Disaster Resilience: A Sustainable Way for Niue

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Abstract. The increasing frequency of natural hazards and disasters, due to climate change, severely compromises Niue’s fragile economy and its future as a sovereign nation. Sustainable measures to building resilience and preventing natural hazards from turning into disasters are urgently needed to reverse Niue’s population decline. Urban renewal and development projects formulated based on individual’s experiences, outdated attitudes and approaches, or research conducted through pan-Pasifika and western lenses, and without the necessary policy controls, have severely compromised the safety of people and property. The dearth of research on sustainable and resilient planning, design and building practices, suited to the unique conditions of Niue and its people aggravate this situation. The paper presents traditional solutions and key findings from community-based studies conducted in Niue and from disaster preparedness and community resilience research in the Asia Pacific region. Using a case study approach the paper discusses new and sustainable solutions, methods and materials that are economically viable and practical, and resonate with local people, traditions, practices and the place. The aim of the paper is to demonstrate the opportunities that exist locally for devising and designing sustainable solutions to Niue’s problems.

1. Introduction

‘Savage Island’ was the name given to Niue by early colonizers due to the fierceness they encountered from the local warriors fighting to protect their tiny island home from foreign invaders [1]. The resilience and tenacity of the Niuean people, which ensured the island’s sovereignty from colonial dominance, had also enabled human inhabitation of a harsh island environment for several generations prior to the arrival of European explorers to the Pacific. Known as the ‘Rock of Polynesia’ Niue is one of the largest raised coral atolls in the world with an area of 269sq.km [2]. Formed entirely of coral limestone and with no lakes or rivers, fresh water can only be harvested through deep bore wells; in addition its soil is considered unsuitable for large scale cultivation of most varieties of crops [2]. The steep limestone coastal cliffs that lift Niue 24m above sea level along with the coral reefs that surround it entirely with just a single break, makes fishing an arduous means of livelihood for the islanders [2]. Niue’s geographical location in the pacific region does nothing to ease the difficulties of inhabiting it; lying in the path of numerous natural weather events cyclones and droughts are a regular occurrence, causing havoc on the already fragile sustenance sources and living environments of the island’s population [2]. Recent studies on the impacts of climate change in the pacific region have shown an increase in the frequency of droughts and cyclones due to global warming [2, 3], and studies on climate change and food security in the region have identified the impacts of likely adverse weather conditions on food production and sourcing and the fragile future situation of small pacific island nations as Niue [2-4, 7].
Extreme weather events have had a direct and indirect devastating impact on Niue for several generations, and its continuity with increased frequency and intensity, will most certainly imply the future abandonment of this small island by its current youth and future generations who have a relatively safe haven with reliable educational and economic opportunities in New Zealand, which has granted Niuean’s citizenship [5]. While natural disasters significantly undermined Niue’s economy and its socio-cultural fabric [2, 3, 6], factors as climatically inappropriate and westernised building methods, materials and planning practices contribute to the widespread damage resulting from natural hazard situations as cyclones, and to the demoralising effect of ongoing damage to lives, property, public infrastructure, and livelihood sources [6] that drive Niuean’s to find safety and security in New Zealand [3]. The devastating outcomes of Cyclone Heta in 2004 on Niue is a good example of this situation, it not only destroyed infrastructure but also caused an exodus of Niuean’s to New Zealand [7] upsetting the steadying of population numbers Niue was experiencing at the time, and desperately needed to sustain the future of the country.

The worst damage from Cyclone Heta, and the Tsunami that resulted, was experienced in Ailikuki, the more modern built up south of the island’s capital Alofi established on a highly exposed stretch of the island by early missionaries. The island’s national infrastructure including its only hospital, national museum, public library, the Niue Hotel and the government-owned housing development Amanau Apartments were completely destroyed [2]. Other parts of the island, where local communities had established themselves several generations back in naturally protected areas and followed low built architecture traditions, experienced less damage. This situation sheds light on the seriousness of the issue of inappropriate planning and building methods and practices, and the importance of privileging traditional knowledge and resilient practices in fragile developing nations as Niue. New Zealand continues to support Niue’s economy, as it has done for several decades, by providing nearly 50% of its GDP through various budget support programmes [2, 3] in addition to economic aid which was estimated at NZS$13.8 million for 2016-2017 [8].

