Beyond Architecture: A Multisystemic Framework for Sustainable Disaster Recovery

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Abstract: The frequency and intensity of disasters worldwide are accelerating due to a complex interplay of factors. Climate change and environmental degradation are exacerbating natural disasters such as floods, droughts, and landslides, while man-made crises such as war and terrorism fueled by religious and ethnic conflicts are recurring. Furthermore, explosive population growth and dense urbanization are leading to a significantly higher incidence of emerging infectious diseases than ever before. These multifaceted crises disproportionately impact vulnerable populations in developing countries, where resource constraints exacerbate the impacts. Temporary structures are a standard response, but their long-term use has been widely criticized by researchers for causing numerous problems, including loss of community and psychological distress for survivors. This study addresses this critical gap by proposing a holistic, multisystemic framework designed to build true resilience beyond simple disaster response. This framework is based on five core principles: comprehensive local contextual analysis, rational integration of local traditions and modern technologies, strategic inclusion of community facilities and shared spaces, proposals for long-term environmental restoration systems, and the development of adaptable, integrated master plans. To demonstrate the adaptability and flexibility of this framework, it is applied to a comparative analysis of five case studies representing diverse geographical and socioeconomic conditions: desertification in Spain, an earthquake in Turkey, landslides in Nepal, a volcanic eruption in Indonesia, and an epidemic in the Democratic Republic of the Congo. This analytical approach led us to propose a novel, context-specific architectural model and integrated master plan. Ultimately, the results of this study demonstrate that this adaptive model offers a transformative paradigm for disaster recovery, shifting the focus from immediate, short-term relief to a sustainable process that actively regenerates human societies and surrounding ecosystems for a more resilient future.

Keywords: Multisystemic Framework; Disaster Resilience; Adaptive Modular Architecture; Post-disaster Reconstruction; Ecological Restoration; Community Resilience

1. Introduction

As the frequency and severity of natural and man-made disasters accelerate globally, the importance of community resilience and sustainable architectural interventions is increasingly recognized. Traditional disaster response has primarily focused on short-term evacuation and relief, but there is now an urgent need for architectural research and proposals that simultaneously enhance the resilience of both humans and the planet. This study critically examines the architectural limitations of existing disaster response methods and proposes a framework for new architectural models aimed at improving disaster resilience. while previous studies may have addressed psychological or social resilience in isolation, this paper's contribution is the development of a unique, five-principled framework that systematically links architectural design with long-term ecological restoration and community well-being in a singular model.

Through a comparative analysis of five case studies—desertification in Spain, earthquakes in Turkey, landslides in Nepal, volcanic eruptions in Indonesia, and epidemics in the Democratic Republic of Congo—modular architectural models tailored to the unique climatic, social, and cultural conditions of each region are presented. Each project goes beyond simple building design to serve as an integrated manual and guideline for ecologically grounded disaster-responsive design. This approach not only supports immediate disaster relief but also provides pathways for sustainable redevelopment and recovery, contributing to the long-term resilience of vulnerable areas.

2. Literature Review

A comprehensive literature review is essential to ground the proposed framework in the existing discourse. This section critically examines three key thematic areas: the disproportionate effects of disasters on vulnerable populations, the necessity of shifting from short-term relief to durable, long-term housing solutions, and the current efficacy and persistent limitations of modular architectural approaches.

2.1. Inequality of Disaster Damages and Resilience

Disasters often recur in the same regions, with damage and response varying significantly based on local conditions (Machlis et al., 2022). A World Bank report highlights that damages are more severe for developing countries and low-income populations, where repeated disasters have a cumulative impact. The poor are 1.8

times more likely to reside in vulnerable, hazard-prone areas and housing, leading to greater damage and slower recovery (Hallegatte & Walsh, 2021). These communities, facing limited income, are forced to prioritize basic needs over reconstruction, resulting in more severe long-term consequences.

2.2. Temporary Housing Facilities and Medium- to Long-term Residences

Most disaster response housing focuses on short-term, temporary facilities. However, extended use of such housing can lead to psychological issues like PTSD and a loss of community cohesion (Park, Youm, & Kang, 2022; Charlesworth & Fien, 2009; Felix, Branco, & Feio, 2013). This has prompted researchers to call for sustainable, integrated post-disaster reconstruction frameworks (Karaman et al., 2024). Governments, including those in Japan and the U.S., now recognize the need for long-term disaster resilience planning that goes beyond short-term response to include comprehensive policy-making over several years (Cabinet Office, Government of Japan, 2021; NIST Technical Note 1795, 2013, McAllister). Durable and energy-efficient long-term housing can contribute to residents' mental and physical stability, enhance quality of life, and ensure environmental sustainability by reducing maintenance costs and preserving social networks (Park, Youm, & Kang, 2022; Charlesworth & Fien, 2009).

2.3. Effectiveness and Limitations of Modular Architecture

Modular architecture offers advantages in resilience, speed, resource efficiency, and sustainability compared to conventional construction (Kamali et al., 2025). Its factory-based prefabrication allows for rapid mass production and customization for large-scale disaster recovery (Adeyemi et al., 2024; Ginigaddara et al., 2023), while also producing less waste and saving resources (Tavares et al., 2021). However, modular construction is often limited by logistical challenges, such as transportation and access to factories, which can increase costs, especially in remote disaster-affected areas (Tavares et al., 2021; Felix, Branco, & Feio, 2013). Materials not locally sourced can further complicate maintenance. A primary critique is that modular architecture's emphasis on standardization often comes at the expense of local culture and user needs (Hwang & Kim, 2022).

2.4. Problems Identified and Research Gaps

A review of existing research revealed that architectural responses to disasters, primarily temporary facilities, often fail to holistically address long-term psychological and social issues. While modular construction is effective for rapid response, it frequently overlooks local contexts. These findings highlight a critical need for an integrated framework that addresses these interconnected challenges, which existing studies have not comprehensively explored.

3. Material and Methods

Through a preceding literature review, inequalities in disaster impacts and resilience, issues related to temporary housing, and the effectiveness and limitations of modular architecture in disaster response were re-examined. Based on this, five research frameworks were derived, adopting a multilayered approach that includes not only structural aspects but also social, cultural, and environmental factors.

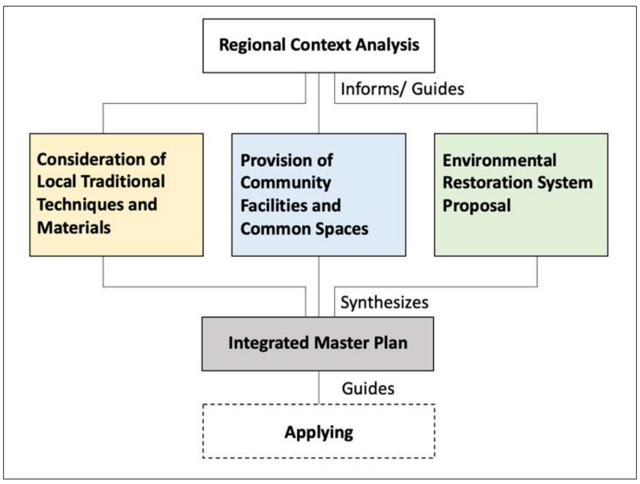

Figure 1 Conceptual model of a multi-system framework

Regional Context Analysis is both the starting point of the research and the most fundamental data layer, providing an in-depth understanding of a region's unique climate, topography, social, cultural, and economic characteristics, as well as its existing architectural traditions. Based on the results of this regional context analysis, three core frameworks are organically derived and applied. These three elements are comprehensively integrated into a practical blueprint, and the integrated master plan not only offers individual architectural proposals but also serves as an adaptive manual and guideline tailored to each region's unique characteristics.
The case studies were selected as representative regions for each disaster type (desertification, earthquake, landslide, volcano, epidemic). The selection was based on the specific characteristics, frequency, and scale of damage documented in international research and official reports. To demonstrate the universal applicability of the framework, the cases were intentionally chosen to cover a wide range of geographical and socio-economic contexts, including Europe, Asia, and Africa.
while past modular construction has prioritized standardization, the framework proposed here redefines modularity as a tool for creating adaptable, context-sensitive solutions that respect local traditions and community needs.

