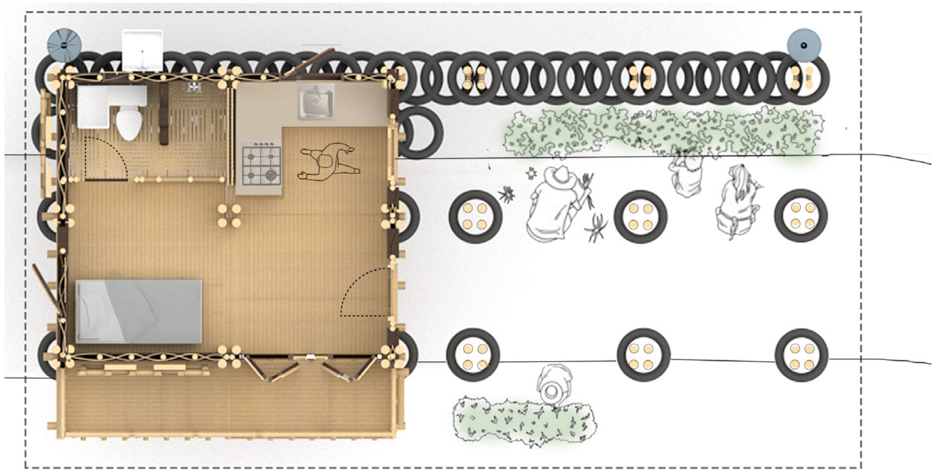


6
Dwelling Proposal

House Phases

Phase 1

Each house is constructed in four phases. The process begins with building the entire structural system and roof, followed by infilling the walls. In the first phase, the house includes essential elements: a kitchen, bathroom, and sleeping area, resembling a studio layout. The remaining space under the roof, still within the property boundary, can be utilized for personal purposes. Residents have the freedom to use this outdoor area for growing crops or raising animals such as chickens and ducks, making the space adaptable to their needs.

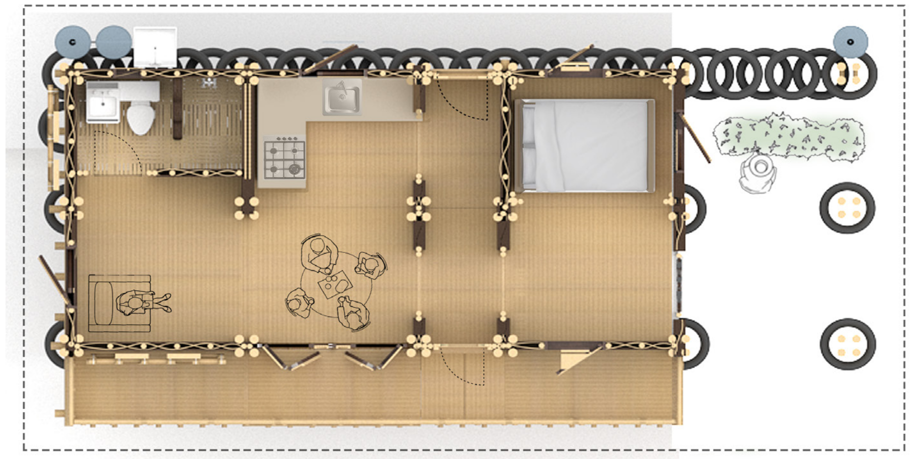


Floor Plan (n.t.s)

Architectural Proposal

Phase 2

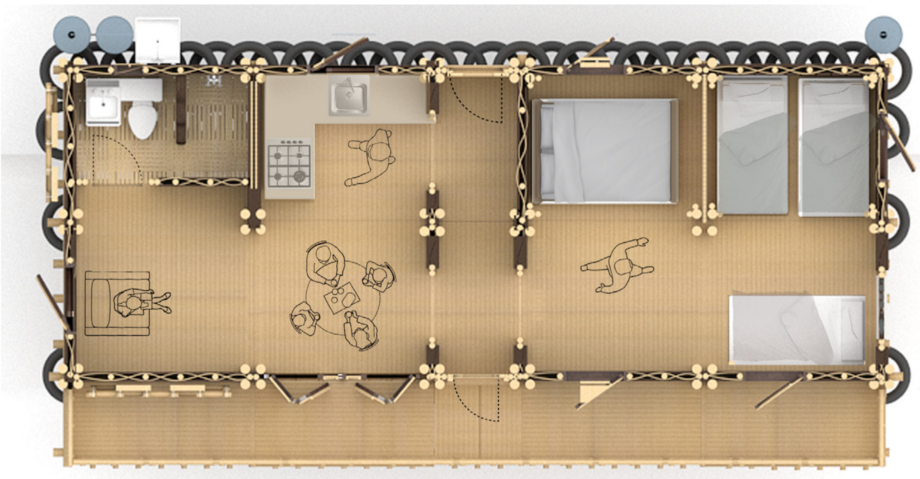
Phase two involves extending the house to include a separate system for social and common spaces, along with an additional sleeping area and an entry hallway. The design still retains unused space beneath the roof and within the property boundary, allowing residents to continue using this area for gardening, harvesting crops, or keeping pets



Floor Plan (n.t.s)

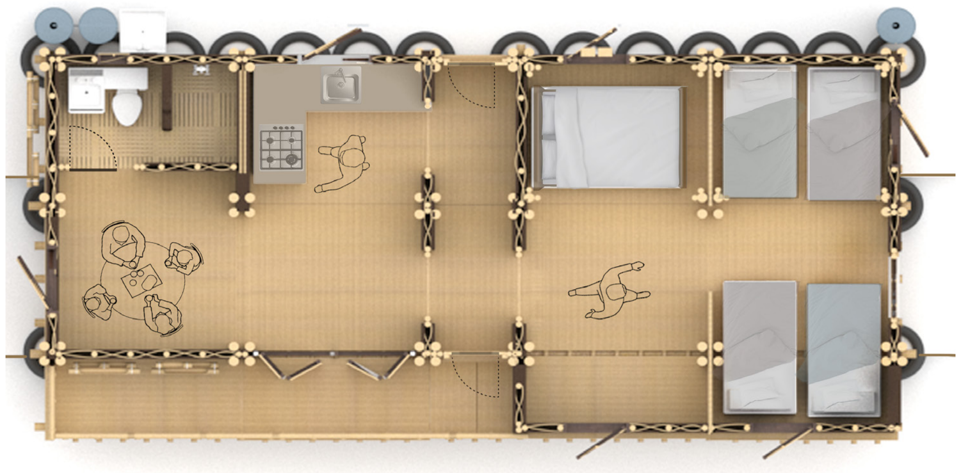
Phase 3

Phase three completes the full extent of the house's structural system, incorporating an additional bedroom. For families needing extra space—whether for a growing household or storage—a loft can also be added, providing a flexible solution to accommodate changing needs.

