

The image features two tall palm trees, one on the left and one on the right, with their fronds extending towards the center. In the background, there is a faint, stylized illustration of a tropical beach with waves and a clear sky. The text is centered within this background.

**Adapting South Tarawa
to Climate Change**

Adapting South Tarawa to Climate Change

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Abstract

Addressing climate change is urgent, and architects need a set of skills in order to design structures capable of adapting to it. One way to investigate how architects can design to adapt to climate change this is through design-led research using an extreme case (Kiribati, is one such location) where climate change is affecting the islands in several ways. Within Kiribati is the atoll Tarawa (the capital), where internal migration from outer islands has caused rapid urbanisation.

South Tarawa has a land mass of 16sqkms (Kiribati Census, 2022) and sits low to the sea at 3m being the highest point (Mulhern, 2020), Clearly this point of the atoll is at risk in regard to sea level rise and land erosion is already present. Some land accretion has occurred however in the past few decades (Webb et al., 2010). This, along with climate-induced storm surges and overtopping (when the ocean washes over the entire island) has prompted locals to construct some dwellings elevated from the ground. These dwellings are traditionally constructed from locally grown pandanus and coconut palms, debris washed ashore, and some imported materials such as corrugated iron (Whincup, 2010), however concrete and iron structures are becoming more common.

Many communities Te Moananui Oceania rely on the surrounding ocean to provide much of their resources (Kiddle et al., 2021). Tarawa is one of these, but due to the urbanisation (in South Tarawa) and climate change issues there are significant roll-on effects with waste management, sanitation, migratory patterns of sea creatures as well as coral bleaching and ocean acidification (Johnson et al., 2015). The Kiribati Ministry of Environment, Lands and Agriculture Developments (MELAD) is currently exploring land reclamation options in order to house 30,000 citizens well (Liddell, 2024), but due to the dynamic nature of the atoll (Tuck et al., 2019) and the encroachment and destruction the sea poses, a more resilient, adaptable and climate positive solution should be considered to ensure longevity of the community (culture) and atoll (ecology).

Nature-based solutions (NbS) are actions to address societal challenges through the protection, sustainable management and restoration of ecosystems (ICUN, 2024). This research aims to incorporate carefully selected NbS in an architectural sense that will improve, enhance, or regenerate the climate, ecology and culture while addressing the overarching issues relating to urbanisation in South Tarawa.

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Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor used artificial intelligence tools or generative artificial intelligence tools (unless it is clearly stated, and referenced, along with the purpose of use), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.



18/10/2024

Positionality Statement

I am genuinely concerned about the increasing global human population and its contributions to climate change and the ecology. In order to become a better architect, I am focusing on this extreme example of urbanisation in South Tarawa, where the effects of climate change can already be seen among other ecological and cultural issues.

In an ideal world, a more collaborative approach would be taken to avoid 'outsider perspectives' (Cauchi, 2021) as I am not I-Kiribati, nor do I have any ancestral ties to the country. Ways I have tried to make this ethical are by working closely with the Nature-based Urban design for Wellbeing and Adaptation in Oceania (NUWAO) team who are presently carrying out research in Kiribati and have ethics approval from Victoria University of Wellington. This research will be published at a later date but forms the basis of many of my investigations here. NUWAO aims to develop nature-based urban design solutions, rooted in Indigenous knowledges that support climate change adaptation and individual and community wellbeing in different contexts across Aotearoa and Oceania. It is a research project funded by the Royal Society of New Zealand under the Marsden Project fund. More about NUWAO is here: www.nuwao.org.nz

With limited architectural education opportunities available in the Pacific islands, I feel somewhat obligated with the education I have had access to in Aotearoa New Zealand, especially within the School of Future Environments at AUT where I have been immersed and inspired by many different architectural interventions on varying scales that relate to Oceania. With the limited architectural knowledge I now possess, I want to be able to utilise it, especially in places that would highly benefit from it, in an ethical way.

I am motivated by the knowledge that there is no 'Planet B' which drives me to investigate how architecture may be capable of conserving or regenerating our planet, particularly through the use of NbS. I believe that architecture can aid with ways in which humans, and more than humans, can live in harmony and support each other to create equitable and thriving interconnected socio-ecosystem.

Acknowledgements

Firstly, my supervisors, Dr Maibritt Pedersen Zari and Sibyl Bloomfield. Thank you for all your support, guidance, knowledge wisdom and general “just do it” vibes. I am truly grateful to have had both of your support.

To my parents, who not only sheltered me but also pushed for me to go back to university, “why not?”. Thank you for housing me, feeding me and babysitting. I am eternally grateful for you both.

My little sister who continuously provides me with optimism, positivity and a space to vent and relax, thank you for all you do for me.

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My aunty Hannah, who also provided the “why not” go back to university attitude. Thank you for your support and for proofreading this thesis.

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Lastly, to Castiel, without you I don’t know where I would be or what my life would look like. You gave me the nudge I needed to pursue my passion for architecture. I will forever be grateful for you my child.

Chapter 1

Introduction

Why is this research necessary?

South Tarawa is becoming one of the most densely populated areas in Oceania; in contrast it is one of the lowest carbon emission contributors, yet they are one of the most affected peoples of climate change (Mitchell, 2017). Kiribati's major income comes from fishing licenses and the exportation of copra from the coconut palm (World Bank, 2011). Frequent El Niño and La Niña events pose issues to the fishing trade and sea inundation is a contributor towards the decrease in copra exports and other vegetation (Evers, 2023).



Introduction

Why is this research necessary?

What is the issue?

Due to climate-induced issues such as sea level rise and other ecological and cultural matters South Tarawa is faced with several further ripple effects, like high density and urbanisation of South Tarawa and access to clean water and fresh healthy food. The location of Tarawa, limited land and job opportunities (due to increasing population levels) and climatic conditions are contributors towards Kiribati being one of the poorer countries in Te Moananui Oceania (World Bank 2011). With rising sea levels, and the low-lying nature of the atoll, the land is at risk of disappearing. The atoll provides food, fresh water and shelter among other ecosystem services, including the traditional community meeting house (Mwaneaba). The culture, social justice and economic issues related to relocation (or 'managed retreat') mean people are seeking to stay in South Tarawa so architectural responses are needed.



Introduction

Why is this research necessary?

Why is it important?

Because South Tarawa is the urban part of Kiribati, some locals are reliant upon imports for sustenance rather than traditional practices. Food, water, and energy security are issues, as is human and solid waste management. Displacement, disconnectedness, isolation, reliance, and unsustainability are all words that could be related to South Tarawa if it were to be lost to the sea and the community were forced to relocate. My favourite quote since beginning this research is from Karen Zhang “when ethnic groups are disbanded and displaced, their culture, including languages, is susceptible to assimilation with new culture or being gradually lost over generations” (2011).



Introduction

Why is this research necessary?

How can architecture address this issue?

Investigating how architecture can improve and maintain sovereignty in an increasingly urban environment, where resources are limited, and climate-induced sea level rise are imminent is important so that architects can become useful as responses to climate change become urgent. Kiribati is an extreme case, but these same issues will be faced by other communities in the future as climate change progresses. To investigate appropriate architectural strategies that respond to climate change, this research takes a materials radius system approach, relies on previously collected data, prioritises cultural understanding and working with nature.

Exploring and analysing suitable NBS, climate adaptations and other climate responses where climate, ecology and culture are either minimally or positively impacted is key. Applying these techniques in design work that accommodates and meets the needs of the community while also producing positive impacts on the climate, ecology and culture guides the research.

Introduction

Research Question

The aims for this thesis are to explore, design, prompt further exploration of, and illustrate how nature-based solutions can enhance the climate, ecology and cultural wellbeing of South Tarawa, Kiribati.

The central research question is: How can urban nature-based solutions and climate adaptation in the context of architectural design, enhance resilience, ecology and human wellbeing in South Tarawa, Kiribati?