4. Research Frame

Based on the literature review, five integrated and sustainable research frames were established to propose new typologies of disaster-responsive architecture:

- Investigation of Regional Context

Existing modular architecture emphasizes standardization for global application, often poorly accommodating local climate, culture, and user needs, causing long-term discomfort (Saifudeen & Mani, 2024; Hwang & Kim, 2022). This study addresses this by analyzing the region's climate, geography, politics, economy, society, history, culture, and demographics to inform the design of mid- to long-term residential facilities.

- Consideration of Local Traditional Techniques and Materials

In disaster-affected areas, especially those in developing countries or with low-income populations, modular construction can face logistical constraints. Utilizing proven traditional construction techniques and sustainable local materials has also demonstrated excellent performance in disaster resilience (Ali, Muntaqa, & Ahmed, 2024). Therefore, this research rationally combines the strengths of modern technologies with the traditional techniques and materials of the region.

- Securing Community Facilities and Commons Spaces

To enhance regional community and disaster resilience, it is necessary to secure not only residential units but also modularized community facilities and common spaces, such as hospitals, health centers, daycare centers, religious facilities, and community parks.

- Proposal of Environmental Restoration Systems

Many previous studies have focused on the resilience of humans and communities to disasters (Terblanche, Sousa, & Niekerk, 2022; Bakic, Ajdukovic, 2021; Huang et al., 2018; Li et al., 2023; Maruya & Watanabe, 2018; Shi et al., 2021), as well as the resilience of architecture (Ali, Muntaqa, & Ahmed, 2024; Samsuddin, 2025; Ginigaddara et al., 2023; Edem et al., 2024). However, this research proposes a mid-to-long-term scenario that considers the restoration of ecological systems capable of reducing disaster damage over time. To this end, the ecology and vegetation of the region were also examined together.

- Integrated Master Plan as Architectural Manual and Guideline

An integrated master plan that combines architectural units and ecological systems is presented to serve as an adaptive disaster response manual and guideline for each region.
while past modular construction has prioritized standardization, the framework proposed here redefines modularity as a tool for creating adaptable, context-sensitive solutions that respect local traditions and community needs. Using the above five research frameworks, five disasters and regions were analyzed as case studies, and new architectural models to respond to disasters were proposed. In Europe, desertification in Spain and earthquakes in Turkey were addressed; in Asia, landslides in Nepal and volcanic eruptions in Indonesia were studied; and in Africa, infectious diseases in the Congo were examined. The detailed contents of each case study are as follows.

5. Case Analysis and Contexts

To validate the adaptability of the multi-systemic framework, this section conducts a comparative analysis across five distinct global case studies. Each case begins with a comprehensive context analysis covering the region's unique topography, society, and history, and examines the rational application of local traditional techniques, materials, and long-term environmental restoration systems.

5.1. Desertification (Spain)

As of 2008, 74% of Spain's territory is classified as desertified, with 18% designated as high-risk zones (McMurtry, 2019). Despite various mitigation efforts since joining the UN Convention to Combat Desertification in 1994, excessive development in agriculture and tourism has increased environmental burdens. Andalusia's Mediterranean climate, characterized by low precipitation and severe drought, has exacerbated desertification, with regions like the Guadalquivir Delta and Cordoba experiencing agricultural droughts, soil erosion, and a sharp decline in olive production (UAM, 2023; Kim, 2015). While Spain traditionally used dry-climate irrigation methods, recent intensive agriculture has accelerated soil nutrient depletion and groundwater pollution, further intensifying desertification (Gruère et al., 2020; Xinhua, 2024). These conditions have also created social issues, including reduced agricultural productivity, shifts in economic structure, rural community decline, and rising unemployment (García-López and Muñoz-Rojas, 2018).

Andalusian traditional architecture is optimized for dry climates with white lime walls, interior patios, and ceiling balconies (Lopez de Asiain, 2016). A notable housing solution responding to climate change is the semi-underground Casa Semienterrada, designed by Javier Barba (1986). This hillside house has living spaces half-buried underground, providing thermal insulation in summer and using geothermal energy in winter to enhance energy efficiency and climate adaptability (Terrón-Laya, 2025; BC Estudio Group, 2025). Such semi-underground modular architecture is proposed as a new typology to address desertification in Spain.

For sustainability, a shift from intensive farming to agroforestry and swale irrigation systems is considered, as they improve climate resilience, restore biodiversity, and support water conservation (Prajapati et al., 2024; Greener Land, n.d.). Permaculture mini-farms can also be proposed to counter community disintegration. Permaculture is an integrated design principle that emulates natural ecosystems to create sustainable human habitats, applicable to various scales from farms to communities (Mollison, 2018).

5.2. Earthquake (Turkey)

Located at the convergence of four major tectonic plates, including the Anatolian Plate, Turkey is highly susceptible to seismic activity. The catastrophic 2023 earthquakes (magnitudes 7.8 and 7.6) resulted in an estimated 50,000 fatalities. The disaster had a profound psychological impact, particularly on children, with approximately 1,360 becoming separated from their parents and facing critical issues of survival and emotional recovery.

Research from Save the Children (2024) indicates that 51% of affected children exhibit psychological and behavioral disturbances, including anxiety, aggression, and trauma symptoms like PTSD, nightmares, and hypersensitivity. Children who survived building collapses often display heightened sensitivity to indoor environments and instinctively avoid spaces they perceive as unsafe. Teachers have also observed age-specific regressive behaviors, such as thumb-sucking and bedwetting, along with an increased dependency on caregivers (Aydos et al., 2025). These children, especially those aged 4–12, are particularly vulnerable, and the trauma may have long-term effects on their development (Fan and Kang, 2025). Furthermore, those separated from caregivers face compounding crises aggravated by overcrowded temporary settlements, poor hygiene, and exploitation risks. Addressing these issues requires safe housing, psychosocial support, and child-tailored educational assistance. Recognizing the positive role of religion in psychological stability, the proposed trauma healing shelter includes a musalla, a designated prayer space for Islam, the dominant religion in Turkey.

5.3. Landslides (Nepal)

The Himalayan region’s climate change progresses about three times faster than the global average. Key drivers include elevation-dependent warming, glacier melt, and monsoon instability causing irregular rainfall and temperature fluctuations (IPCC, 2023). Nepal has experienced frequent and severe natural disasters, including landslides intensified by prolonged monsoons and abnormal rainfall. Between 2012 and 2024, Nepal faced about 44,000 natural disaster incidents causing 5,667 deaths and damage amounting to roughly 20% of GDP (National Statistics Office et al., 2024). The mountainous terrain covers over 80% of Nepal, with steep slopes (25–40 degrees), fragile geology, thin soils, sparse vegetation, and monsoon rains driving recurring landslides (Shrestha, 2022).

Dolakha district is a key example, exposed annually to landslide risk due to steep slopes, poor road access, unstable geology, and rising groundwater (Department of Mines and Geology, Government of Nepal, 2022; Shrestha et al., 2012). Villages generally rely on gravity-fed water, rainwater tanks, and small drainage channels but lack formal drainage systems, putting them at risk from floods and landslides (Asian Development Bank, 2013). To counter this, a multifaceted approach is proposed: hillside bench terraces, vegetation for soil stabilization, efficient drainage, and modular housing designs that are easily relocated and rebuilt. This aims not only to reduce immediate disaster damage but to enable long-term ecological restoration and strengthen the soil base.