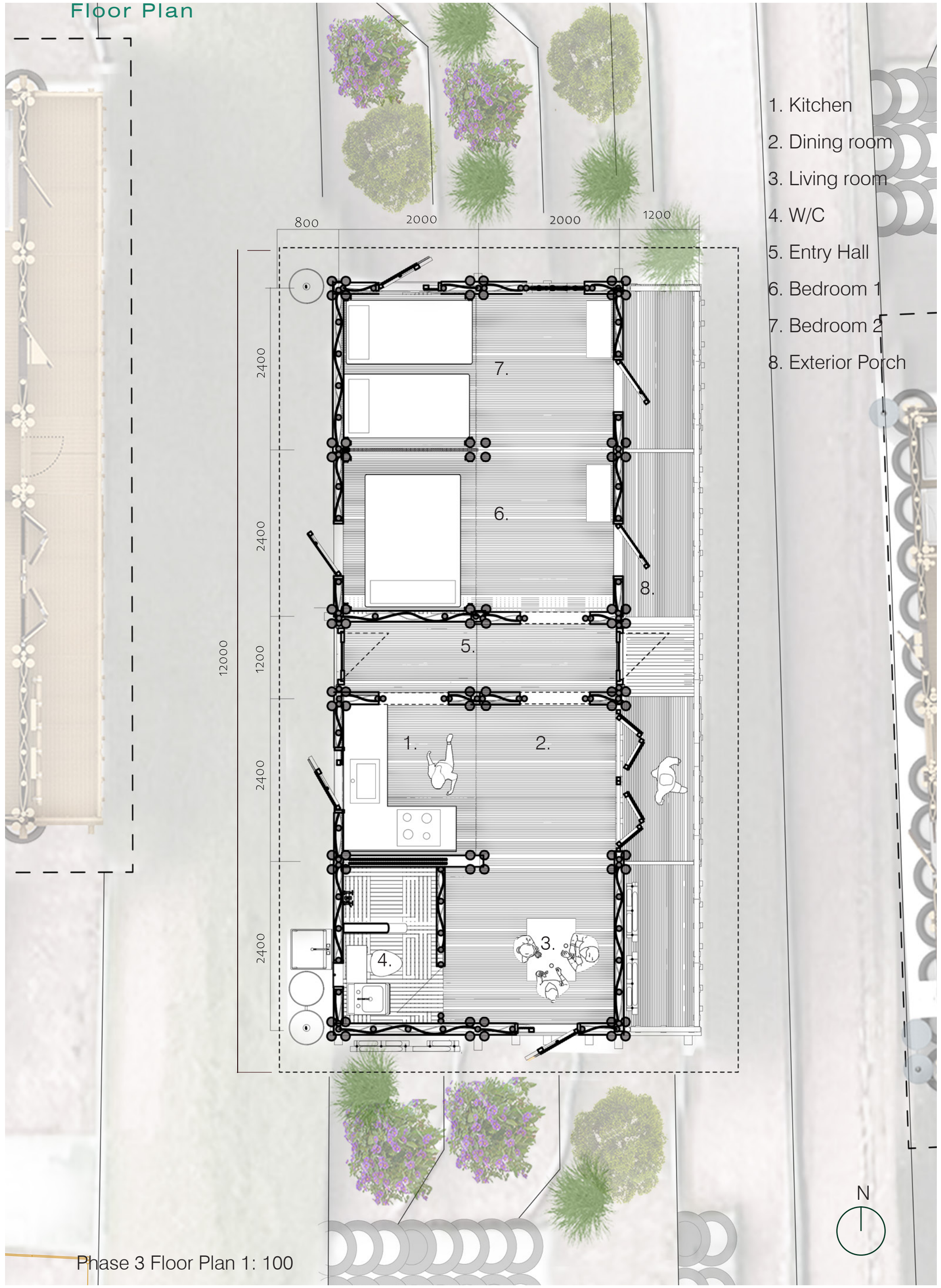


Phase 4

Phase three completes the full extent of the house's structural system, incorporating an additional bedroom. For families needing extra space—whether for a growing household or storage—a loft can also be added, providing a flexible solution to accommodate changing needs.



Floor Plan



Phase 3 Floor Plan 1: 100

Elevations

East Elevation 1:400

From the bottom of the mountain looking upwards towards the cluster.

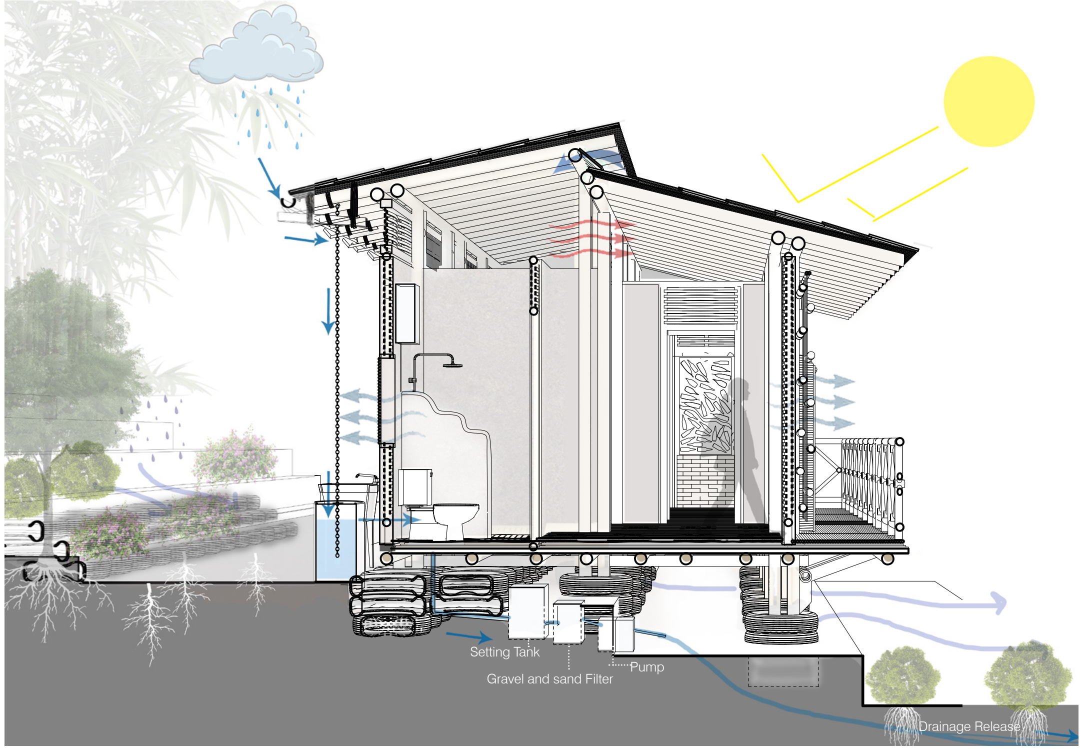
West Elevation 1:400

From the top of the mountain looking down.