The research aims are focused on devising architecture that:

1. Increases food security by:
 - Providing alternative cultivation techniques that will be adaptable to climatic conditions.
 - Providing spaces for healthy food growing education and training, to ensure the knowledge is open and shared, therefore empowering the community.
 -
2. Increases water security by:
 - Incorporating water harvesting systems and water recycling systems which are beneficial to humans and the environment.
3. Reduces waste by:
 - Minimizing or repurposing waste and the effects of it on the community, ecology and climate.
4. Reduces overcrowding by:
 - Designing generous spaces for all living things to promote healthy living environments and enhance wellbeing.

Bearing in mind the highly dynamic and already resilient nature of the atoll and the community, the goal of this research is to show how NbS can improve and enhance upon that and therefore aid with climatic, ecological and societal issues that align with the lifestyle and values of I-Kiribati people.

Chapter 2

Research Methodology Introduction

The design methodology carried out throughout this thesis is derived from Alice Crady's Researchers Process Model (2018), who has taken inspiration from the Hasso Plattner Institute of Design at Stanford's design thinking model (d.school, 2024) and the Neilson Norman Group's Design Thinking 101 framework (Gibbons, 2016).

The methodologies in brief have five of six stages: **Empathise** is understanding the user of which the design will be meant for. **Defining** what the main problem is for the gathered information. Generating many alternative ideas is the **ideate** stage. Creating **prototypes** of the designs to understand the design and not where flaws may be. **Testing** the design involves getting the users feedback but, in this case, heavy evaluations and analysis against all of the collected information will be undertaken. Design Thinking 101 has a sixth stage which is self-explanatory, **implementation**.

This is a design-led research thesis and although the two methodologies mentioned are not, the same principles apply. Design takes place throughout the entirety of this research and evolves as new information is gathered.



Research Methodology

Research Design

The methodology follows a design principle where some steps may overlap, such as ideate and define, where the brainstormed ideas may alter depending on the relative data acquired. The same relates to the development design phase where previous conceptual ideas may prove to be more significant than recognised. The ideate phase is an overlapping phase as design begins with one or several ideas and does not stop occurring throughout; in this thesis ideas may continue to flow long after the conclusion of the research. The steps are as follows:

Empathise:

Gathering relative and reliable data for the site to obtain context, restrictions, and understanding of the environment and the community will provide insight and direction through the design process. Collecting case studies to further the guidance of design through comparison is important.

Define:

Analysing and presenting the data found in an effective and clear manner, where the data then shows themes or ongoing issues which then inform the deliverables/framework and aims of the project moving forward. These aims may alter throughout the conceptual stage depending on the driving principles, and design reflections and reviews.

Ideate:

Brainstorming and conceptualising many architectural ideas relating to the aims and objectives while continually reflecting/critiquing against relative outcomes. Several imperfect designs may be formed but could have the potential for development where the idea behind the design sets the base/foundation for a better solution.

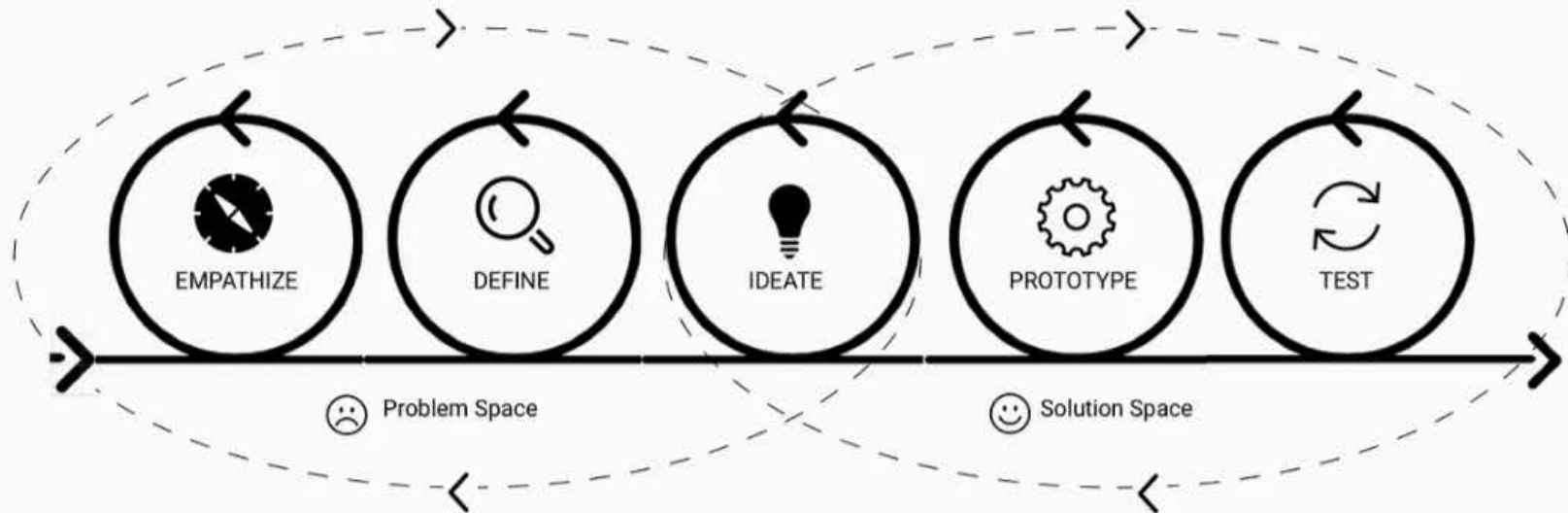
Prototype:

Sketching, modelling, locating and analysing developing concepts (against the aims and objectives) to address strengths and weaknesses with design construction, layout, materiality or practicality for the intended site and users. Where any of the subject areas deemed flawed or weak, they can then be rectified in design development or with further prototyping.

Develop:

Continuation of one developed conceptual design where a final design aligns with the aims, objectives and theoretical framework (following chapter). A final analysis and critique of the design and conclusion is undertaken where further exploration of design work or ideas may emerge. Therefore, building upon the research question: How can urban nature-based solutions and climate adaptation in the context or architectural design, enhance resilience, ecology and human wellbeing in South Tarawa, Kiribati?

Design Researcher Model



METHODS	<ul style="list-style-type: none"> • Ethnography • Field Studies • 1:1 Interviews • SME Interviews • Diary Studies • Surveys • (Qualitative, Quantitative) 	<ul style="list-style-type: none"> • Competitive Analysis • Comparative Analysis • Card Sort Studies • Task Analysis • Journey Mapping • Empathy Maps • Job Stories 	<ul style="list-style-type: none"> • Design Thinking • Design Principles • Crazy 8's • Design Sprints • User Stories 	<ul style="list-style-type: none"> • Sketch • InVision • Wireframing • Lo-Fidelity • Hi-Fidelity 	<ul style="list-style-type: none"> • Usability Testing • (Qualitative, Quantitative) • Heuristic Evaluation • Desirability Studies • A/B, MVT Testing • Eye Tracking • Click Tests • Tree Testing
ACTIVITIES	<ul style="list-style-type: none"> • Find Allies • Talk with Experts • Use Good Ethics • Find Data Sources • Choose UX Metrics • Involve Stakeholders 	<ul style="list-style-type: none"> • Identify Themes • Prioritize Insights • Create Deliverables • Present Findings • Prioritize User and Business Needs 	<ul style="list-style-type: none"> • Map Features to Needs • Facilitate Brainstorming • Generate Micro and Macro Ideas • Keep User in Focus 	<ul style="list-style-type: none"> • Design for Universal Access • Provide Clear Insights & Statistics • Serve as User Advocate 	<ul style="list-style-type: none"> • Create Participant Screening Q's • Refine Task Scenarios • Monitor Success Metrics • Create Testing Plans