2. Aim and Method

This paper presents the findings of a study carried out with the aim of (a), identifying a sustainable architectural solution to the effects of climate change on Niue, and (b), to increasing the resilience of the Niuean people to the damaging effects of ongoing natural events, and thereby (c), support the economic growth of Niue and reduce future population drain. The study focused on identifying a set of criteria which can be utilised as a guide for developing an ecological, resilient and sustainable architectural response to Niue’s cyclone conditions, which can also contribute to building local capacity, skills and knowledge and thereby improves the economic condition and livelihood opportunities available to local people. The paper begins with a discussion of the key issues affecting the disaster resilience and recovery of communities in Niue. This is followed by key finding from community and site based studies and literature reviews, both historical accounts on Niue and recent studies on post disaster reconstruction in Asia and the Pacific. Finally the paper presents and discusses briefly a case study which applied the key findings to a hypothetical architecture design project and tested their potential to support design outcomes that meet the aims (a), (b) and (c) mentioned above.

3. Issues and Findings

3.1. Problem

The dearth of research on sustainable practices in Niue has negatively affected its development for several decades. Modern development endeavors have been formulated based on individual’s experiences, outdated attitudes and approaches, or the findings of research conducted through Pan-Pasifika or western lenses [3]. The lack of critical assessment of urban renewal and redevelopment projects and their sustainability and resilience to natural hazards, particularly since the 1990’s and following the devastation caused by Cyclone Ofa [3], resulted in widespread damage to these development projects in 2004 following Cyclone Heta [2]. In addition, the unique contextual characteristics of Niue have made it a testing ground for a range of ad-hoc and experimental building projects [2]. However, the lack of evidence-based design and building practices has meant that these
projects too have not been suitable to Niuean culture and context and as such has not benefited the people [2, 3].

The conditions that contributed to this situation is the ongoing and gradual westernisation that has taken place over several decades, through processes of christianisation, European education systems, modernization [3], and since of late globalisations. This has contributed to the undermining of the value of traditional knowledge and practices causing these to be ignored, discarded and eventually forgotten. This situation has also cultivated a preference for imported ideas, practices, materials, technologies and guidelines, most of which are not suited to Niue’s unique local context or living practices, and as they are often applied without adaptation or modification to suit local environmental conditions and culture they fail [3].

Currently Niue imports most, if not all, of its building materials except for the aggregate used in the foundations of buildings, albeit the availability of some materials locally [2, 3]. The damage caused by collapsed buildings and debris in natural hazard conditions have demonstrated the disastrous effects of using heavy and solid materials as concrete or sharp flyaway materials as sheet iron roofing in volatile environments as Niue. What is not readily acknowledged in post disaster analysis is how these imported materials and poor adaptation of non-vernacular construction systems have exacerbated fragile economies, as in Niue, by increasing the damage to lives, property and the natural environment [6].

Sourcing resources locally by growing and manufacturing the materials needed for building projects, devising new vernacular planning and design solutions using local knowledge and skills offers huge advantages both for developing local capacity and improving livelihood opportunities and thereby the country’s economy [2, 3, 6]. Such processes also ensure quicker recovery from disasters and greater resilience both in the short and long term [6]. Additionally, land in Niue is scarce and every effort must be made to explore sustainable and resilient methods for redeveloping sites destroyed by natural hazards and to reduce the damaging effects of natural hazards on living environments, livelihood sources and public infrastructure. Reviewing the issues Niue faces and identifying sustainable methods and practices to replace current practices is urgently needed and vital for improving the resilience of local communities and for ensuring a sustainable future for this small island nation currently under serious threat population drain to New Zealand.

3.2. Lessons

Key findings from community-based research, empirical studies, and interviews conducted in Niue in 2017 and the analysis of post disaster accounts by locals demonstrated the negative consequences of local traditions and practices being replaced by westernised and imported methods and materials, and highlighted the lack of innovative solutions sensitive to the local context. A primary finding from these studies was that the replacing of traditions with modern knowledge and technologies have not necessarily ensured the safety of people and property in disaster situations [2, 3, 6]. The loss of lives in the situation of Cyclone Heta in 2004 was significantly reduced only because people had followed traditional safety practices and taken refuge in caves, amongst the large above ground root networks of well-established banyan trees, locally known as the ‘Ovava’ tree, and in similar natural shelters as their ancestors had done in the past. It is believed by some Niuean elders interviewed that traditional stone buildings with walls of thicknesses of over 1 meter, constructed by Niuean ancestors, and capable of withstanding the forces of natural hazards were demolished early in the 20th century due to westernised mindsets that feared their collapse in cyclones. The buildings that have replaced traditional thatch architectures of Niue and the early stone structures are made of imported concrete and sheet iron, which are neither suited to the tropical heat or the hazardous conditions of Niue [3]. Several such homes in local villages can be seen abandoned and damaged beyond repair after a cyclone.