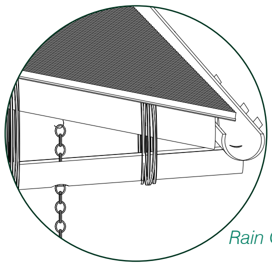
North Elevation 1:400

Garden Cluster Visualization

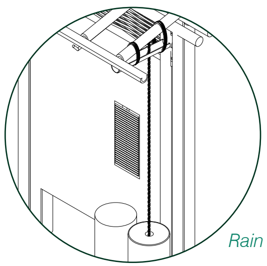
Climate Design Principles



Transversal Section 1:200



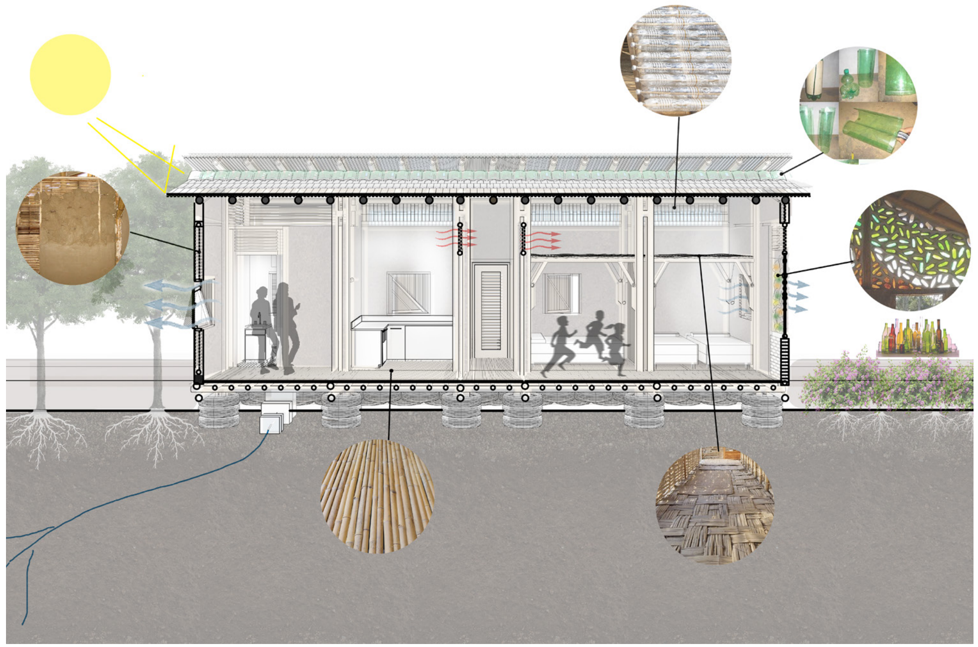
Rain Collection system



Rain Collection system

The climate-focused sections highlight the passive techniques integrated into the housing system. Drawing inspiration from vernacular architecture, the large roof eaves and overhangs provide shade for the walls, protecting them from direct sunlight and maintaining cooler indoor temperatures on hot, sunny days. Additionally, the adobe/bahareque construction of the walls offers excellent insulation, retaining heat during the

Climate Design Principles



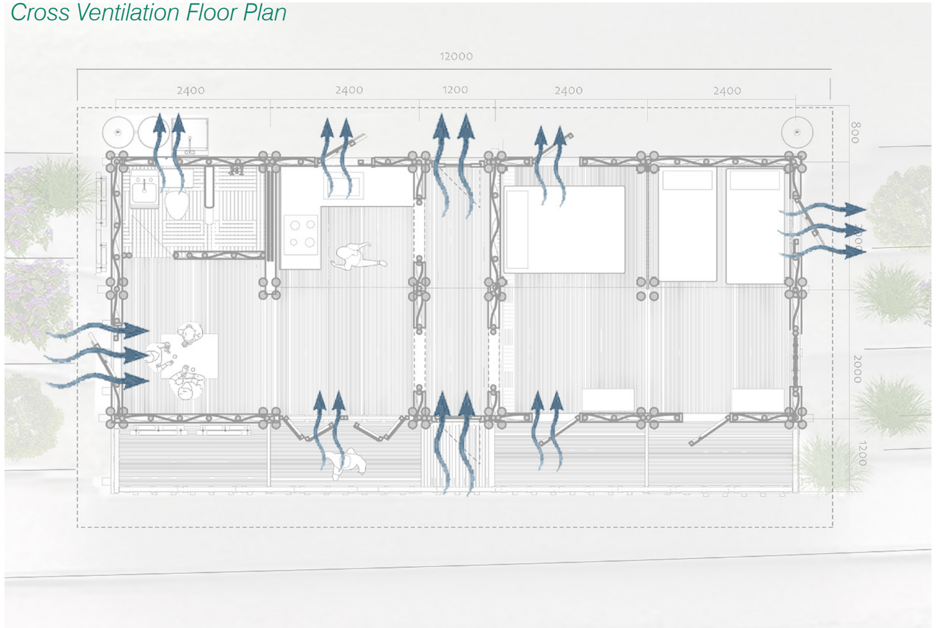
Longitudinal Section 1:300

night and preventing rapid heat loss, unlike the steel sheets and tarps currently used by the community. The roof overhang also shields the structure from rain, enhancing the durability of the walls and the overall structural system.

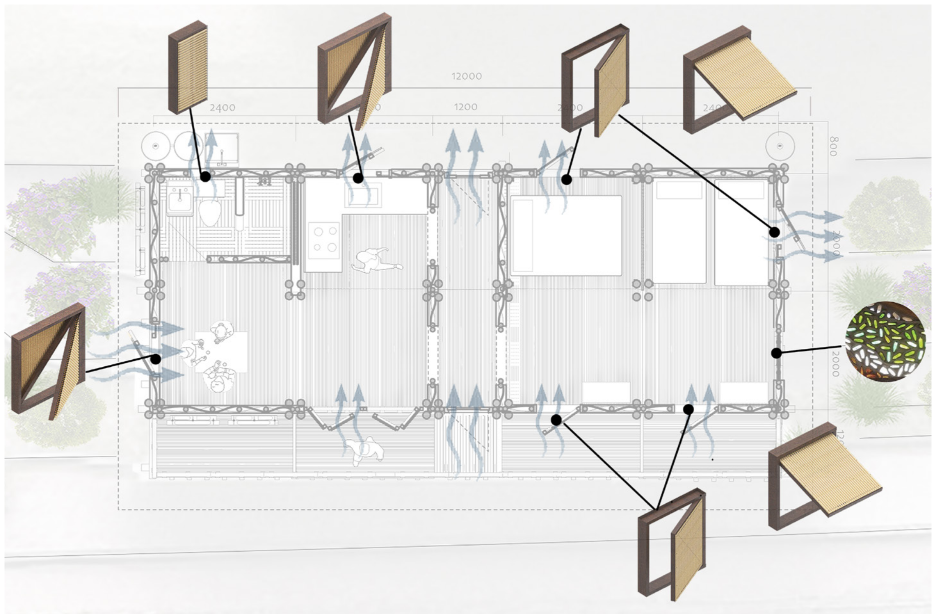
The design incorporates a rainwater collection system, which supplies water for showering, sinks, laundry, and toilet flushing. The black water system employs either a composting toilet or a filtration system. This process begins with a settling tank, followed by layers of filtration through gravel, sand, and woodchips. Finally, a pump distributes the filtered water to irrigate crops and plantations.