5.4. Volcano (Indonesia)

Indonesia is located on the Pacific Ring of Fire, with over 120 active volcanoes. On November 4, 2024, the Lewotobi Laki Laki volcano erupted, causing severe damage that included 9 deaths, over 60 injuries, and the destruction of approximately 2,000 homes. The government responded by raising the volcanic alert to the highest level and permanently relocating about 16,000 residents (ExpatGo, 2024). Despite Indonesia's frequent volcanic activity and the operation of monitoring systems and expanded shelters, the number of refugees continues to increase due to poor conditions in temporary shelters (Asian Development Bank, 2023).

Evacuations involve large groups due to the region's family- and community-centered lifestyle, with an average household size of 4–5 persons. Residents, who engage in agriculture on fertile volcanic ash soil and maintain religious rituals honoring the volcano, continue these traditional practices (Rozaki et al., 2023).

After disasters, the government provides concrete permanent housing (Huntap), but such houses are ill-suited to traditional lifestyles, community bonds, and local environments, causing discomfort. Huntap homes lack architectural completeness, ventilation, expandability, and fail to reflect local culture, leading to loss of regional identity (Andi, Akbar, and Tutang, 2024; Nursamsir, 2022).

Following the Palu earthquake, around 30% of residents attempted to return to original villages. While modern homes offer rapid construction advantages, they have structural weak points and limited disaster responsiveness, such as vulnerability to volcanic ash loads and poor ventilation. Traditional homes are more flexible but susceptible to fire and other hazards (Kumar, 2024). Improvement strategies include eco-friendly materials like bamboo-concrete composites and coconut fiber panels, and reinterpretation of traditional structures with earthquake-resistant curved roofs and flood-resilient stilts. These contribute to sustainable housing models preserving architectural identity and enhancing disaster resilience.

5.5. Ebola (Congo)

The Ebola virus, first identified in 1976 in the Democratic Republic of the Congo and Sudan, causes a highly fatal hemorrhagic fever transmitted through contact with infected bodily fluids. Symptoms include severe bleeding and organ failure within 7-14 days (WHO, 2025). Between 2018 and 2020, an outbreak in the Kivu and Ituri regions infected 3,470 people and caused 2,280 deaths. Although vaccines and treatments have reduced fatality rates, new infections continue in 2025 (WHO Africa, 2022).

The response faces challenges due to poor medical infrastructure, ongoing conflict, vast territory, and difficult transportation. Organizations like WHO, UNICEF, and MSF encounter distrust, conflict, and educational deficits, which hamper effective contact tracing, vaccination, and patient care. Patients escaping treatment centers and refusing transfer augment transmission. Violence against healthcare workers further disrupts services (Diarra et al., 2023; Sweet and Kasali, 2024).

The Ebola epidemic has profoundly altered Congo’s traditional funeral customs and community activities. Restrictions on traditional funerals have caused psychological and economic distress and heightened distrust in health authorities, which in turn has led to attacks on treatment centers (MSF, 2019; Katembula et al., 2021). Although WHO-standard treatment centers maintain strict infection control through separated pathways and ward management, they can provoke patient and family isolation and anxiety due to limited information. Consequently, transparent communication about treatment processes and support for patient stability and connections with the outside world are essential.

Building trust with local communities requires ongoing support and education. Establishing community facilities where residents can acquire accurate information about Ebola and reduce vaccine and treatment hesitancy is critical. These spaces support and develop education, culture, and religion, serving not only as healthcare providers but as central hubs of social cohesion. This approach strengthens relationships between residents and healthcare staff and increases vaccine coverage, effectively curbing Ebola spread.

Due to conflict and poor infrastructure, local people in the Democratic Republic of the Congo construct buildings from readily available materials. Urban areas primarily use scrap metal, while rural and peri-urban areas use earth and wood. However, both materials have limitations in structural stability and durability. In 2014, the United Nations Human Settlements Programme (UN-Habitat) initiated the ‘Sustainable Housing Reconstruction Project in Eastern Democratic Republic of Congo,’ which aimed to construct sustainable pilot homes for families displaced by land disputes. This project utilized locally available earth as the main construction material, minimizing the use of cement or rebar. To overcome the weak durability of earth, adobe (sun-dried earth bricks) and compressed earth blocks were employed, resulting in sturdier and more sustainable housing. The construction process involved local residents, generating income and fostering community formation (UN-Habitat, 2016).

6. Architectural Typologies for Disaster Resilience

Building upon the context analysis of Section 5, this section presents five distinct architectural typologies and their integrated master plans, each specifically tailored to the respective regional and disaster challenges. These proposals demonstrate the practical application of the five-principled framework, moving from conceptual theory to concrete, context-sensitive design solutions.

6.1. Green-Transition Self-Sufficient Ecological Modular System

Figure 2 Project Metadata for Green-Transition Self-Sufficient Ecological Modular System

Category	Detail
Location	Carcabuey, Córdoba, Spain
Disaster Type	Desertification
Proposal / Action	Ecological Restoration & Self-Sufficient Housing
Team Members	Kim, H., Kim, N.Y., & Jo, Y.G.

The site chosen for the green transition self-sufficient ecological modular system is the village of Carcabuey in Córdoba province of Spain. The village experiences a Mediterranean dry climate with less than 400mm of average annual rainfall and summer temperatures up to 40°C. These conditions, combined with limestone terrain, have led to rapid soil erosion, low water retention, and ecosystem degradation, accelerating desertification. Once a thriving olive-farming village, Carcabuey has seen a sharp decline in productivity due to climate change, resource depletion, population decline, and aging, which complicates recovery. The village is regarded as a "climate recovery pilot site" suitable for demonstrating ecological modular housing and self-sufficient agriculture to combat desertification (Junta de Andalucía — Consejería de Agricultura, 2022).

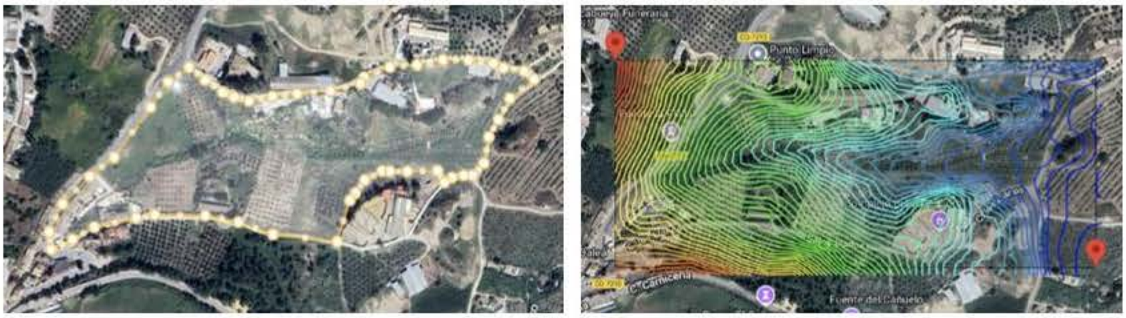

Figure 3 A site location for the green transition self-sufficient ecological modular system

The modular ecological restoration system is a long-term project carried out over 20 years in five-year phases. During years 0 to 5, the foundation is established and modular prototypes are presented; years 5 to 10 focus on ecological expansion and formation of village networks; years 10 to 15 involve conversion to a climate-resilient hub village; and years 15 to 20 entail policy dissemination and establishment of a standard model. This project aims to re-green a total of 87 hectares, transforming the area into a climate refuge and a center for ecological tourism and education. (see Figure 4).