Although there is no written record of Niuean building traditions and architecture prior to its settlement by missionaries, early European accounts hint at elongated oval forms of thatched structures arranged in community clusters and sitting sheltered amidst groves of tall coconut palms [1, 9]. Following settlement of Niue by Samoan and British missionaries from the London Missionary Society, buildings within the grounds of the mission were constructed in the same traditional
This architecture is given by B.C Thompson who visited the island in 1901, he states that the natives preferring to live in the ‘thatched hovels’ of their ancestors had built traditional homes behind the stiffly arranged row of white washed concrete cottages [9]. Thompson also notes that the new houses stood on the landside of a grassy lawn that extended to the edge of the cliff [9]. From this we can gather that the new houses stood exposed to the natural elements and wind forces, unlike the tree sheltered pre-Christian villages.

From Thompson’s accounts we know that in 1901, 11 traditional villages were positioned around the island, established most likely on the safest sites on the island, and the land granted to the missionaries was separated from these villages and in an area known as Alofi [9]. Alofi, is a coastal stretch to the south of the Tuapa, the village in which the king had resided and here was established a church and houses for the mission [9]. Subsequently Alofi developed into the capital of Niue. Following Cyclone Heta in 2004 Alofi sustained heavy damage and the more exposed south Alofi where most modern public infrastructure and housing had evolved from the foundations established by the missionaries was completely destroyed [10]. Villages located in and around traditional sites sustained only minor damage from the cyclone, perhaps due to the careful positioning of these based on the knowledge of ancestors, who most likely were competent sailors and navigators and understood the natural weather hazards that afflicted the island. Following its 2004 destruction and its history of vulnerability to cyclonic winds, storm surges and high waves Alofi as assessed as a high-risk area, and the Niuean government proposed relocating the capital to the upper plateau around Fonuakula [11].

From these site studies and literature reviews key actions were identified for increasing the resilience of local communities, living environments and recovery after disaster. These are listed below in Table 1.

Table 1. Key Actions informed by site studies and literature reviews.

| 1. Identify, improve and build local capacity |
| 2. Improve and diversify livelihood sources  |
| 3. Safeguard traditions and traditional knowledge |
| 4. Utilise traditional knowledge effectively to improve living environments |
| 4. Develop building technologies to suit local conditions, skills and capacity |
| 5. Adapt modern and proven technologies, methods and systems to local conditions |
| 6. Utilise traditional craft (eg. weaving, lashing) to improve design and construction |
| 7. Grow and source building materials locally |

3.3. Lessons from Asia and the Pacific

To overcome the problems Niue faces it is essential to draws from lessons learnt from the wide range of studies conducted in the Asia Pacific region following recent natural disasters as the 2004 Asian Tsunami, 2008 Wenchuan Earthquake, China, 2008 Cyclone Nargis, Myanmar, 2010 and 2011 Christchurch Earthquakes, New Zealand, 2011 East Japan Earthquake, 2013 Typhoon Haiyan, Philippines, 2016 Cyclone Winston, Fiji, to name a few. The vast body of research that has emerged in recent years related to disaster preparedness, recovery and reconstruction from Asia and the Pacific including World Bank and UN publications provide valuable insight on reconstruction processes including post disaster governance structures and governance issues, funding and donor organisations involvement, disaster preparedness, and methods for building community resilience [3, 6, 11-17]. Research on reconstruction efforts following recent disasters also highlight the issues with top down and bottom up approaches to rebuilding, multiple actor involvement in rebuilding processes ranging from governments to local councils, local and international donors, religious organisations and insurance companies, and the consequences of this on the speed and success of recovery efforts [11-17]. They also highlight the impact of the lack of coordination across various organisations and at
various levels, inequality in the distribution of funds and development benefits, unsuitability of development projects to culture and context and lack of accountability [6, 11-17]. In addition studies also demonstrate how poor and vulnerable communities are disempowered through these development endeavors, the value of being prepared for disaster and having in place well considered disaster risk reduction and recovery strategies as well as rebuilding strategies [6, 11-18]. The Sendai Framework for Disaster Risk Reduction 2015-2030, the outcome of the United Nations World Conference on Disaster Reduction in Sendai in 2015 together with those studies mentioned above reinforces the need to act “with a renewed sense of urgency within the context of sustainable development and poverty eradication, and to integrate, as appropriate, both disaster risk reduction and the building of resilience into policies, plans, programs and budgets at all levels and to consider both within relevant frameworks”[18].