Climate Design Principles

Cross Ventilation Floor Plan

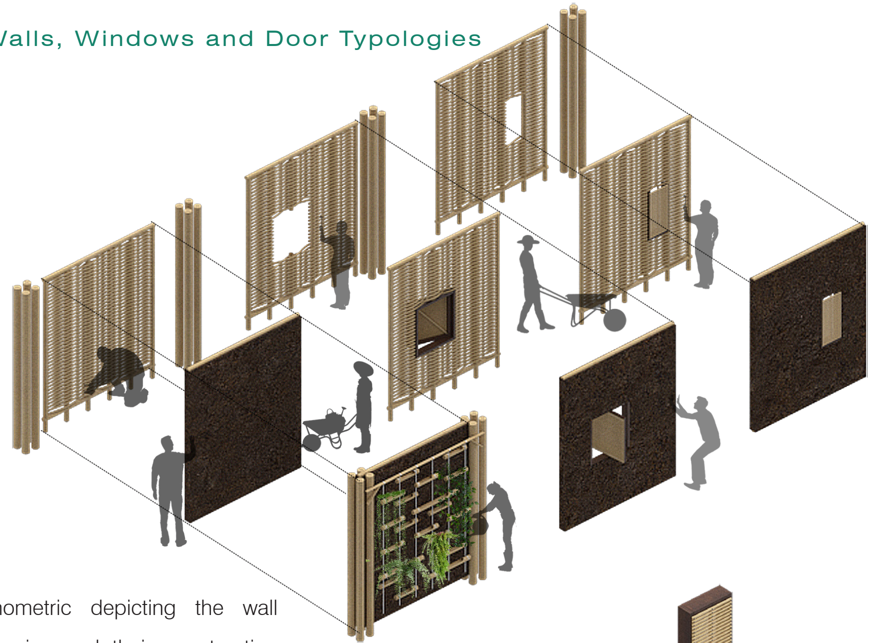


Suggested Window Design Floor Plan

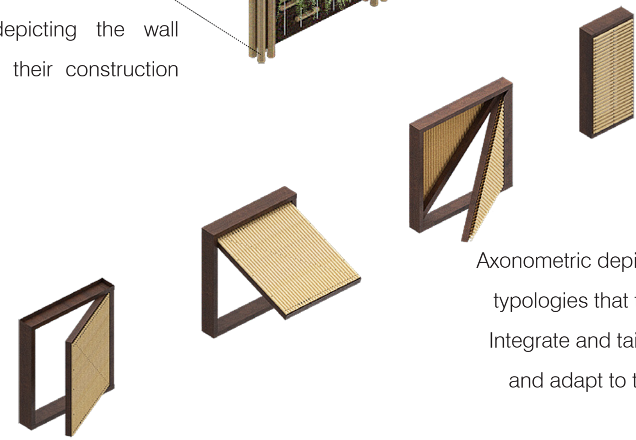


Architectural Proposal

Walls, Windows and Door Typologies

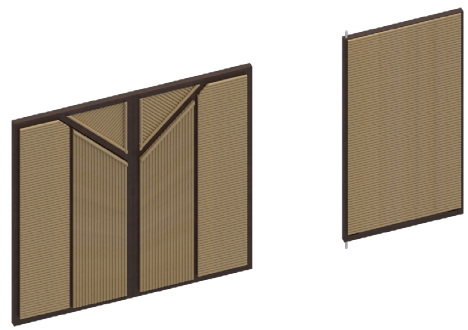


Axonometric depicting the wall typologies and their construction process.

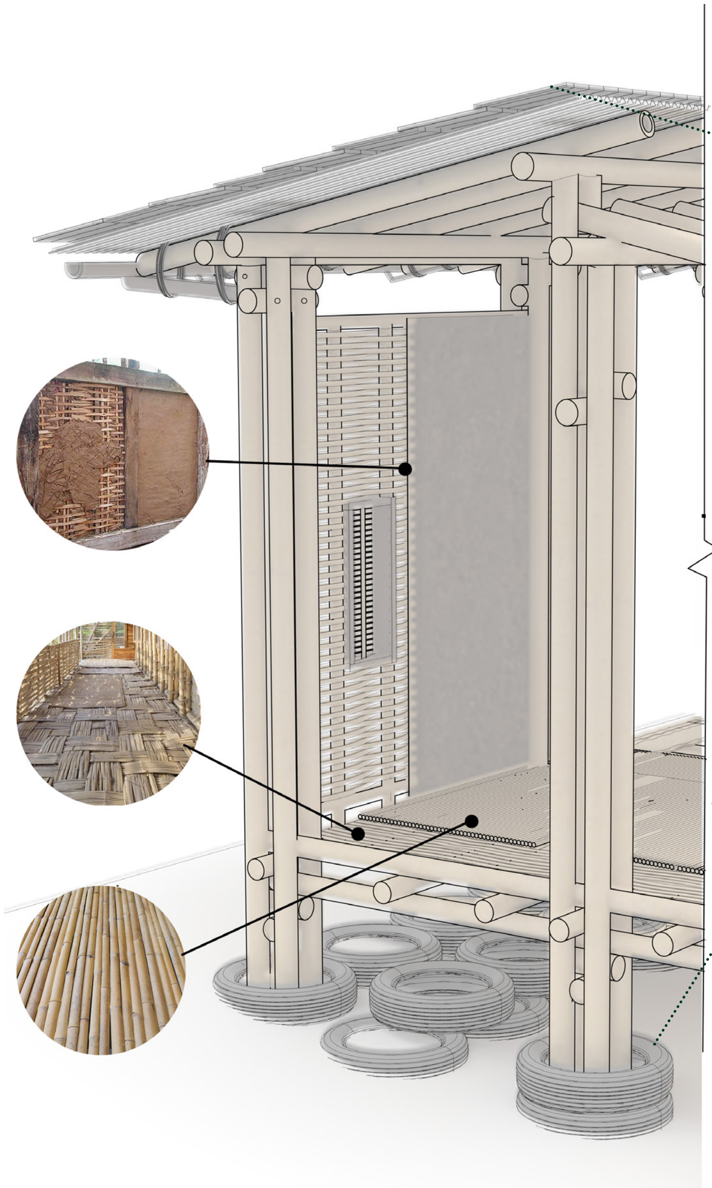


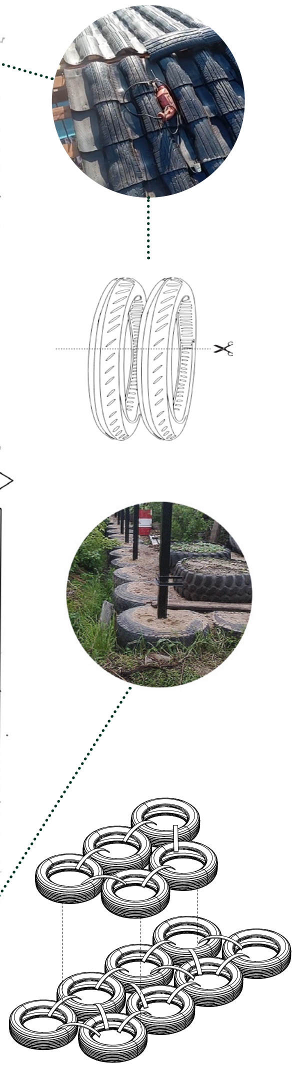
Axonometric depicting the window typologies that the residents can Integrate and tailor to their needs and adapt to their preferences.

Axonometric illustrating two door typologies: sliding and pivoting doors, each varying in complexity and material requirements. Residents also have the option to repurpose existing doors for use in main entrances and bedroom spaces.