Figure 4 Modular Ecological Restoration Project Scenario

period	Main Stages & Details
0 – 5 Years	Foundation & Modular Prototype - Begin restoration (33 hectares) - Pilot modular housing (20 units, semi-underground/underground types) - Restore basic land, design rainwater retention and sunlight system - Apply solar and passive ventilation structures
5 – 10 Years	Ecological Expansion & Village Network Formation - Accumulated restoration: 58.7 hectares - Large-scale expansion of modular residential community (80 households) - Installation of communal farms, storage, community kitchen - Introduction of community infrastructure

10 – 15 Years	Climate Resilience & Conversion to Resident Villages - Achieve 76.4 hectares of restored area - Recover biodiversity (vegetation, insects, wildlife) - Expand villages to 3–4 locations, settle 200 residents - Initiate linkage with EU ecological restoration projects
15 – 20 Years	Policy Expansion & International Modeling - Over 87 hectares restored - Connect aspirations, stabilize staple crops - Launch carbon reduction project, designate ecological managers - Join international eco-village networks, expand policy model
After 20 Years	Expected Outcomes After 20 Years - Over 87 ha restored (87% of total area) - 34 villages total (each ~4,080 households) - ~200–500 people (cooperative community structure) - Energy 100% / Water 90% / Food >80% - Restoration of native plants, insects, pollinators, etc.

The system is designed for self-sufficiency, addressing energy, water, food, and waste management within each unit without external dependence. Housing uses a semi-underground design for insulation and geothermal heating/cooling. Greywater from bathrooms and kitchens is purified and reused for crop cultivation via swale techniques. A composting area recycles organic waste to enrich farmland soil. The agricultural zone integrates permaculture and agroforestry, achieving both food production and ecological restoration.

Reflecting Carcabuey's deep Catholic tradition and communal lifestyle, the plan includes community facilities such as religious spaces, communal kitchens, dining areas, lounges, and meeting rooms. These spaces are designed to support worship, maintain local identity, and foster social cohesion. For ecological restoration, thirteen crops adapted to arid conditions were selected for self-sufficiency. Trees like jojoba, olive, agave, pomegranate, fig, moringa, and palo verde were chosen for their deep roots to prevent soil erosion and contribute to the long-term greening of the village. Fast-growing moringa and palo verde trees provide shade to improve the microclimate. Short-cycle crops like aloe, rosemary, Swiss chard, beet, and carrot are suitable for daily self-sufficiency and medicinal use, while cassava provides a storable carbohydrate source for food security. These plants require minimal water and promote year-round harvesting, serving the dual goals of self-sufficiency and ecological restoration in desertified areas.

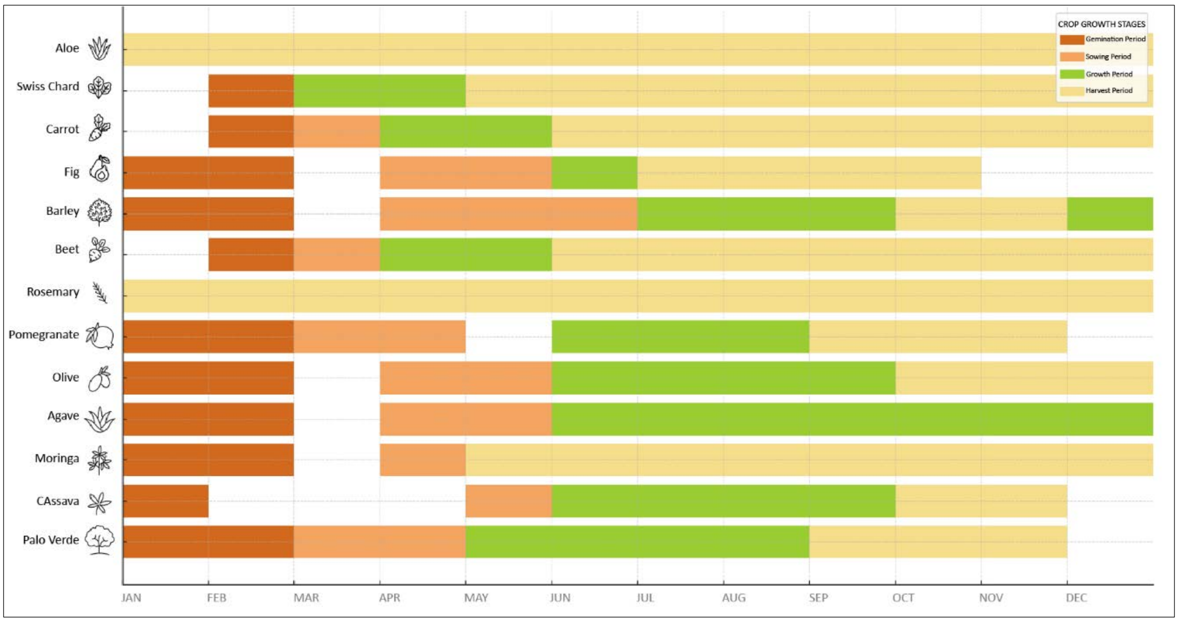

Figure 5 Seasonal Plan According to the Growth Stages of Selected Crops

Figure 6 the Integrated Master Plan

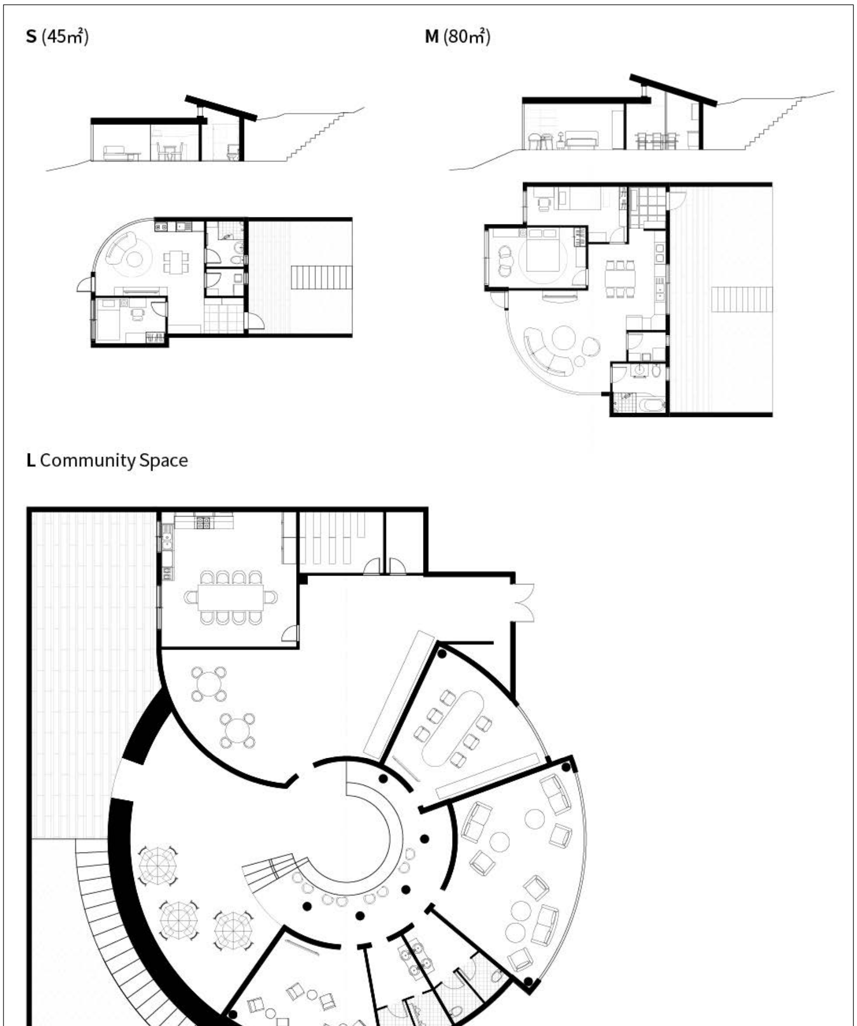

Figure 7 Modular Units

6.2. Earthquake Survivor Orphan Children's Trauma Healing Shelter

Figure 8 Project Metadata for Earthquake Survivor Orphan Children's Trauma Healing Shelter

Category	Detail
Location	Kahramanmaraş, Turkey
Disaster Type	Earthquake
Proposal / Action	Trauma Healing Shelter (Mid-to-Long-Term)
Team Members	Kim, H., Lee, Y.B., & Yang, Y.S.