Table 2 lists some key lessons and recommends actions for consideration in Niue when planning for future disaster preparedness and recovery. These are some key points identified for the purpose of devising a sustainable solution for a resilient architecture that could reduce the risk of natural hazards from developing into disasters, prevent loss and injury to life and minimise damage to property and livelihood sources. The aim of the table is to clearly outline the current situation and the actions required to ensure development projects contribute to building the resilience of local people, local economies and local environments.

| Table 2. Key Lessons and Actions for Disaster Resilience Planning in Niue. |
|-----------------|------------------------------------------------------------------------------------------------------------------|
| Lessons         | 1. Funding: high dependence on NZ, international governments, donor organisations and private insurance for recovery after disaster due to the under-development of opportunities for economic growth and food production locally [2-8].
|                 | 2. Relocation: no place to relocate to after a disaster other than to NZ but at severe negative consequence to Niue’s economy and future [2-7,14].
|                 | 3. Top down and westernised approaches: likely to be imposed in situations of external funding through bureaucratic processes, may not align with local aims [3,12,14-17],
|                 | 4. Imported materials, methods and skills; does not build capacity and resilience at local levels [3,7,10,14-17]. |
| Actions         | 1. Local engagement: communities to take ownership of all future development endeavor at various levels and capacities to ensure their suitability and sustainability. 
|                 | 2. Positive contribution: to the local economy, socio-culture and environment must be demonstrated by all proposed development projects.
|                 | 3. Localised knowledge: clear understanding of local environments, capacity, traditions, local resilience structures, suitability of new technology and materials to Niuean culture and context to be demonstrated by all key actors involved in the planning and implementation of development projects.
|                 | 4. Tried, tested and adapted: technologies, methods and materials tried and tested in similar environments conditions and adaptable to suit local conditions to be used. |

4. Case Study
One of the national development goals outlined in Niue’s National Strategic Development Plan is to become self-sustainable and self-reliant [5]. Two main sources of income for Niuean’s outside of government employment or welfare programmes, is from locally owned and operated small scale eco-tourism endeavors and agriculture [3, 7, 10]. Based on this information and the key lessons and actions listed in Table 1 and 2 above, the case study project focused on a speculative architectural proposal for facilitating the strategic economic and social development of local communities through a rural or village-based eco-tourism programme, managed and financially supported by a centrally based vocational training, tourism and cultural complex.
A site in South Alofi, the exposed coastal stretch on which the public center of Niue, destroyed by cyclone Heta in 2004 had once stood, was selected as the testing ground for this speculative resilient and sustainable architecture project. The diversity of the project programme and aims allowed for the design and construction solutions developed to be adapted and tested at various scales. The project intention was to satisfy the three aims of the study, (a), identifying a sustainable architectural solution to the effects of climate change on Niue, (b), to increasing the resilience of the Niuean people to the damaging effects of ongoing natural events, (c). support the economic growth of Niue and reduce future population drain.

4.1. Sustainable site intervention for safety from natural hazards
Detailed site studies revealed the multiple hazards that needed to be considered and potential solutions [10]. From these it was established the safest location for the building complex would be further inland on the site and on higher ground. The gradual rise and depressions on the land would allow the building forms and foundations to wrap around and hug the hard limestone terrain and form protective cave like spaces. Studies on sites prone to similar natural hazards to Niue and precedent design projects from an international context demonstrated the benefits of planting heavily, with native coastal trees and shrubs the most exposed and dangerous parts of the site particularly the flat terrain close to the cliff edge and susceptible to water surges and tsunamis to minimize wave damage [10]. These solutions were found to be feasible alternatives to the building of massive seawalls and engaging in large engineering projects, and better suited to local capacity and context when combined with early warning systems.