Façade Fragment and materiality

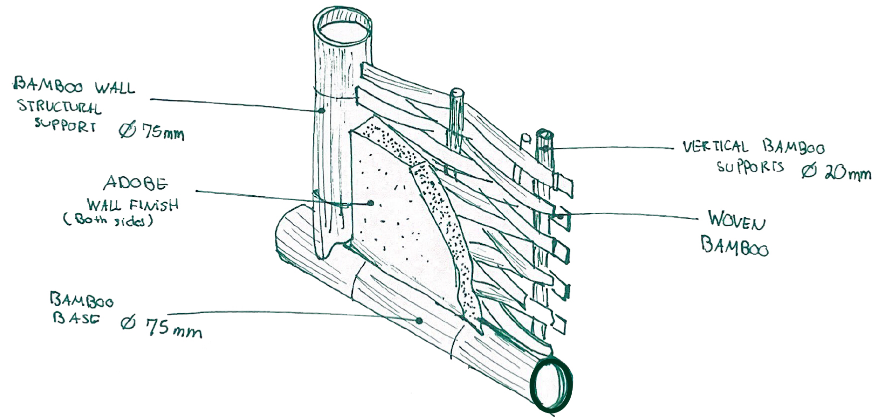




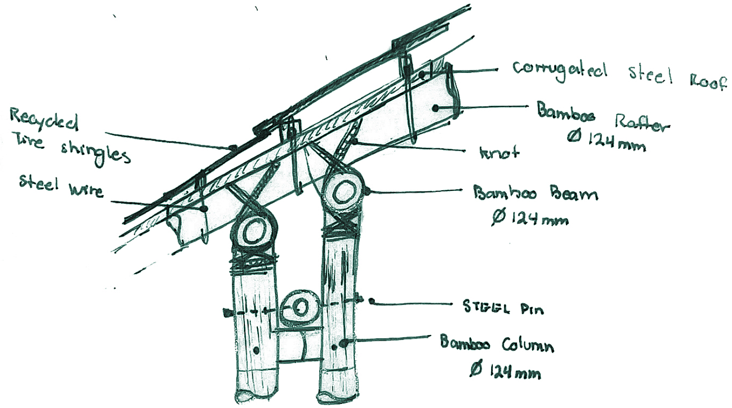
Tire Connection detail

Details and Connections

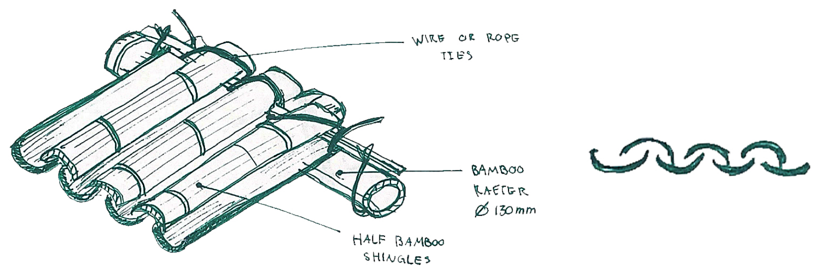
Wall Structure Detail



Roof Detail Connection Detail

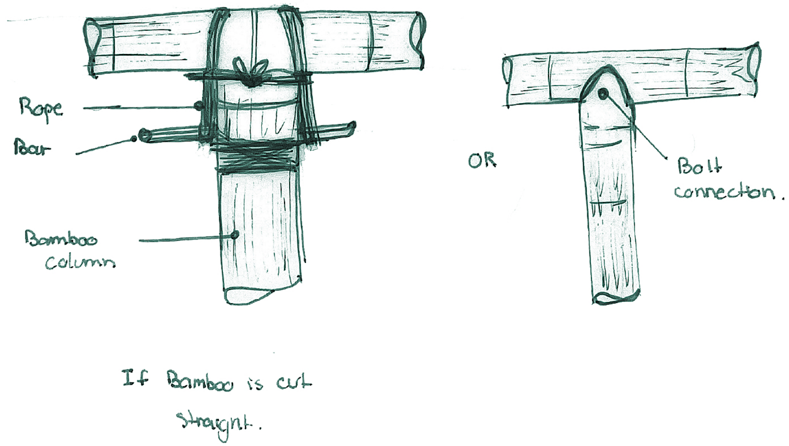


Alternate Bamboo Roof Detail

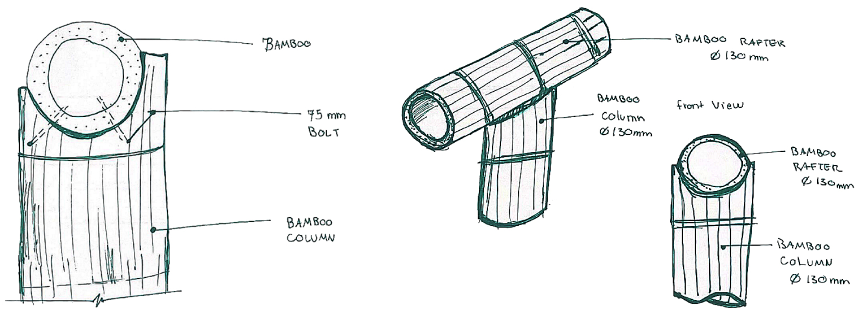


Details and Connections

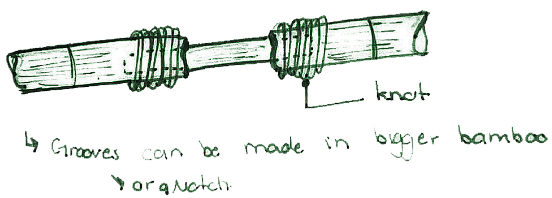
Column to Beam Connection A & B



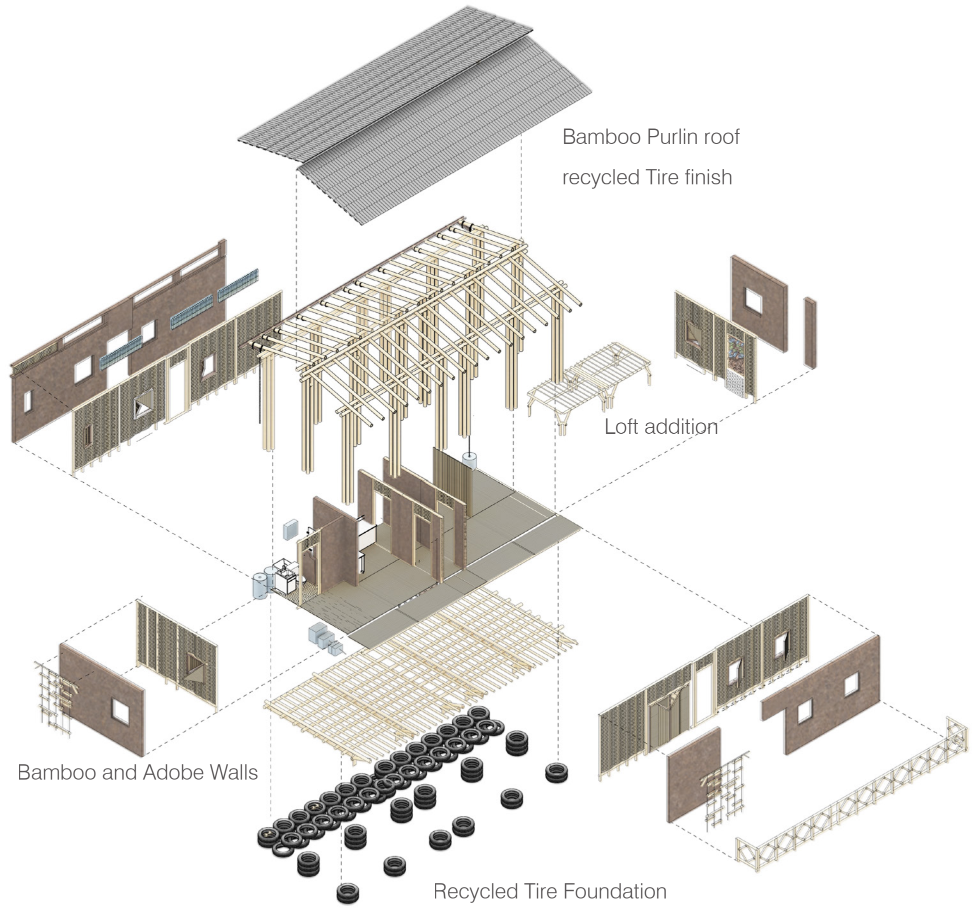
Alternate Column to Beam Connection



Clamp Connection- Floor Structure Extension

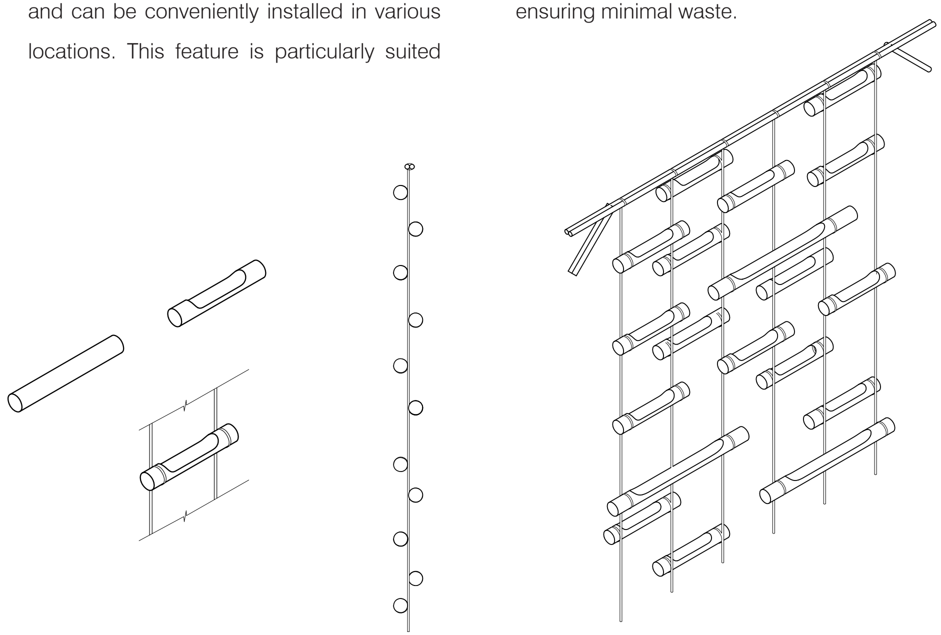


Exploded Axonometric- Construction Elements



Vertical Garden and Railing Design

The inclusion of a vertical garden is optional, allowing residents the flexibility to decide based on their preferences. However, it offers valuable additional space for cultivating plants and can be conveniently installed in various locations. This feature is particularly suited for growing herbs such as basil, cilantro, and rosemary, enhancing both functionality and culinary possibilities. Additionally, it can be easily constructed using leftover materials, ensuring minimal waste.