Figure 2 Alice Crady Design Research Model (Crady, 2018)

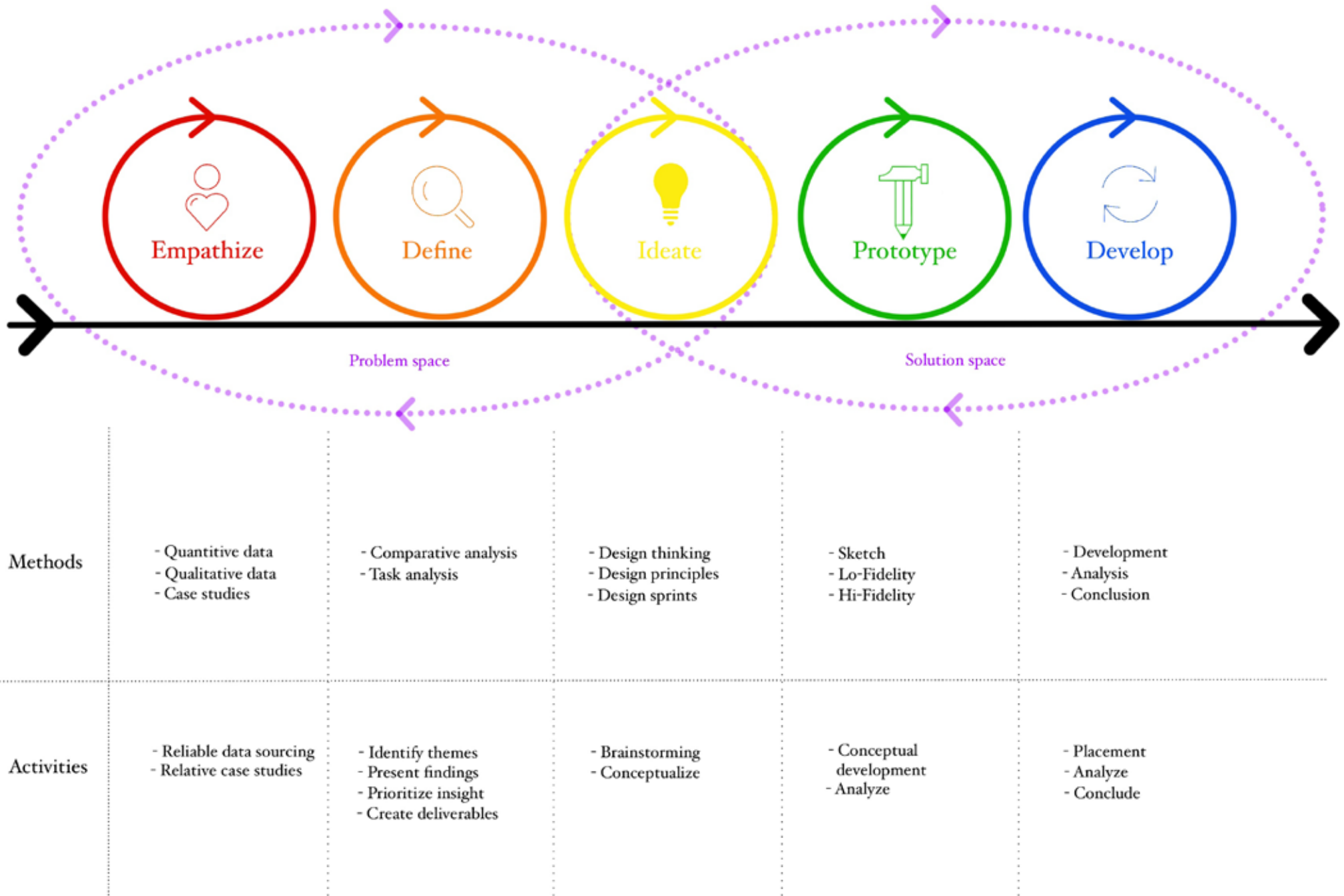


Figure 3 Authors Methodology Diagram adapted from Alice Crady's (2024)

Chapter 3

Literature Review Introduction

The following chapter contains a literature review where similar research shows the need for accommodation/housing, food and water security, and climate adaptation and how this is being carried out. Unresolved issues and limitations of any of the ideas posed and why they are or would be in this research paper are also included. Further justification for this research is then stated.

From the literature review along with the site analysis comes a theoretical framework where climate ecology and culture are the focal points.

Precedent studies are the evaluated against the theoretical framework, where they align with some or all of it. Analysis and conclusions are made which highlight the key elements that will be considered or included in future design work.

Literature Review

The increasing urbanisation, climate change and the societal issues of South Tarawa will be at the heart of this research, where the wider issues of each will be explored and analysed to gain a better understanding of the site in order to propose viable and resilient adaptation response/s.

Studies on population growth in other countries state that “the single-family home...is no longer meeting the needs of our changing population” (Niederhaus et al., 2013). This is said to be true in many of the Pacific Island nations where multigenerational living is common practice, yet the traditional living arrangements are not able to withstand the current conditions of the changing climate. For example, frequent storm surges and overtopping (where the ocean washes over the land in storms or high tides) negatively impact many components of a residential unit. These conditions alongside the lack of access to clean fresh water, sanitary solid and human waste management systems, and lack of fresh produce contribute to an increase of diseases and sickness such as diabetes, high blood pressure and heart and lung disease (Kim, 2024).

Considerable attention needs to be given to sea level rise as projections that are likely to be very conservative, show an increase between 275mm and 738mm by the year 2100 (Church et al., 2013). Low lying islands such as Tarawa Atoll are particularly susceptible to storm surges, coastal erosion and frequent ‘overtopping’ (Espejo, 2023).

Particular attention needs to be paid to the cultural values of the Indigenous people (I-Kiribati) of Kiribati. Insight from ongoing NUWAO research shows the lifestyle and general requirements are far different than that of other places such as Aotearoa New Zealand. Eating times revolve around when the fisherman come in, rain is treasured, the breeze is highly valued, and residential living arrangements are not determined by thick separating walls.



Figure 4 Uro's Floating Islands (Wikimedia Commons, 2024)

Literature Review - *continued*

An article has been published (Sustainable artificial island concept for the Republic of Kiribati, Lister, et al., 2015) which outlines some of the major issues that are associated with South Tarawa. An artificial island is proposed, where it is said that gradual relocation of the population would take place while having minimal impacts to daily activities (Lister, et al., 2015), however the materiality and cost of building such a structure is costly and may not be culturally appropriate. A more localised approach may prove to be more suited much like the Uro's floating islands of Lake Titicaca, which are constructed from locally harvested totora reeds and roots (Montali, 2022) which the local community cultivates and constructs themselves. Ongoing projects such as the Kiribati Organic Producers (Cantieri, 2014), Kiribati Agriculture Strategy, (MEDLAD, 2022), Pacific Soils Project (CISRO, n.d.), The South Tarawa Water Supply Project (Ministry of Infrastructure and Sustainable Energy, 2019)) and others are committed to improving the health and resilience of the atoll.

Relocating the population is a thought the (previous) Kiribati government has had. They have even purchased land in Fiji as a last resort but have since concluded that that land will be used for agriculture to cultivate nutritious food for Kiribati citizens (Pala, 2021). Other members of the community have faith that if they support the environment, it will continue to support them (Bloomfield, n.d.).

This information shows the government, citizens, and outsiders that the people of Kiribati are tied to their land and have no intentions of leaving it anytime soon, which is counter to the previously perpetuated image of Kiribati as a victim of climate change, or a kind of human equivalent of a polar bear (Wiig et al., 2008). Recent years have sifted this dialogue to one of resilience and determination to stay. Latai-Niusulu (2019) discusses notions of reliance in Oceania as a justice issue.