The trauma healing shelter for earthquake-affected children is designed as a mid-to-long-term temporary protective facility, intended to care for children who have lost their homes and families due to the earthquake and are suffering from trauma. The shelter serves as a "bridge to recovery," aiding children's psychological healing and adjustment before they can smoothly integrate into public protection systems. It provides a stable living environment and helps children regain psychological stability and daily routines by living with trustworthy adults. The modular design features a single-story structure that ensures structural stability and accessibility, facilitating easy evacuation and rapid rescue operations during earthquakes. The building overall is designed to offer an open atmosphere with multiple entrances to allow dispersed evacuation and access in emergencies. Soundproofing is incorporated to shield children from external noise and enhance psychological comfort, and seismic resistance is included to help withstand repeated aftershocks. Specialists provide emotional support, and programs help children aged 4–12 regain social skills and self-esteem through peer interaction. Most spaces, except essential sanitation, are outside to accommodate children fearful of enclosed spaces. The tentative site is an open area in front of the Baykar container settlement in Kahramanmaraş, Turkey. Since many children who lost parents in the earthquake feel anxious and fearful when left alone in unfamiliar environments, the site was chosen to be adjacent to the settlement, enabling children to live near adults and naturally interact with them. The location on a main road near the settlement entrance also facilitates efficient delivery of relief supplies.

Figure 9 A site location for the Earthquake Survivor Orphan Children's Trauma Healing Shelter

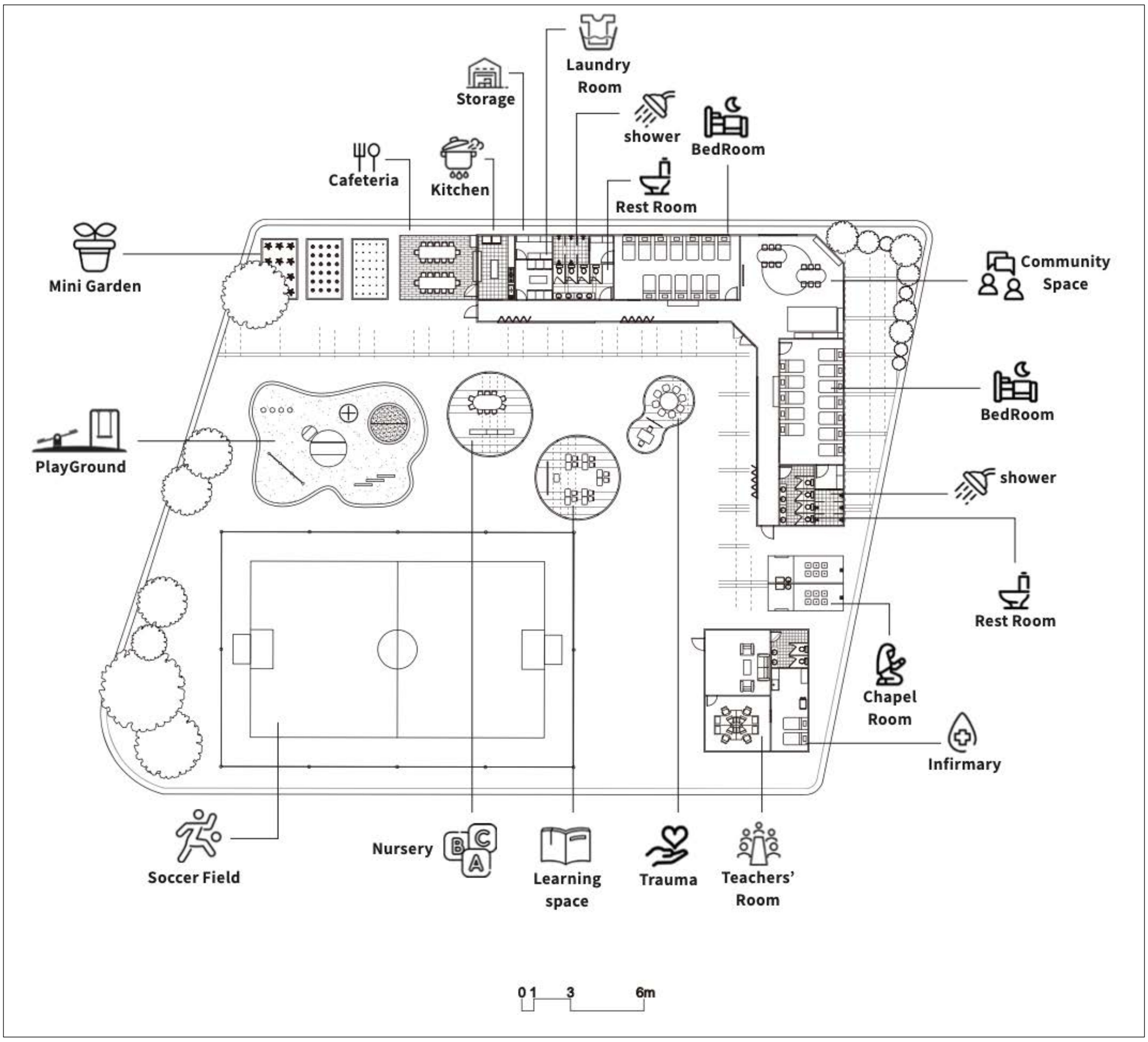

Figure 10 the Integrated Master Plan

6.3. Hillside Long-Term Modular Housing

Figure 11 Project Metadata for Hillside Long-Term Modular Housing

Category	Detail
Location	Lapilang, Dolakha, Nepal
Disaster Type	Landslide
Proposal / Action	Modular Hillside Housing & Soil Stabilization System
Team Members	Kim, H., Song, J., Song, N., & Lee, H.

Bagmati Province in Nepal experiences the highest landslide frequency in recent years. Dolakha district, in particular, suffers from geological and topographical instability, causing repeated evacuations and infrastructure failures. The mountainous terrain and poor road networks significantly impede recovery and rescue efforts [McAdoo et al., 2018]. In Lapilang village, a 2024 landslide forced 150 out of 901 households to abandon their homes. This study selected Lapilang due to its repetitive disaster exposure, proposing a modular hillside system integrating habitats, agriculture, and vegetation.

Figure 12 A site location for the modular hillside system

The proposal uses vegetation native to the Lapilang area to stabilize the soil. Deep-rooted oak trees contribute to slope stabilization and serve as windbreaks, while broom grass (Thysanolaena maxima), with dense fibrous roots, can reduce runoff and soil loss by up to 88% compared to bare land, making it ideal for slope rehabilitation. Additionally, three types of crops are planted seasonally based on root depth, arranged vertically from shallow-rooted (herbs), medium-rooted to deep-rooted plants from top to bottom. This vertical root stratification minimizes competition for water and nutrients among plants and optimizes soil space usage. Arranging these crops on both sides of residential modules facilitates efficient circulation and agricultural water use (HIMCAT Team, 2008).