The railings shown in the renders throughout this book represent the most complex design option. However, they can be customized to suit the preferences and needs of the residents. Using the same techniques applied in constructing the house walls and structural system, these railings can be easily adapted and built, ensuring both functionality and personalization. They can also be painted.

7

Project Management Structure

Stakeholders and Connections

Stakeholder Analysis

Stakeholder Roles

Architect:

As the project architect, I began by researching landslides and incorporating vernacular techniques into the design, guided by site analysis to improve community quality of life, integrateing them into the initial design conceptualization. My responsibilities include developing a design that meets the community's needs while addressing their socioeconomic context. This approach has informed the use of recycled and biobased materials, ensuring both sustainability and cost efficiency.

Community Leader:

The community leader is a key stakeholder, serving as the primary point of contact and vital link between the project team and the community. They facilitate open dialogue, encourage community input, and provide essential feedback to ensure the project meets the community's needs. With their deep connections and understanding of the community, the leader fosters trust between the community and project stakeholders, creating a collaborative and smoother project process. Their role has been instrumental in organizing community meetings and consultations, pivotal during the co-designing stage.

Bamboo Experts:

As the community has no prior experience with building or working with bamboo, organizing a workshop on planting, selecting, cutting, and connecting bamboo is essential. Collaborating with non-profit organizations specializing in bamboo construction can provide valuable guidance and expertise. Potential partners include Bambúcultura Colombia and Fundación EcoCiencia, both dedicated to educating communities on sustainable bamboo practices.

Community Members:

The community members are key project stakeholders, serving as clients and builders. Their valuable input plays a crucial role in shaping the design, ensuring it meets their needs and preferences. For the project to succeed, the community must come together to work toward a shared objective, fostering a sense of ownership and collective responsibility. Additionally, by participating in the construction process, they will acquire skills that can be passed down to younger generations, ensuring the sustainability and long-term benefits of the initiative.

Local Entrepreneurs and Businesses:

This development will equip community members with valuable skills, enabling and encouraging them to start small businesses such as weaving bamboo baskets and tools. The communal and vertical gardens integrated into the houses can also provide fruits and vegetables for sale, creating additional income opportunities. Furthermore, by operating in a sustainable, low-carbon manner, the community could establish connections with eco-tourism, attracting visitors and generating revenue. Together, these initiatives have the potential to bring economic growth and self-sufficiency to the community.

NGOs and Non-Profit Foundations:

NGOs, non-profit organizations, and foundations play a crucial role in kickstarting the project by fundraising and raising awareness. They can help mobilize volunteers to assist the community in collecting used tires, gathering and donating materials, and participating in construction and gardening efforts. Additionally, these organizations can facilitate knowledge-sharing by inviting other communities to learn from this initiative, inspiring them to adopt similar sustainable practices.

Government:

The government supports communities during construction by providing temporary housing, financial aid, and subsidies, especially for low-income groups. It can offer grants, low-interest loans, and tax incentives while facilitating access to technical training and expertise. By collaborating with engineers and planners, it ensures quality and safety standards. Additionally, the government aids long-term success by developing essential infrastructure like roads, water, and sanitation.

Universities & Educational Institutions

Universities and educational institutions can play a crucial role in supporting the project. For instance, agriculture students could assist the community in the most optimal gardening way and maintain communal gardens, vertical farming systems, or sustainable food production methods, while urban planning students and faculty could collaborate on strategies for future expansion, ensuring scalability and resilience. Additionally, universities could explore the implementation of renewable energy solutions, such as solar panels or other technologies, which could even be developed or 3D-printed on campus. This interdisciplinary approach fosters collaboration, empowering the community and students..

Community Organization Analysis

Current Community Organization Structure

During the site visit, I had the opportunity to observe firsthand how the community is organized and operates. Leadership is typically provided by one or two community leaders, with the rest of the community divided into four key groups: Youth, Single Mothers, Working People, and the Elderly. Each group plays a vital role in maintaining unity and fostering the community's growth.

Community Leader

Builds strong relationships by knowing each community member and their unique skills, leveraging these talents to benefit the community.

Acts as an advocate and representative, voicing the community's needs and interests.

Establishes partnerships with public schools to secure scholarships for students and collaborates with foundations and nonprofits to provide additional support.

Community

Youth

- Organize activities and sports events to engage the community.
- Leads youth walks and hikes to promote physical health and connection with nature.
- Provides tutoring and mentorship for younger children to support their education and personal development.

Single Mothers

- Create and sell knitted goods to support their livelihoods.
- Engage in recycling initiatives to generate income and promote sustainability.
- Provide childcare by looking after other mothers' children while they are at work.

Working People

- Typically employed in manual labor roles.
- Contribute as recyclers, supporting both income generation and environmental sustainability.
- Possess practical skills in construction, carpentry and agriculture.

Elderly

- Contribute to household tasks when able, such as cleaning and caring for children.
- Preserve and pass down cultural values and traditions.
- Engage in social activities within the community,
- Participate in knitting.

Proposed Project Community Organization

Community Leader

- Coordinates between community groups, identifying where individuals best fit to maximize their contributions.
- Builds relationships with foundations and NGOs to secure recognition and funding for community initiatives.
- Guides cultural sensitivity efforts, ensuring the preservation of the community's unique identity and traditions.
- Maintains trust by fostering strong relationships within the community and with external stakeholders.