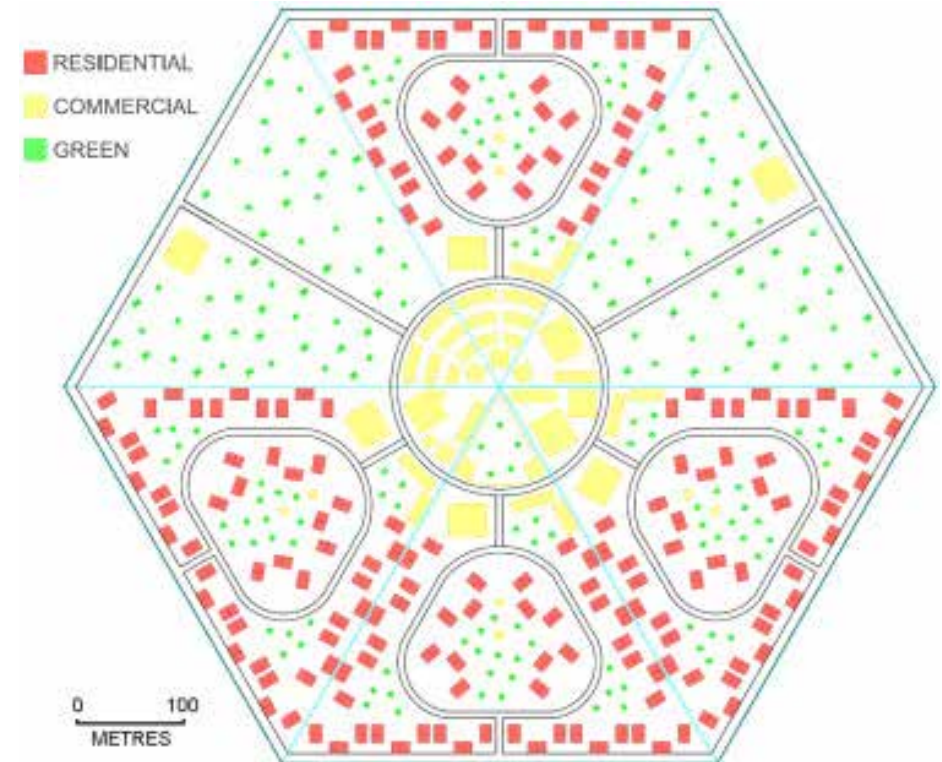


Figure 5 Artificial island concept (Lister, Net al., 2015)

Literature Review - *continued*

Within the atoll and much of the rest of Oceania, there are other general issues, such as tensions between the demands of urbanised societies and traditional values, customs and rights of subsistence communities, land tenure and its attendant customary rights and genuine community participation in debate and decision making (White et al., 2004). Land tenure is something which is typically passed down generationally; this has caused some discrepancies with some projects (specifically water reserves), where private landowners feel they are not compensated fairly (White et al., 2004).

A paper published by the Australian Agency for International Development (AusAID) implies that the Kiribati government needs to establish more formal social protection mechanisms to support the most vulnerable (Kidd et al., 2012). It dives into the traditional ways the I-Kiribati support system worked with kainga (extended family) and how it has become uncommon, and which may be problematic to the nation both economically and socially.

South Tarawa faces several 'wicked problems' meaning social or cultural problems that are difficult or impossible to solve because of their complex and interconnected nature (Wong, 2023). Significant intersecting problems include the population density, food, energy and water security, waste management, and sea level rise along with other climate induced issues. Attention is being given to population growth, urbanisation in South Tarawa, food production and water supply, but it appears that little thought is being given to the imminent issue of the rising sea. There are also limitations to sustainable materials, education, and training, which could be improved upon through education, knowledge sharing, and upskilling where more modern technologies are incorporated.

The opportunity for alternative solutions such as NbS, could prove to be optimal for Tarawa, with research showing that there are adaptation strategies and techniques that would be suitable (Pedersen Zari et al., 2019) for the Atoll. Further research to include the climate, ecology and culture might produce more useful results in terms of community engagement, acceptance and resilience while also promoting ecological resilience and cultural appropriateness. Therefore, this research focuses on, improving and/or regenerating the environment, and enhancing the wellbeing of the community by illustrating a potential future for Kiribati where it become more self-sufficient and less reliant on imports or international support while maintaining a sense of sovereignty in the face of climate change impacts.

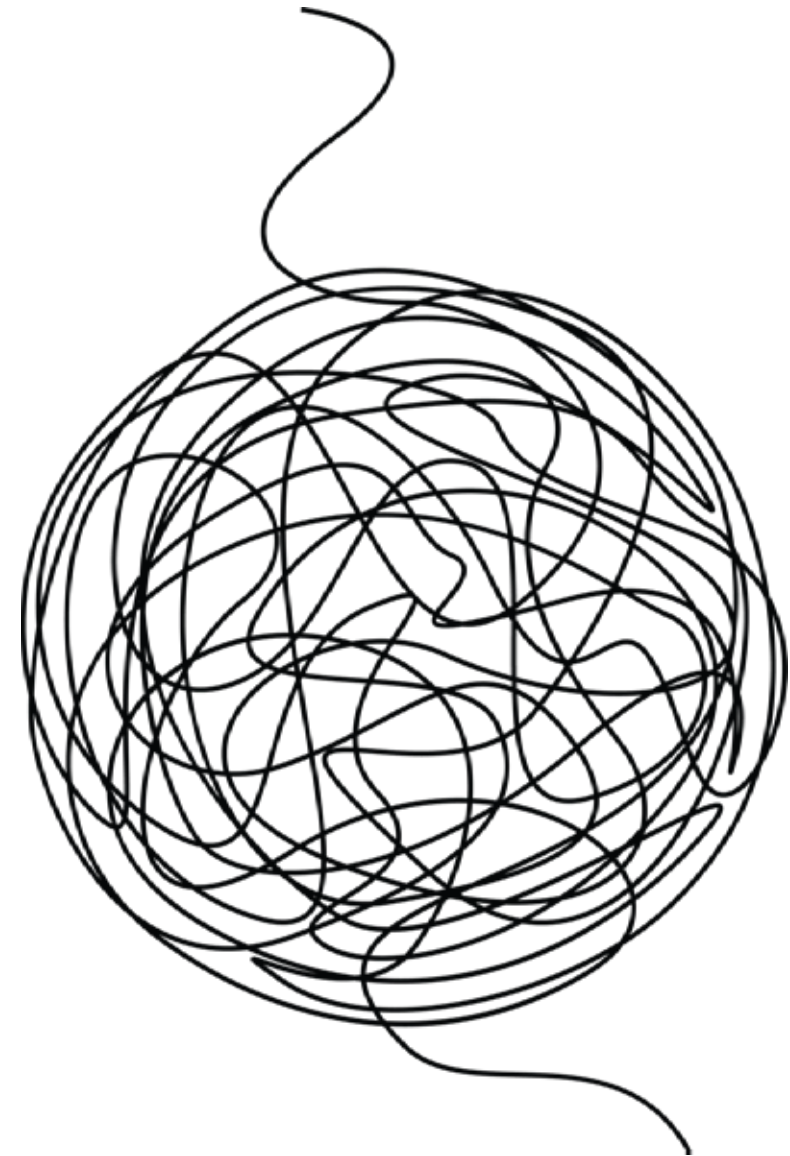


Figure 6 Wicked Problem visualisation (Thurlow, n.d.)

Literature Review Theoretical Framework

This framework revolves around the three axes of enquiry: Climate, Ecology and Culture.