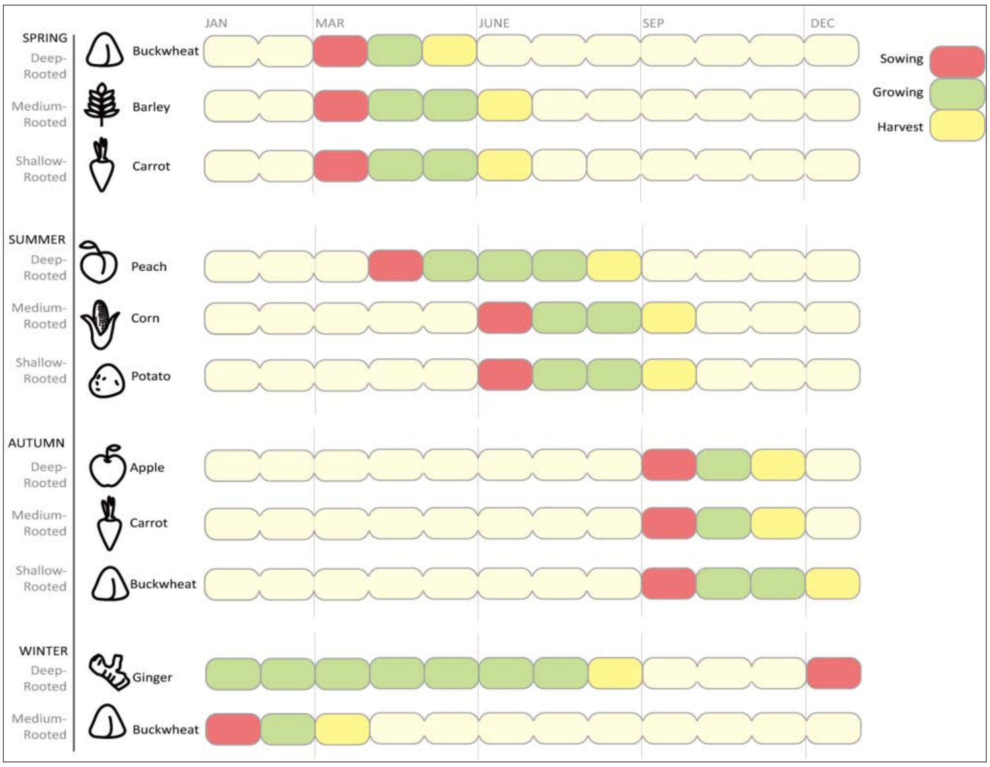

Figure 13 Seasonal Plan According to the Growth Stages of Selected Crops

For sustainable drainage, rainwater is collected behind houses and channeled through drainage ditches into larger waterways. Roof rainwater is harvested, filtered, and purified for domestic and agricultural use. Greywater undergoes natural filtration and is reused for agriculture, and ecologically designed toilets assist natural waste processing or composting. Residential modules are constructed with local wood and soil materials: oak frames for load and moisture resistance, soil infill for insulation and humidity control, and bamboo connectors for flexibility, seismic resilience, and impact absorption. Wall modules standardize at 1100×1000 mm. The layout employs bench terracing with interwoven fields, houses, and vegetation, which stabilizes soil during heavy rains.

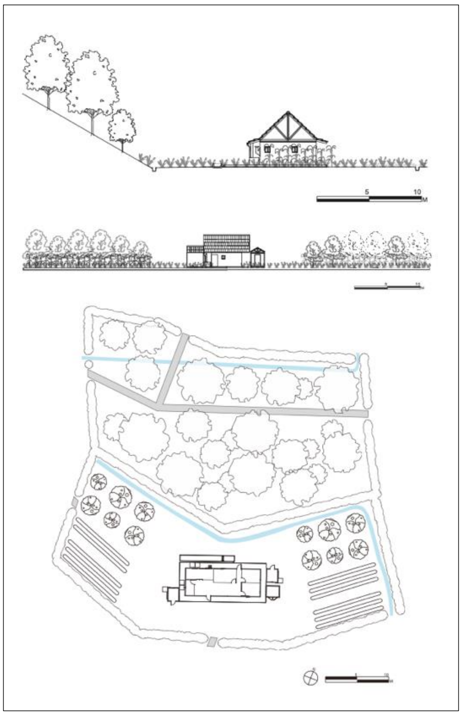

Figure 14 the modular hillside system

This integrated ecological system enables water use for farming and daily life even during dry seasons. For landslide- and flood-prone areas like Lapilang village, community-type evacuation facilities suitable for medium- to long-term stays are essential. Group temporary housing should replace daily functions for weeks or months after a disaster, supporting mental and physical stability, community cohesion, hygiene, and disease prevention [Ju et al., 2020]. Accordingly, the project master plan includes such community-oriented facilities.

Figure 15 the Integrated Master Plan

Figure 16 Modular Units

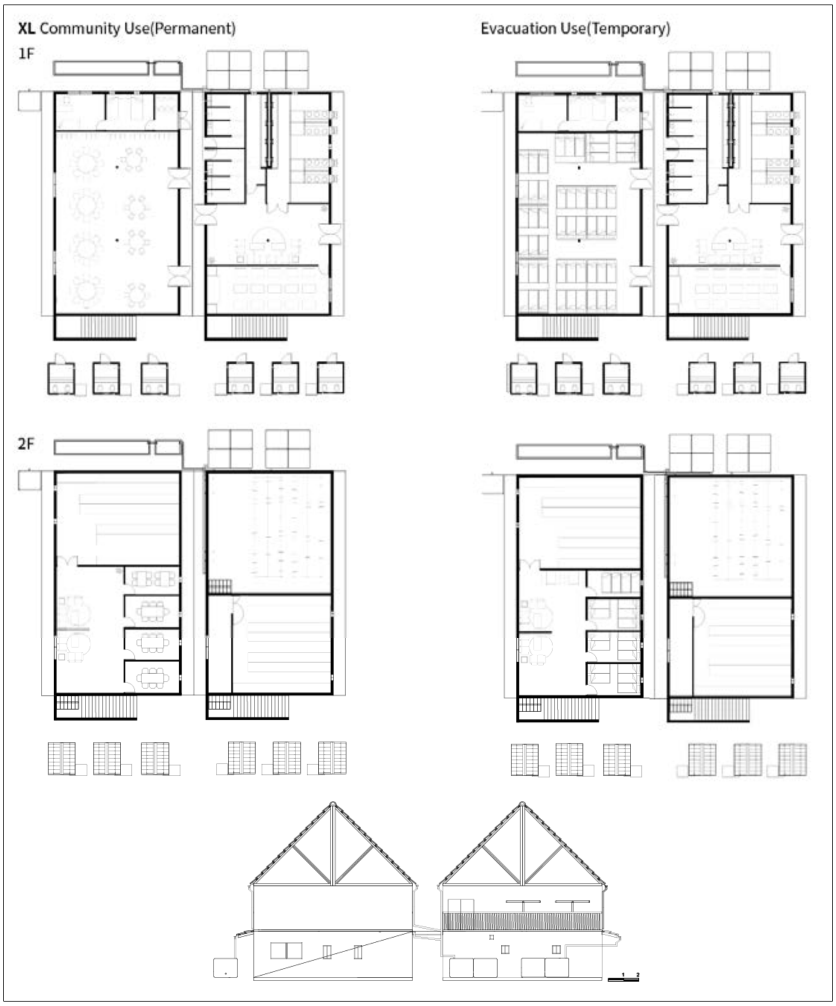

Figure 17 Community Units

6.4. Permanent Modular Housing Compound

Figure 18 Project Metadata for Permanent Modular Housing Compound

Category	Detail
Location	Indonesia (Volcano-Affected Area)
Disaster Type	Volcanic Eruption
Proposal / Action	Community-Centered Permanent Housing (RISHA Model Improvement)
Team Members	Kim, H., Kim, Y.R., Yang, U.J., & Yun, S.W.

Since 2020, the Indonesian government has been developing HunTap complexes nationwide to accommodate residents displaced by natural disasters such as volcanic eruptions and earthquakes. HunTap is a prefabricated modular housing system constructed to provide a stable living environment within a short period, with the RISHA model of approximately 36 square meters serving as the standard. The basic interior design is simple, but the overall complex consists of uniform houses arranged in a grid pattern to form a clustered collective housing community (Ministry of Public Works, 2024).