Community

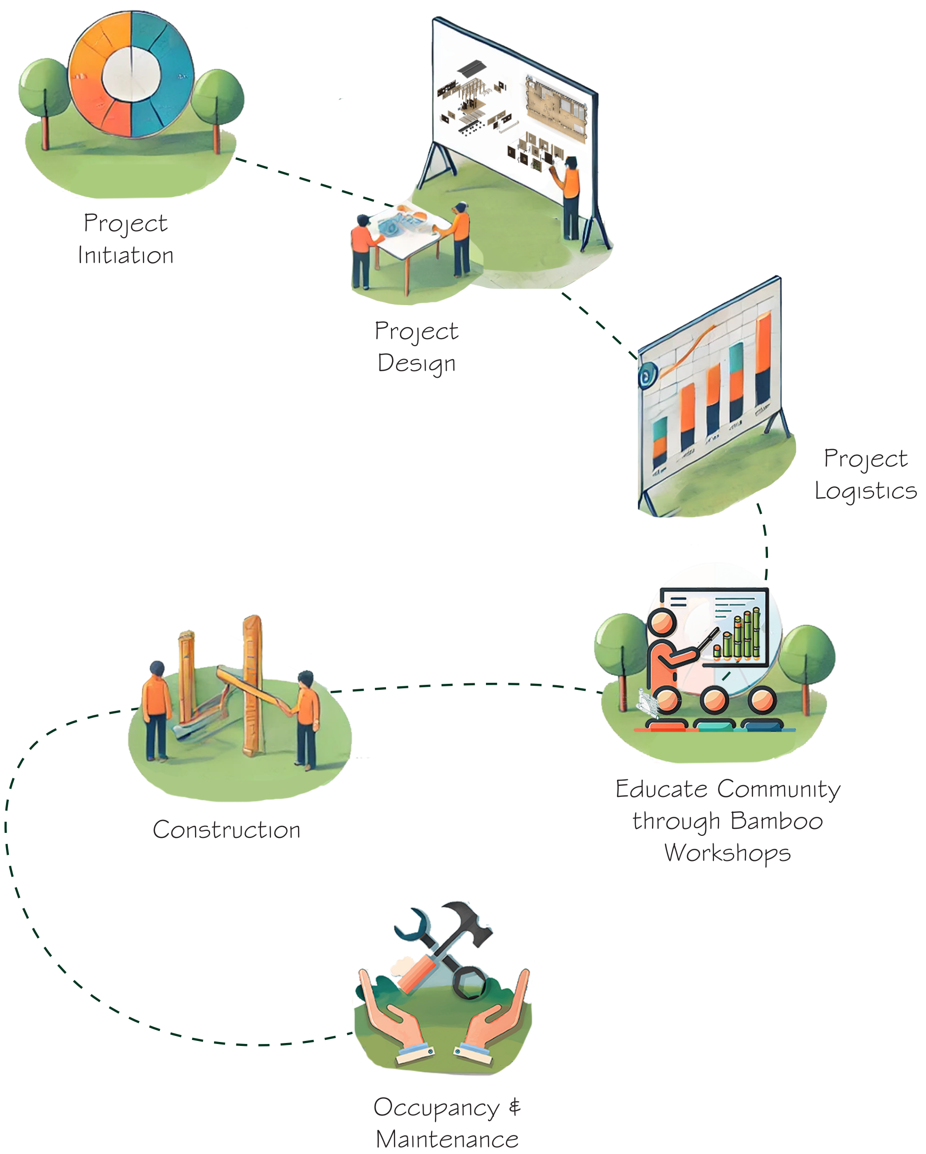
Youth · **Elderly**

- The elderly share agricultural knowledge, advising on which plants can be planted together and which should not.
- Both the elderly and children assist with gathering and carrying small, lightweight bamboo pieces.
- They participate in designing or decorating the structure, adding creative touches such as painting or embellishing panels.
- Contribute to weaving bamboo panels for walls and flooring, combining creativity with hands-on work.
- Prepare the bamboo and rope for vertical gardens.

Single Mothers · **Working People**

- Single mothers can help coordinate materials, manage tools, and prepare meals and drinks to support workers on-site.
- Single mothers can also provide care for children during work hours, ensuring their safety and allowing others to focus on construction tasks.
- Working people can build structural elements, assemble bamboo pieces, and install walls and floors.
- They can also dig and add the tire foundations.
- Work to prepare materials and prefabricate elements.

Project Development



Project Development Process

Project Initiation:

- Site Analysis and Co-Design Process: Conduct a thorough analysis of the site and engage the community in a co-design process. This involves identifying key stakeholders to ensure the project's feasibility and to initiate fundraising efforts for resources.

Project Design:

- Define clear design objectives that reflect the community's needs and aspirations. Develop architectural concepts and initial sketches.
- Create a design that allows for flexibility and modularity, accommodating future changes and expansions.
- Research and select local and recycled materials that align with the socioeconomic conditions of the community.
- Produce detailed construction drawings and collaborate with various stakeholders, such as engineers and landscape architects, to refine the project.

Project Logistics:

- Arrange temporary accommodations for residents currently living on the site during construction.
- Identify and source bamboo and other materials, ensuring cost efficiency and a clear procurement timeline.
- Contact bamboo vendors, negotiate pricing, and organize transportation logistics to deliver materials to the site.
- Gather the community to communicate the project's goals, timelines, and impacts, ensuring transparency and involvement.

Bamboo Workshops:

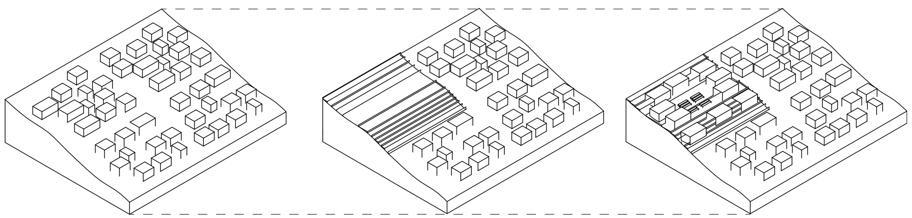
- Conduct workshops to educate the community on the various aspects of working with bamboo.
- Train the community on how to plant, nurture, and maintain bamboo for long-term sustainability
- Teach skills for selecting, cutting, and joining bamboo pieces for construction projects.
- Offer hands-on training on bamboo weaving for creating walls, mats, and other functional elements.
- Provide guidance on bamboo maintenance to ensure durability and prevent damage over time.

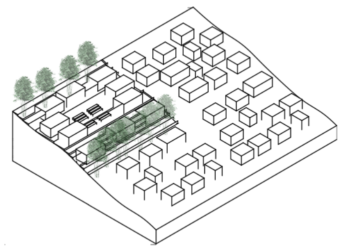
Construction:

- Construction:
- Distribute tasks among community groups to promote collaboration and ensure an efficient construction process
- Terrace the land to create level building areas.
- Excavate and create foundations for houses with recycled car tires
- Assemble the bamboo structural frame
- Install the roof structure to protect the interior during further construction.
- Attach prefabricated bamboo walls and plaster them with adobe for insulation
- Engage each family in adding personal finishing details to their home, fostering a sense of ownership and pride.

Occupancy and Maintenance:

- Perform a thorough deficiency check to ensure all houses meet structural stability and safety standards.
- Families can move into their homes
- Develop a shared maintenance schedule for communal areas and resources, fostering collaboration and ensuring long-term upkeep.





Project construction Phases

1. The houses within the perimeter of the new cluster space must be cleared, with all functioning doors and materials salvaged for reuse in the new project. Any remaining unusable materials should be recycled to minimize waste.
2. The area should then be terraced to ensure landslide mitigation techniques. Should be done on entire site to ensure ground is levelled.
3. Once Terraced, houses may begin to be built following the Manual provided.
4. Plants around and within the cluster may be planted to ensure long-term slope stabilization.
5. The next blocks can commence construction following the same process.

Reflection

I began by identifying landslides as a global issue with severe consequences and explored how architectural engineering could mitigate their impact. Focusing on South America, particularly Colombia, where landslides are a prevalent hazard, I analyzed the Plan of Territorial Use to identify the most vulnerable areas in semi-urban zones on the periphery of cities like Bogotá, characterized by steep topography, challenging weather conditions, and a consistent demographic profile.

The project aimed to design a housing typology that prioritizes safety while improving the quality of life for displaced communities, often forced to settle in informal developments. These settlements lack proper urban planning, contribute to deforestation, and fail to meet basic living standards. Self-built homes are frequently structurally unsound and made with substandard materials, increasing risks in landslide-prone areas. These factors underscored the need for sustainable architectural solutions. To address the socio-economic challenges of these communities, I focused on bio-based and recycled building materials. As the project developed, it became clear that a replicable housing typology was only part of the solution. The scope expanded to designing a self-sustaining housing block system that incorporated landslide mitigation techniques. This included a complete cluster layout with carefully designed interstitial spaces. During the site visit and discussions with the community, the importance of social spaces emerged as a priority. To meet this need, the design incorporated a community garden, a children's park, a material storage and workshop space, and an outdoor lounge. These features aim to foster social interaction, support communal activities, and enhance the overall quality of life within the housing block.

The project aligns closely with the architectural engineering studio, which emphasizes the integration of architectural and engineering techniques. It also resonates with technological themes such as Biodiversity & Nature Inclusivity and the "make" ethos, empowering communities to construct their own sustainable housing solutions.