Understanding and considering these three topics along with the aims and objectives, the architectural design outcomes should align with this framework in order to answer the research question: **How can urban nature-based solutions and climate adaptation in the context of architectural design, enhance resilience, ecology and human wellbeing in South Tarawa, Kiribati?**

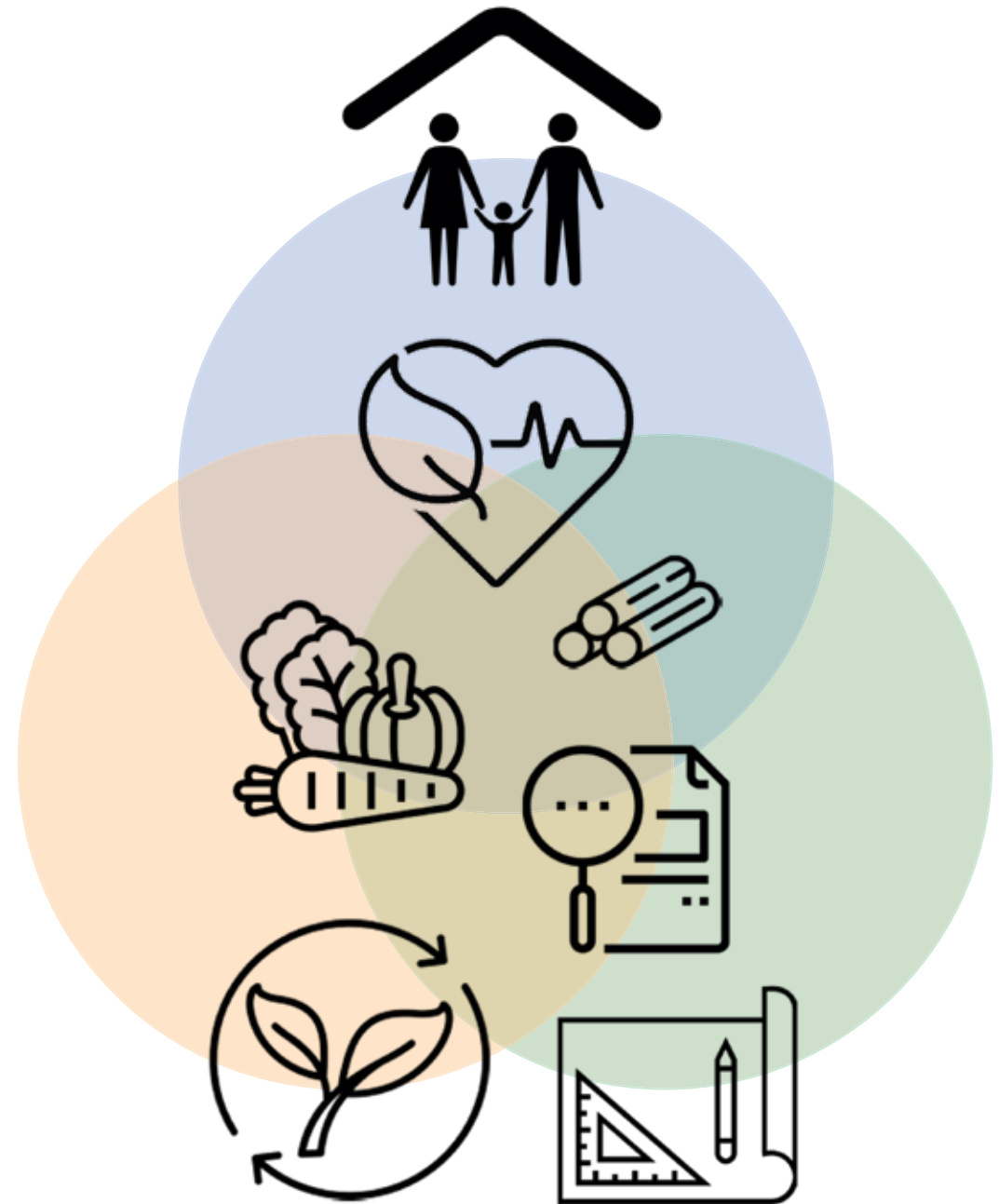


Figure 7 Authors representational diagram of Theoretical Framework (2024)

Literature Review Theoretical Framework

Climate

The unique climatic conditions of the atoll as a whole, show how dynamic it is therefore the architectural intervention should:

- Incorporate local materials where possible and community knowledge or opportunities for education or training
- Show practical climate adaptation response/s in particular to rising sea levels
- Show positive impacts on the environment

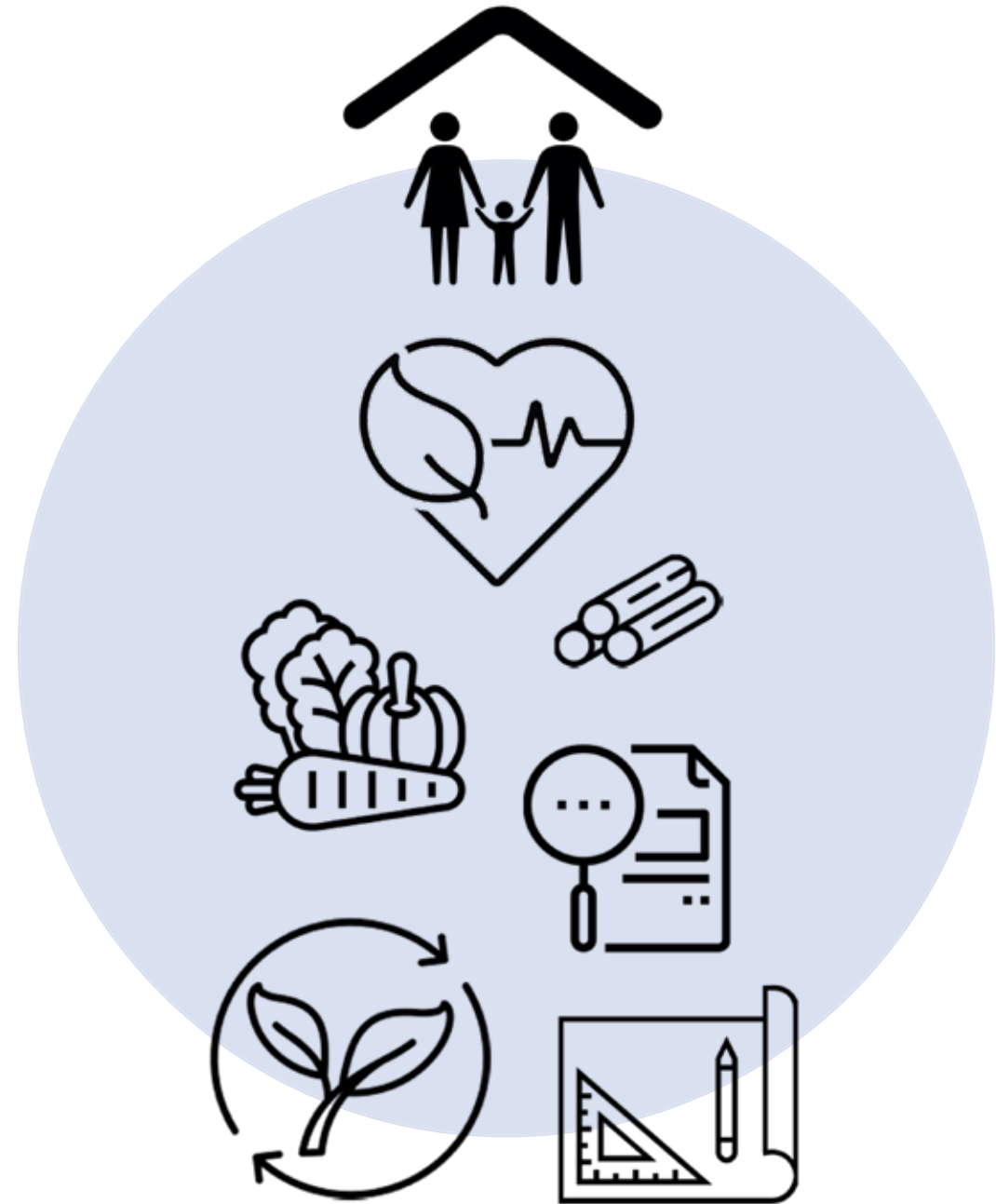


Figure 7 Authors representational diagram of Theoretical Framework (2024)

Literature Review Theoretical Framework

Ecology

Nature-based Solutions show a way in which humans can work with nature to provide equality and wellbeing to both hence the following points should be included in designs where applicable to architectural intervention or as an additional benefit.