4.2. Building form, structural systems and materials for resilience
Achieving resilience to cyclones was the key aim of the building form and structure, inspiration for this was drawn from the structural principles of the native Ovava tree which has evolved an ingenious structural system that has sustained this tree in harsh weather conditions for several decades, and structurally supports its branches as they spread out far and wide. Through process of physical modelling, the capacity of an organically interconnected above and below ground structural system was established. From these studies emerged a built form and construction system suited to the site and context. Bamboo was identified, after study of its versatility, unique qualities and sustainable nature as a suitable material for the structure.

The structural capabilities of bamboo can be maximized by combining multiple reeds and by bending it to create curved forms and round shapes that deflect with cyclonic forces. Traditional tying and lashing techniques were tested for securing these forms and shapes in a manner that allows the building to flex and move within acceptable limits in cyclonic conditions. A large central and several secondary structural cores were designed to act in a manner similar to the central trunk and supportive above ground root networks of the Ovava tree. This system supports the building laterally and vertically when cyclonic forces are applied. A system of raised concrete foundation piles, designed similar to the ground root network of the Ovava tree, protects the bamboo and anchors the sub structure to the ground. Formed as a circular maze these cave like foundations are also a protective vertical barrier to tsunami waves that may reach the building. In addition low entry points with step down entrance spaces, strategically located in response to the terrain and raised foundations, minimizes heavy and turbulent winds from forcing uplift in the curvilinear sub structure. The roof, a diaphragm system inspired by traditional basket weaving techniques, acts like a lattice brace that links and structurally reinforces the whole building to resist lateral loads. Local traditions of thatching and local palm material resources were considered for roof coverings. The proposed building design is adaptable to domestic and public scale buildings and is a structurally safe, sophisticated and aesthetically beautiful response suited to the environment, local culture and local capacity.

5. Discussion
Community resilience is a measure of how effectively a community bounces back after a natural disaster. As such the architectural response focused on not just structural resilience of the built form and reducing damage to lives, property and the environment in a disaster situation but also on how
architecture can contribute to building the economic resilience of the community. With this aim, design concepts, construction methods and material that resonates with traditional knowledge and skills was identified. Bamboo a sustainable building material suited structurally for cyclonic conditions and architecturally for its environmental and aesthetic benefits to Niue was selected. Additionally bamboo is a resilient plant that can be locally cultivated, harvested within a short and treated at village levels cost effectively. Also current familiarity with the material and its wide range of uses beyond construction makes training attractive to local. This increases its viability as a sustainable livelihood source as pioneered by the Green School in Bali [19] and when cultivated locally a readily available environment friendly and versatile resource as evidenced in its use in contemporary architecture in southeast Asia [19, 20, 21].

Integrated into the building design and the landscaping of the complex are methods for renewable energy systems as solar, wind, biogas and biomass, and reliable food cropping systems such as hydroponics, aquaponics and greenhouses, and water collection and treatment. This was done with the intention of not only developing an efficient self-sufficient built complex but also as system to train and upgrade the skills and knowledge of local people to enable transfer and application of these systems at a village and domestic scales. In addition, urban planning and design guidelines for the complex and site were developed to be adapted and applied to similar exposed sites. Through design the aim of having ecologically sensitive and locally accessible solutions that resonate with local knowledge and understandings and increase economic opportunity was achieved. Importantly architectural and planning solutions were developed around the cultural values, knowledge and beliefs of the people, and by utilising the natural environment as design inspiration and a key resource for a sustainable and resilient solution for Niue.

6. Conclusion

This project demonstrates the opportunities that exist locally for devising sustainable solutions to the key issues faced by Niue, primarily lack of resilience to the natural hazards that afflict this island nation. As the paper demonstrates in-depth research is essential for context and culture appropriate solutions and to prevent development projects that are potentially harmful to people and thereby to a fragile economy and resilience of a small island nation. In the last two decades a vast body of research has emerged from the Asia-Pacific region on disaster preparedness, disaster resilience and disaster recovery. These studies provide valuable lessons for Niue and must to be considered when planning for future disasters. In addition the building and material technologies, and methods, that have been developed in Asia and the Pacific in the last decade are proving to be highly advanced, more appropriate to local conditions and significantly different to the western modernisation approaches and methods that have dominated development endeavors in emerging economies up to now [19, 21]. These offer a sustainable way forward for non-western small island nations as Niue. As research has shown the main aim of development agendas for Niue must aim prevent the transplanting of western and unsuitable methods and technologies and instead ensure projects that contribute to the sustainable development of the island and increase the resilience of its people.

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