My research was elemental in shaping the design and recommendations. By analyzing the socioeconomic conditions, environmental factors, and community needs, I identified critical elements such as landslide mitigation, sustainable materials, and the importance of social spaces. These insights directly informed the development of a self-sustaining housing block system. Conversely, the design process highlighted gaps in the research, such as the need for deeper exploration into community-driven construction techniques and how to optimize bio-based materials for structural safety. This iterative process ensured that the research and design informed and refined each other. Furthermore, I had to add more to my research especially on the foundation style whether embedded into the terrain or on stilts. The conclusion was a mix of both.

My approach, rooted in site-specific research, stakeholder engagement, and iterative design, was valuable in addressing a complex, multi-faceted problem. Methods such as community consultation, site analysis, and relevant insights from vernacular architecture. Additionally, combining architectural and engineering perspectives allowed for a holistic approach to sustainability and safety. The methodology was effective in bridging theory and design, ensuring that the solutions were both feasible and impactful.

Academically, this project contributes to discussions on integrating architecture with engineering to address natural hazards, advancing the use of bio-based materials in disaster-prone areas, and emphasizing community participation. Societally, it tackles issues of displacement, unsafe housing, and environmental degradation, while fostering empowerment through self-build initiatives. Ethically, the project respects community agency by involving them in the process and prioritizing sustainable, low-impact solutions. The use of bio-based and recycled materials, coupled with community-driven construction, can inspire adaptable solutions in other disaster-prone areas. While the design is tailored to Bogotá's periphery, its core engineering strategies—such as biotechnical slope stabilization, tire retention walls, drainage, adaptation to the mountain's contours, and terracing. While also taking into account self-sufficiency, safety, and inclusivity.

Further reflection questions:

– How can the inclusion of local traditions and construction techniques further enhance the community's engagement

REFERENCES

Arias PA, Garreaud R, Poveda G, Espinoza JC, Molina-Carpio J, Masiokas M, Viale M, Scaff L, van Oevelen PJ (2021) Hydroclimate of the Andes Part II: hydroclimate variability and sub-continental patterns. Front Earth Sci 8:1–25. https://doi.org/10.3389/feart.2020.505467

Adhikary, N. (2016) 'Vernacular architecture in post-earthquake Nepal', *International Journal of Environmental Studies*, 73(4), pp. 533–540. doi: 10.1080/00207233.2016.1179011.

Ceylan, S. (2022), "Vernacular architecture of Turkish eastern Black Sea region: a case study in Senoz (Büyükdere) Valley", *Open House International*, Vol. 47 No. 3, pp. 513-532.

Choudhury, Ankita & Chettry, Vishal. (2023). Investigation of bioclimatic design features in vernacular architecture of Northeast India: Case studies of Assam-type houses and stilt houses (Chang Ghar) in Assam, India. Indian Journal of Traditional Knowledge. 22. 659-668. 10.56042/ijtk.v22i3.5757.

Córdoba Alvarado, A.et all , Proceso de Revision del Plan de Ordenamiento Territorial de Bogotá D.C Documento de Diagnostico por Localidad No. 4 San Cristobal. 1–121 (2020). Bogotá, Cundimarca; Secretaria de Planeacion.

Diaz, D. (2024). Learning from Vernacular Architecture to the Develop Potential Methods in the Colombian Periphery to Mitigate the housing crisis in Landslide-prone topography. Delft.

Frey, P. (2010). *Learning from vernacular towards a new vernacular architecture*. Actes Sud

Garcia-Delgado, H., Petley, D. N., Bermúdez, M. A., & Sepúlveda, S. A. (2022). Fatal landslides in Colombia (from historical times to 2020) and their socio-economic impacts. *Landslides*, *19*(7), 1689–1716. https://doi.org/10.1007/s10346-022-01870-2

Gasparini, Graziano, Margolies, Luise. Inca Architecture. Indiana University Press. 1980.

Hasgül, E., Olgun, İ. and Karakoç, E. (2021), "Vernacular rural heritage in Turkey: an intuitional overview for a new living experience", *Journal of Cultural Heritage Management and Sustainable Development*, Vol. 11 No. 4, pp. 440-456.

Julistiono, E. K., & Arifin, L. S. (2005). *The Sustainable Traditional Structural System of 'Tongkonan' In Celebs, Indonesia* (dissertation). The 2005 World Sustainable Building Conference, Tokyo.

Khadka, Shyam & Acharya, Sabin & Acharya, Ayush & Veletzos, Marc. (2023). Enhancement of Himalayan irregular stone masonry buildings for resilient seismic design. Frontiers in Built Environment. 9. 1086008. 10.3389/fbuil.2023.1086008.

Manurung, Parmonangan. (2017). Local Wisdom of Structure and Building System Traditional Architecture In Responding To Nature. International Journal on Livable Space. 2. 14. 10.25105/livas.v2i1.1655.

Ng, T. N., & Lin, H.-T. (n.d.). *An analysis on Microclimate and Construction of Tongkonan and Alang-alang in Tana Toraja of Sulawesi, Indonesia* (dissertation).

Nilhan Vural, Serbülent Vural, Nihan Engin, M. Reşat Sümerkan, Eastern Black Sea Region—A sample of modular design in the vernacular architecture, Building and Environment, Volume 42, Issue 7, 2007, Pages 2746-2761, ISSN 0360-1323,

Pınar, E. (2018), "The examination of structural details of Eastern Black Sea region's vernacular architecture", International Journal of Social Sciences, AGP Special Issue, Vol. 6, pp. 60-75.

Protzen, P. (2005). Arquitectura y Construccion Incas en Ollantaytambo. Second Edition. Pontificia Universidad Catolica del Peru.

Rapoport, A. (1969). *House form and culture.* Englewood Cliffs, N.J., Prentice-Hall.

Salgın, Burcu, Ömer F. Bayram, Atacan Akgün, and Kofi Agyekum. 2017. "Sustainable Features of Vernacular Architecture: Housing of Eastern Black Sea Region as a Case Study" *Arts* 6, no. 3: 11.

Sanandam Bordoloi, Charles Wang Wai Ng, The effects of vegetation traits and their stability functions in bio-engineered slopes: A perspective review, Engineering Geology, Volume 275.

Sestini, V., & Somigli, E. (1978). *Sherpa architecture*. Unesco.

Susanne Bodach, Werner Lang, Johannes Hamhaber, Climate responsive building design strategies of vernacular architecture in Nepal, Energy and Buildings, Volume 81, 2014, Pages 227-242, ISSN 0378-7788.

and ownership of the project?

- How could future technological advancements in bio-based materials further improve the feasibility and performance of this project?

The final phase of the graduation period will focus on testing the design's flexibility by giving each house within the cluster a unique character, reflecting the individuality of its residents. This approach explores customization techniques that transform a house into a home. Additionally, demonstrating how the same modular and construction methods can be used to create various elements would empower the community to continue building and adapting their homes independently, equipped with the foundational skills and techniques they have learned.

ECO RESILIENT COMMUNITIES

Housing for Landslide-Prone Precipitous Terrain in Bogotá's Informal Settlements

Around the globe, natural disasters are becoming increasingly frequent and devastating due to climate change. Among these, landslides pose a severe threat, particularly in Colombia, where precipitous terrain exacerbates their impact. The most vulnerable are informal communities, whose homes are often swept away by the relentless rains of winter.

This book delves into innovative solutions inspired by vernacular architecture, focusing on resilient engineering, sustainable construction techniques, and passive design principles. It presents an architectural proposal tailored to the community of Vereda Panamá in the Cerezos neighborhood of Soacha, Cundinamarca—serving as a guide for creating safer, more sustainable housing in the face of a changing climate.

Accompanying this book is a detailed construction manual, offering step-by-step instructions to guide the practical implementation of these techniques. Together, they provide a comprehensive resource for building resilient and sustainable communities.

Daniela Diaz Avila | 5901553