- Incorporate NbS suitable to the site to show climate adaptation possibilities
- Show minimal or positive impacts to the ecology
- Show the interconnection between humans and ecologies?



Figure 7 Authors representational diagram of Theoretical Framework (2024)

Literature Review Theoretical Framework

Culture

Culture and local wellbeing paradigms differ to ones of the 'Western' world and should be carefully considered in order to be accepted by locals, and therefore be long lasting and appropriate to place. Ideally interventions and designs are driven by locals, or at least are understood through thorough participatory design methods. This is beyond the scope of the thesis format and timeline, but by considering the following points, a design would be more likely to achieve local acceptance.

- Show understanding of local lifestyles, needs and living conditions/ arrangements
- Support the cultural values of the community
- Show how it can empower the community



Figure 7 Authors representational diagram of Theoretical Framework (2024)

Precedent Studies

Introduction

The following case studies have been selected and analysed in relation to the three topics, Climate, Ecology and Culture. The case studies are relevant to one or all of the topics. They must support the community and show sustainability in some sense (ecological, or economical for example).

Assessments are made against the theoretical framework described in the previous section which provides insight, inspiration and/or implementation of some of the technologies or systems in place throughout the precedents.

The theoretical framework acts as a guide for architectural interventions in South Tarawa. By assessing the following case studies against this, I able to determine if the structures as a whole or parts of them would be a plausible for locating in South Tarawa. By deciphering which parts of the precedents would be most suitable for South Tarawa against the theoretical framework and if these parts align with the aims and objectives I can then implement or enhance upon these to better suit South Tarawa.

Precedent Studies

Homeground, Auckland

Stevens Lawson Architects
Auckland City Mission
Ngāti Whātua Ōrākei

Introduction

Homeground, established in 2022, provides vulnerable people of Auckland, New Zealand sanctuary from the environmental elements as well as other necessary support services for example addiction support. This building, designed by Stevens Lawson Architects with collaboration from the City Mission and mana whenua, is a community hub where services extend to communal dining rooms, community activities, a health centre with pharmacy and varying accommodation arrangements. The roof collects rainwater, which is then dispersed throughout the rooftop community garden. Passive design techniques are also incorporated throughout the building to allow for natural heating and ventilation to occur (Stevens Lawson, n.d.).



Figure 8 Homeground (Stevens Lawsons Architects, n.d.)

Precedent Studies

Homeground, Auckland

Climate

Local materials are used (Stevens Lawson, n.d.) throughout the structure, with some being prefabricated. This demonstrates positive impacts to the environment. The building underwent a lifecycle assessment where the total embodied carbon footprint equated to 129 kgCO₂e/m² (Stevens Lawson, n.d.). While the building process documentation does not mention training or education, the facilities do provide space for learning and growth of both Indigenous and new knowledge (Auckland City Mission, n.d.).



Figure 9 Exterior view of Homeground from Federal street (Smith, n.d.)

Precedent Studies

Homeground, Auckland

Ecology

There are some NbS incorporated throughout the building including rooftop gardens, rainwater harvesting and vertical gardens (Auckland City Mission, n.d.), which show the first steps towards climate adaptation. The location of the building is far from the predicted sea level rise of either of the RCPs, 2.6 and 8.5 (Church et al., 2013). The connection of nature and ecology is not strong but there is use of natural materials with earthy natural tones and artwork on several floors that show underlying influences and concepts of the natural world (Stevens Lawson, n.d.).



Figure 10 Homeground's rooftop gardens (Smith, 2023)

Precedent Studies

Homeground, Auckland

Culture

Having different people/occupants with different social skills and general requirements meant the design must support these various dynamics and social factors. It does so in a safe and comfortable manner with spatial legibility. Providing the occupants with appropriate support and services, including a Te Manawa Ora and a Whānau room, shows the cultural understanding inherent in the design of these spaces. The activities, living arrangements, services and location all aim to empower the individual reflecting the intended purpose of the building, which is not only to accommodate but also to heal and therefore empower its inhabitants.



Figure 11 Artwork on an accommodation floor (Smith, 2022)

Precedent Studies

Homeground, Auckland

Conclusion

There are many climatic, ecological and cultural benefits of Homeground. These benefits are, embodied carbon (climatic), the location and materiality (ecological), and the significant amount of cultural thought, inclusion, and participation. This structure serves as a wonderful example of how all three topics are considered and engaged throughout the building.

If a similar project were to be implemented in South Tarawa, the climatic conditions would be vastly different, where a far more open plan would need to be in effect to allow for maximum airflow. Rainwater harvesting and private and community gardens are already in place on Tarawa but design of additional systems would also need careful consideration given the climatic conditions. A structure like this may be useful in addressing the issue of sea level rise in South Tarawa if it were to be positioned atop pillars or a series of columns where the structure would be away from the sea's encroachment. The cultural connection would be vastly different as the local i-Kiribati have different values, customs, and lifestyles than Aotearoa New Zealand, therefore the Te-Aranga Principles applied throughout Homeground's design would not be culturally appropriate in Kiribati and would need adjusting.

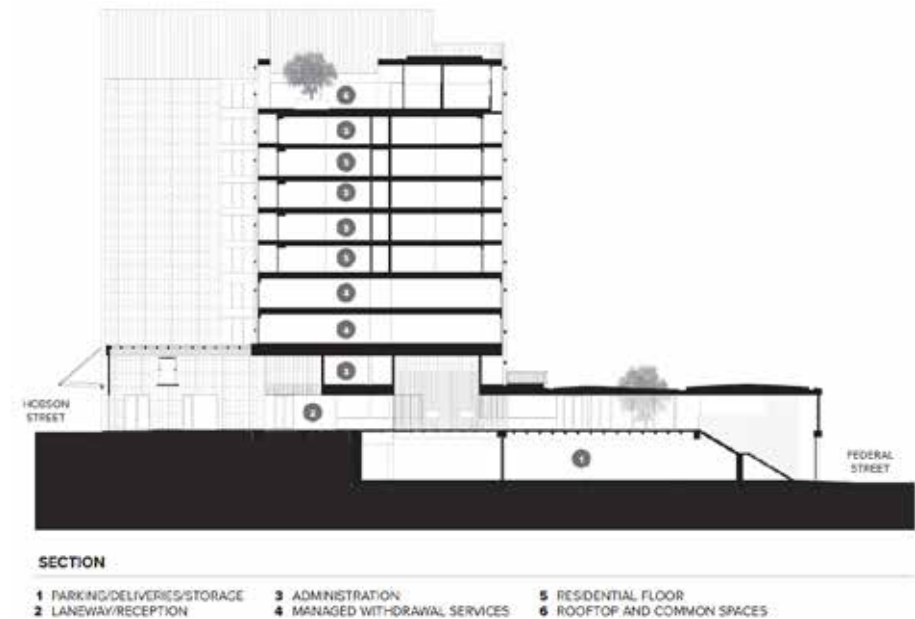


Figure 12 Section of Homeground from Hobson Street to Federal Street (Smith,2022)

Precedent Studies

Schoonschip, Johan van Hasseltkanaal, Amsterdam

Climate

The creators wished to use the most sustainable materials but due to the timing, affordability, location, and environmental impacts some selected materials are not the most sustainable. Concrete, for example has a high embodied energy and associated carbon emissions, however the concrete used throughout this project is recycled therefore, lessening the carbon emissions (Schoonschip Amsterdam, n.d.). The buildings are able to float with the changing tides and therefore, the community has the capability to adapt to the changing sea levels. The environmental impacts are minimal due to the materiality and the location of the structures that are not land based or secured to the canal floor



Figure 14 Floating houses (Nabuurs, n.d.)