This proposed complex addresses the shortcomings of existing HunTap homes by arranging units in a community-centered manner and creating small local clusters to aid community recovery. The housing modules are flexible, single-story structures designed to accommodate households of 3–4 and 5–6 persons. Outdoor spaces are divided into private yards—traditionally used by residents for outdoor cooking—semi-public spaces for interaction among nearby neighbors, and public spaces for collective use by all residents of the complex.

Building materials, including laminated wood made from locally sourced merbau timber and bamboo, provide both traditional appeal and sustainability. The roof is designed with a Pratt truss structure for vertical ventilation, and its slope is optimized to allow volcanic ash to slide off naturally, which significantly reduces structural load increases and collapse risks.

Figure 19 the Integrated Master Plan

Figure 20 Modular Units

6.5. Ebola Treatment and Community Center

Figure 21 Project Metadata for Ebola Treatment and Community Center

Category	Detail
Location	Bukavu Province, Democratic Republic of the Congo
Disaster Type	Epidemic (Ebola)
Proposal / Action	Public Health & Social Trust Building Center
Team Members	Kim, H., Ga, E.H., Kim, E.S., & Yang, Y.J.

The Ebola Treatment and Community Center is designed to go beyond simple ward functions, combining community and ward modules to rebuild trust and foster active cooperation. Located in the Kinshasa area of

Bukavu Province in the eastern Democratic Republic of the Congo, the center is centrally positioned with direct access to a main road. Its proximity to churches, schools, and existing medical facilities facilitates the provision of specialized educational and cultural services for residents and allows for easy access to staff for community space operation.

Figure 22 A site location for the Ebola Treatment and Community Center

Residents can freely access the center through alleyways connected to the village, fostering an open relationship with the facility. The community space offers various programs tailored to local needs, encouraging residents to actively organize and utilize the space. This continuous interaction with medical staff during treatment helps bridge the psychological gap. In particular, educational programs about Ebola can improve residents' awareness and cooperation with treatment efforts and vaccination rates.

To reflect local African characteristics and adhere to strict hygiene standards, the primary building material is compressed earth bricks, with minimal supplementary materials. Due to the high fatality and transmissibility of the Ebola virus, strict infection control measures are essential. Medical staff's paths to and from patient care areas are carefully separated to prevent virus spread.

The center consists of five modules, the smallest of which is a quarantine area for initial testing. Suspected or awaiting patients are transferred to a secondary ward to await test results. If an Ebola infection is confirmed, the patient is transferred to a tertiary ward for medical and supportive care, such as hydration. Upon a patient's death, the body is moved to a nearby morgue, which is strictly limited to medical staff. After careful handling, the morgue is connected to a community facility, providing a space for family and neighbors to mourn.

While strict physical isolation is maintained between the secondary and tertiary wards, visual interaction and safe indirect visits are allowed to alleviate patient isolation and anxiety. This space serves as both a medical facility and a community hub, designed to build trust between residents and staff. The Nursing Station (NS) is the central hub for medical staff to monitor patients, prepare treatments, and manage records and communications. The non-infectious community space, strategically located in a spacious courtyard facing the medical area, is a multi-purpose facility for worship and educational programs. This arrangement facilitates indirect participation, helping to alleviate the psychological burden and mistrust experienced by residents. Additionally, the center includes outdoor communal kitchens for residents to cook and eat together, and a small park with a children's play area, further fostering trust between residents and medical staff.