Precedent Studies

Schoonschip, Johan van Hasseltkanaal, Amsterdam

Ecology

Multiple NbS exist within this community, including rainwater harvesting, floating gardens and water bound nets where flora and fauna are able to latch on. These elements show positive steps towards climate adaptation as well as the generation of positive ecological impacts (Schoonschip Amsterdam, n.d.). The Schoonschip community believes that “nature will find a way if we create the proper conditions” (Schoonschip, n.d.). The community has hopes to revitalise the ecology of the canal through wet-dry banks with textured edging where bird breeding or nesting could take place, and where micro-organisms could be able to latch on. This could create a food chain effect where other creatures will congregate.



Figure 15 Wet – dry banks(Energies Community Hub, n.d.)

Precedent Studies

Schoonschip, Johan van Hasseltkanaal, Amsterdam

Culture

Each of the forty-six housing units were designed by the future residents in collaboration with an architect of their choosing. This act of freedom gave the occupants the ability to choose what they desired or needed which has resulted in a unique and aesthetically creative neighbourhood. The community has in place a corporation, participant agreement and Schoonschip agreement where meetings and signatures are required to allow for expression of interest or problems. These acts not only support the residents, but they also empower the community and members.



Figure 16 Happy residents (Space&Matter, n.d.)

Precedent Studies

Dancing Rabbit Ecovillage, Missouri, USA

Members

Introduction

The Dancing Rabbit was established in the early 1990's by a group of friends who eventually settled on land in Missouri, USA, where they lead a sustainable lifestyle through community driven initiatives. To be a member of this community there are six ecological covenants to abide by and a set of sustainability guidelines. Some of these are: lumber used for construction at Dancing Rabbit shall be either reused/reclaimed, locally harvested, or certified as sustainably harvested (ecological covenant), and try to understand and minimise the lumbers negative impact on global ecological systems (sustainability guideline). There are others that include avoiding exploiting people and cultures and striving to achieve negative population growth through conscious reproduction (Dancing Rabbit, 2024).



Figure 18 Dancing Rabbit Ecovillage residence (Dancing Rabbit Ecovillage n.d.)

Precedent Studies

Dancing Rabbit Ecovillage, Missouri, USA

Climate

With local materiality being a part of the ecological covenants, the community of Dancing Rabbit understands and promotes materials education via workshops and community engagement. The location of this community is far from the sea (it is 1,119.40 km to Lake Pontchartrain in Louisiana (Google maps, 2024)) and therefore the rise in sea levels will have minimal impact upon it in this lifetime. The Dancing Rabbit's sustainability guidelines suggest the need to end reliance on fossil fuels (Dancing Rabbit, 2024), which shows that they are committed to not only leading sustainable lives but improving (and educating others on) the positive environmental impacts of their lifestyle.



Figure 19 Dancing Rabbit household (Dancing Rabbit Ecovillage, n.d.)

Precedent Studies

Dancing Rabbit Ecovillage, Missouri, USA

Ecology

By employing living roofs and renewable energy sources as well as rainwater collection and biodiversity restoration, the Dancing Rabbit community includes many NBS which helps a variety of things, such as extra insulation, water for gardens, and wildlife revitalisation. Most of the procedures and systems in place have a positive impact on the local ecology because the community believes in constructing shelters that integrate into the environment (or ecology) and minimise ecological impacts. The ethos is that as the community relies on the land to provide for them for example wood, the people have to maintain the land and keep it healthy



Figure 20 Dancing Rabbit Gardens (Dancing Rabbit Ecovillage n.d.)

Precedent Studies

Dancing Rabbit Ecovillage, Missouri, USA

Culture

Dancing Rabbit hopes to create its own culture based on “sustainability, cooperation, openness, and support.” (Dancing Rabbit, 2024). The members are aware that their community is a lifestyle far different from the norm. They describe themselves as open meaning they do not isolate themselves from the rest of the world and enjoy sharing their ideas and they “appreciate that we are people of different backgrounds, lifestyles, ages, and world-views” (Dancing Rabbit, 2024). This is illustrated throughout the community where alternative housing arrangements and materials are used, as well as allocation of varying jobs and roles within the community. As the entire overarching idea of the Dancing Rabbit community is about sustainability, the methods being carried by the inhabitants shows a means of generating community empowerment through these.



Figure 21 Dancing Rabbit garden preparations (Dancing Rabbit Ecovillage n.d.)

Precedent Studies

Dancing Rabbit Ecovillage, Missouri, USA

Conclusion

Self-sufficiency, recycling and repurposing are significant throughout the Dancing Rabbit community. This is similar to the Atoll of Tarawa where they were traditionally reliant on the land and resources available to them. The community of Tarawa recycles and repurposes materials for other uses, such as plastic items for dance costumes (Whincup, 2005). However, Dancing Rabbit is far from the ocean and has fertile soil and land available for sufficient amounts of crops to grow. This is different to the Tarawa context. The ideas behind workshops and materials recycling are the standout components that could be carried through this research design work.



Figure 22 Dancing Rabbit Hobbit house (Dancing Rabbit Ecovillage n.d.)

Precedent Studies

The ParkRoyal Collection

Marina Bay, Singapore

John Portman & Associates DP Architects Pte Ltd
retrofitted by WOHA

Introduction

Originally designed by John Portman in 1987 (Ho, 2023), The Parkroyal Collection has since undergone an extensive retrofit, completed in 2013 and designed by WOHA architects. The building has two main functions: a hotel and the Attorney General's Chambers office (Chan, 2014).

The hotel boasts one of the CBD's largest urban farms with two food digesters which turn food into compost, 210 solar photovoltaic cells (Beasley, 2023), and a rainwater harvesting system that captures and retains enough water for the water features and all the landscaping and green walls (Chan, 2014). The gardens collectively cover over 200% of the total original footprint land area (Chan, 2014). The sky gardens allow for partial shading (Chan, 2014), and the large atrium allows for natural ventilation throughout the building, including open corridors. These are some of the contributing factors as to why the building has won four sustainability awards (Beasley, 2023).



Figure 23 ParkRoyal on Pickering (ACME, 2024)

Precedent Studies

The ParkRoyal Collection

Marina Bay, Singapore

Climate

By retrofitting rather than demolishing, approximately 51,300 tonnes of carbon dioxide was prevented from being released into the atmosphere (Pan Pacific Hotels Group, 2024). The source of materials is not documented or easily obtainable, but they are mostly either concrete, steel or timber. In some parts of the structure there may be a mix or composite of any or all three (Council on Tall Buildings and Urban Habitat, 2024). The building sits at 10 metres above the Singapore river level (TopoExport, 2024) and measures around 200 metres away from it (Google maps, 2024). These topographies may be factors in the elevation of the main structure, but no information found supports this theory. With such an array of plants which act as purifiers, the internal air quality is said to be improved, and the solar photovoltaic cells also prevent 148 tonnes of additional energy related carbon emissions from reaching the atmosphere annually (Sustainably Yours, 2024)..