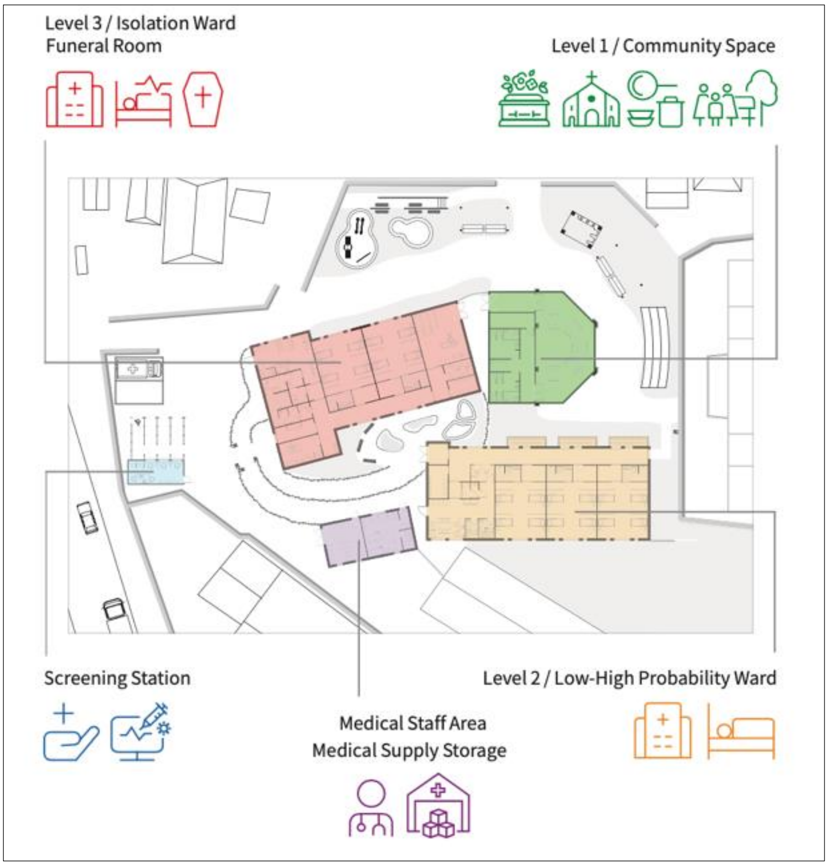

Figure 23 Programmes

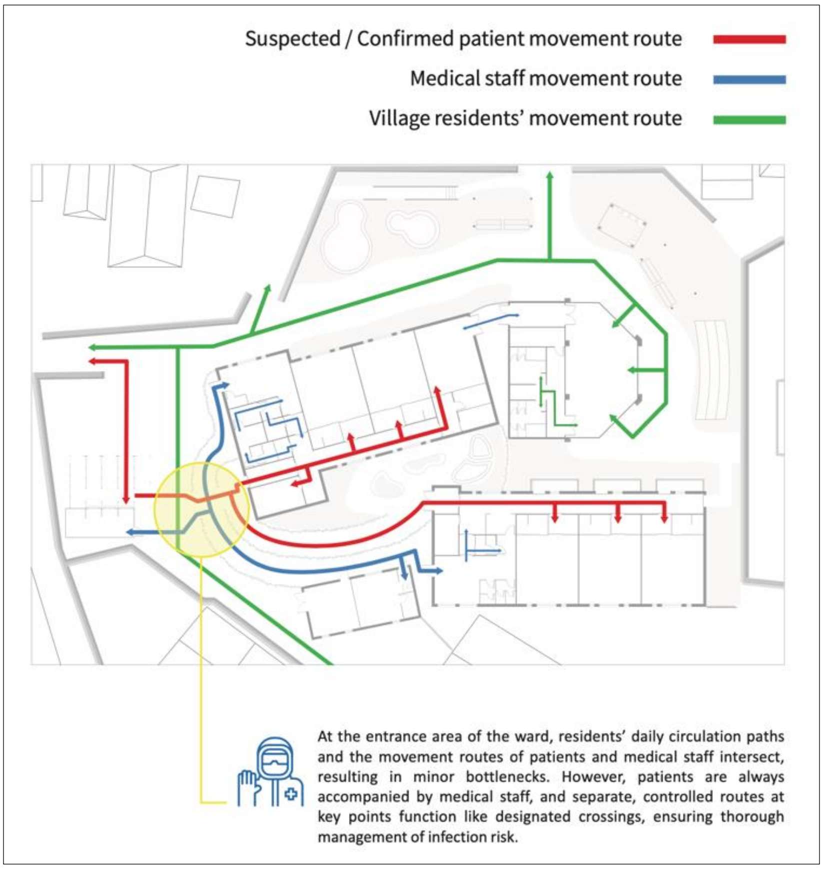

Figure 24 Circulations

Figure 25 the Integrated Master Plan

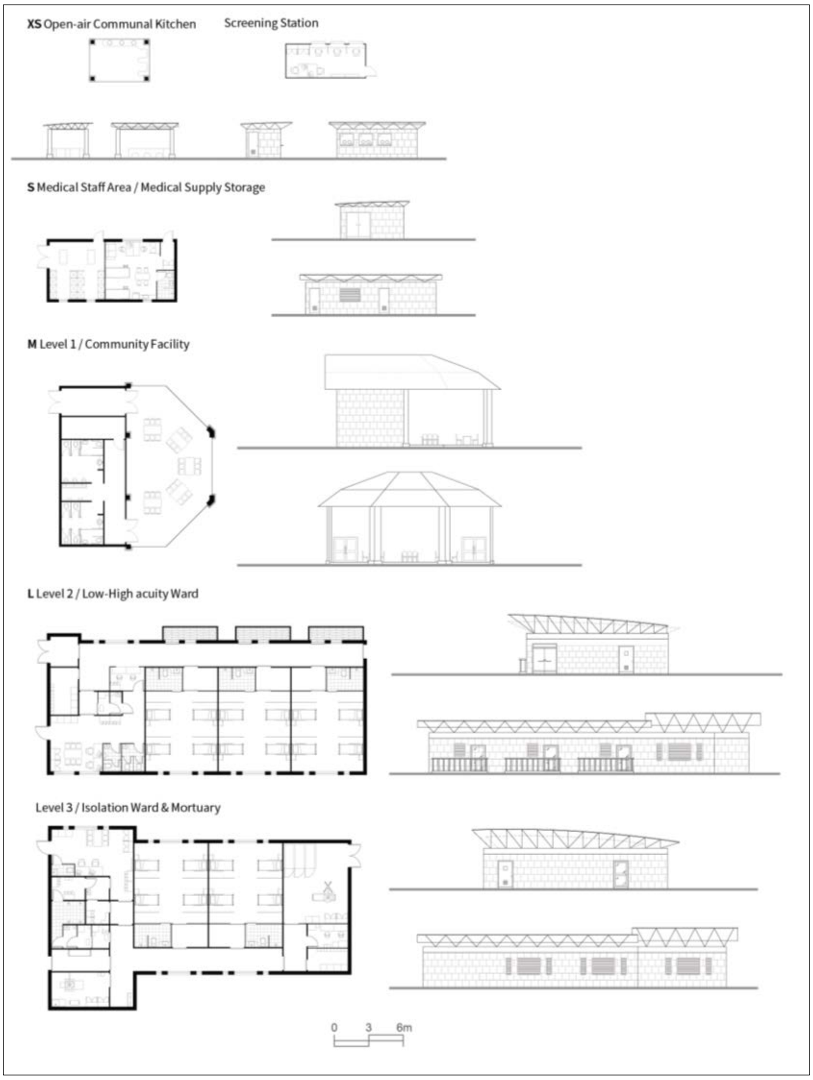

Figure 26 Modular Units

7. Analysis of the Application of Research Frameworks by Case Study

The analysis of applying the research frameworks to each case revealed that the same framework cannot be uniformly applied across all disasters; it varies depending on the specific disaster type and regional characteristics. This variation was particularly prominent in the consideration of traditional techniques and materials, as well as the proposed environmental restoration systems. For example, in Turkey, modern technology proved more effective in disaster response than local traditional techniques and materials. Environmental restoration systems were applicable only to certain disaster types. In the cases of earthquakes in Turkey, volcanic eruptions in Indonesia, and Ebola in Congo, addressing issues such as trauma treatment for affected children, resolving problems in existing housing modules, community restoration, and rebuilding trust in medical personnel were more critical than implementing environmental restoration systems. This demonstrates that research frameworks should not be applied uniformly to all situations; instead, the relative importance of their components shifts according to the specific characteristics of each disaster.

Figure 27 Analysis of the Application of Five Research Frameworks by Case Study

Case Study	Regional Context Analysis	Consideration of Local Traditional Techniques and Materials	Provision of Community Facilities and Common Spaces	Environmental Restoration System Proposal	Integrated Master Plan
Desertification (Spain)	Analyzed acceleration and impact of disaster along with social and cultural context	Applied traditional irrigation methods (acequias) and semi-underground architecture (Casa Semienterrada)	Included religious, community, and shared workshop spaces within the complex Developed vegetation restoration scenarios considering twelve seasons and five-year greenery restoration cycles	Developed vegetation restoration scenarios considering twelve seasons and five-year greenery restoration cycles	Proposed an integrated ecological modular system combining housing units, community units, and ecological restoration systems as a self-sufficient green transition model
Earthquake (Turkey)	Assessed disaster damage status and child trauma from earthquake impact	Applied modern seismic technology due to lack of earthquake-resistant design in traditional Turkish architecture	Proposed spaces for group programs and religious facilities indoors and outdoors	Implementation of seismic-resistant design	Proposed a single modular unit as a trauma recovery shelter for earthquake-affected children
Landslide (Nepal)	Analyzed disaster recurrence, damage status, household ratios, and religious spaces	Proposed use of local wood, earth, and bamboo materials	Included community-type temporary housing and shared facilities for mid- to long-term stays	Selected suitable crops for short- and long-term periods; proposed soil stabilization via rainwater management system	Proposed long-term hillside residential modular typology integrating housing units, community units, and ecological restoration systems
Volcanic Eruption	Analyzed causes of recurrent	Analyzed resilience of	Included community and	An architectural system adapted	Proposed permanent

(Indonesia)	disasters, damage status, and cultural characteristics	traditional houses; proposed use of local merbau wood and bamboo	shared facilities within the complex	to volcanic disaster environments through roof structures designed for volcanic ash loads and improved ventilation	housing complex modular typology integrating housing and community units
Ebola (Congo)	Conducted multidimensional analysis of disaster recurrence; suggested solutions addressing cultural and social issues	Proposed use of compressed earth bricks made from locally available soil	Suggested combined medical and community facilities to alleviate residents' distrust	A phased independent building design for improved sanitary conditions through waste and bodily fluid management, aimed at preventing disease transmission	Proposed a single modular unit for Ebola treatment and community center

8. Conclusion and Discussion

This study proposes a holistic framework by integrating architectural solutions with social and ecological systems. The core academic contribution of this framework lies in its adaptability, allowing for flexible application based on disaster type and regional characteristics. Importantly, the fact that principles such as "environmental restoration systems" cannot be applied uniformly across all disaster types is not a limitation. Rather, it demonstrates that this framework is not a one-size-fits-all solution, but rather a flexible and adaptable tool that prioritizes the principles most appropriate to the nuances of each disaster.

The proposed framework demonstrates its practical relevance through diverse and complex case studies, including desertification in Spain, earthquakes in Turkey, landslides in Nepal, volcanic eruptions in Indonesia, and epidemics in the Democratic Republic of the Congo. Each case presents sustainable architectural solutions that integrate local traditional and modern technologies, while also highlighting the importance of psychological healing and restoration of social cohesion within communities beyond physical reconstruction.

Through this integrated and adaptive approach, this paper argues that disaster recovery should go beyond mere structural reconstruction to aim for long-term community resilience and ecosystem regeneration. The research findings suggest a new paradigm in disaster recovery, offering practical guidance to policymakers, architects, and community stakeholders. However, this study acknowledges its limitations, as the proposed architectural model has not yet been implemented and validated in an actual disaster-stricken area. Future research should therefore focus on performance evaluation through real-world implementation, accompanied by iterative revision and refinement.

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