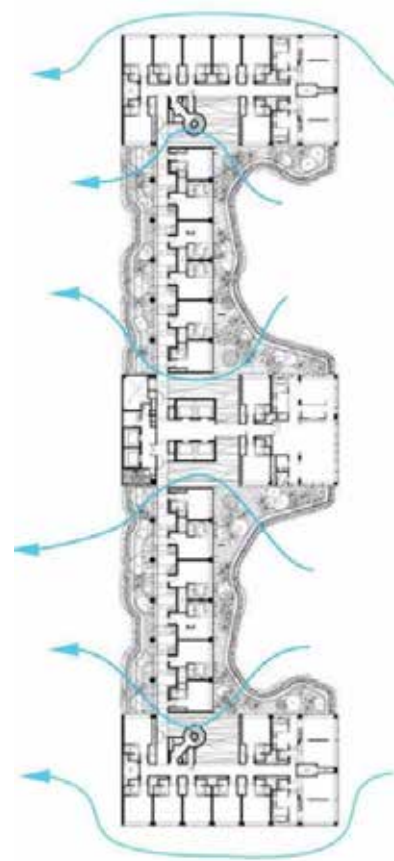


Figure 24 Plan showing airflow (Chan, 2024)

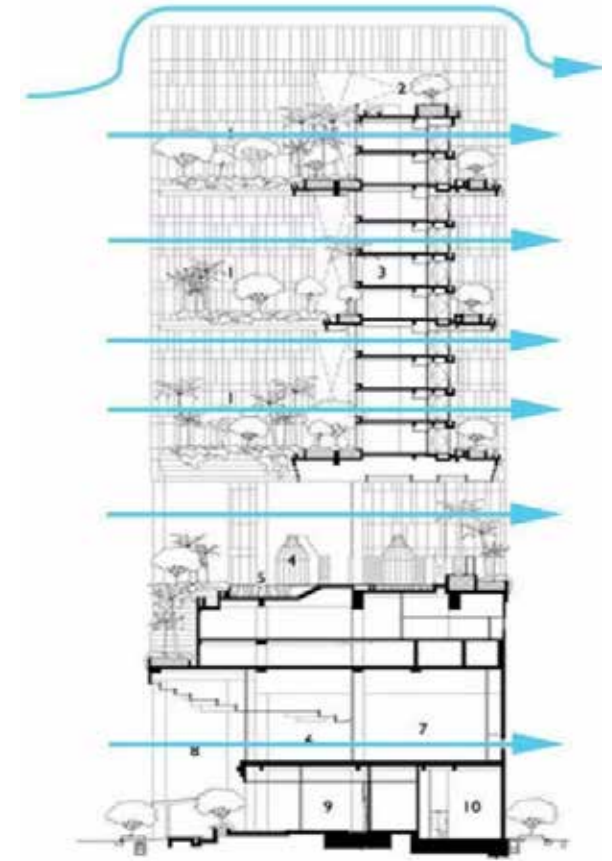


Figure 25 Section showing airflow (Chan, 2024)

Precedent Studies

The ParkRoyal Collection

Marina Bay, Singapore

Ecology

The NbS within this structure not only prevent excess carbon emissions but also relieve pressure from the external infrastructure system. The ecological impact of this building comes largely from the fact that it has been retrofitted rather than a complete new-build. With the extensive number of 2400 trees (Travel Weekly Asia, n.d.), there is potential to provide more than just humans with habitat as well; this also serves as a connection between the two, fostering human-nature relationships.



Figure 26 Rooftop gardens (Beasley, 2023)

Precedent Studies

The ParkRoyal Collection

Marina Bay, Singapore

Culture

The structure serves as an international hotel, which accommodates many different lifestyles and needs. The building itself shows minimal cultural influence aside from the ceiling, which mimicks a terraced plantation. Empowerment of the people in the building is manifest, particularly for the kitchen staff, who are able to grow 20% of the produce used in their restaurants via the rooftop garden (Travel Weekly Asia, n.d.).



Figure 27 Ceiling design (Cyrill, 2023)

Precedent Studies

The ParkRoyal Collection

Marina Bay, Singapore

Conclusion

Retrofitting this structure and including many plants and trees makes a large contribution towards lowering carbon emissions. The influence these have on the climate and ecologies are positive, creating air purification and habitat provision for example. The inclusion of the community and culture of the place are minimal and could be stronger, for example where things as urban orchards could be accessed by the public, instead of being private rooftop gardens. The vegetation of this building is mostly reliant on the capacity of irrigation via rainwater collection. Tarawa faces reoccurring dry periods, so including as much vegetation as this structure would require large water storage and careful plant species selection. It is also at a very different scale of course. What is useful learning from the precedent for the Tarawa context is the passive design for airflow and the benefits of vegetation in creating habitation and reducing temperatures.



Figure 28 Interior of hotel (Beasley, 2023)

Precedent Studies Overwater Bungalows Pacific Islands

Introduction

Overwater bungalows were established by Hugh Kelley, a lapsed lawyer, in Tahiti in the 1960's (Ellwood, 2017). Kelley and his partners (Muk McCallum, and Jay Carlisle) had purchased land in Ra'iātea, which had no beachfront. This led to the three-room bungalow design, inspired by ramshackle perches the local fishermen used; small, elevated platforms with makeshift shading techniques that allowed for easy access to the water for fishing. Present day bungalows operate as they were originally intended, for tourists, but can vary in size and amenities.

Many similar structures can be found around the world. Tonle Sap in Cambodia has many 'stilt' houses (Jaiswal, 2024) as too does Queensland Australia (Thompson, 2015), but for the context of the paper, I will focus on the overwater bungalows of the Pacific islands, including the ones located in Kiribati.



Figure 29 Original bungalows (Kelley, 2017)

Precedent Studies Overwater Bungalows Pacific Islands

Climate

Traditionally, local materials from the islands are used like the pandanus and coconut palms (Surana, 2024). However, since the bungalow concept has taken off, more modern materials are being imported and utilized, like cement for sea floor foundations (Gathy, 2020). Research shows that the majority of the structures are set at such a height that the predicted sea level rises will have minimal effect on them, though, once the sea has risen, the above deck space could be at the mercy of large sea swells or storm surges. There are indirect negative effects towards to climate and environment due to the intention of these structures. Theses being tourism, and transportation.



Figure 30 Bora Bora overwater bungalow (Stefanini, 2016)

Precedent Studies Overwater Bungalows Pacific Islands

Ecology

Some bungalows include container gardens along their walkways, mostly for aesthetic purposes. Almost all bungalows use local materials like thatch from palm leaves for roofing (Surana, 2024). This is an example of the materials radius system which is example of Nbs. Research shows that overwater structures can have negative impacts towards macrophyte and can possibly alter fish behaviours (The Department of the Environment, 2010). The structures also pose threats to the marine life, where the number of stilts or piles create a physical barrier, and the marine species have to navigate around them (Mullen, 2017). Other potential threats are related to shading created from the structures and accessways where they may provide inadequate conditions for coral growth due to their reliance on the zooxanthellae (a photosynthetic cell) (National Ocean Service, 2024). The location of these structures over the water shows a direct connection to marine environment however it may not be a positive connection; anthropogenic effects may deter or inhibit some marine life (Mullen, 2017).



Figure 31 Collection of overwater bungalows (Meyer, 2020)

Precedent Studies Overwater Bungalows Pacific Islands

Culture

Gathy, a Malaysian based architect, explains that in modern construction of these structure, that there may be dust from cement which falls into the ocean. That same ocean area that another person may use to clean their trough (Gathy, 2020). Looking at the Kiribati bungalows, the cultural values are present through the materials and openness of the structure, yet in many others they are designed for first world tourist, with windows, doors and beds. The Kiribati bungalows is made from local materials which shows a sense of self-sufficiency and, therefore, has the properties of empowerment.



Figure 32 Kiribati overwater bungalow (Rowley, 2024)

Precedent Studies Overwater Bungalows Pacific Islands

Conclusion

The intent of the resort style overwater bungalows does not contribute positively to the climate as tourist burn through jet fuel to reach the destination of the desired bungalow. Most of the structures have been built up from the sea level which shows adaptation towards sea level rises. Since the increase in demand for bungalows, there is a lack natural materials, however, many of the roofs are still made from locally sources palm leaves. NbS are not obvious in many bungalows, though the natural materials used in constructing the bungalows in Kiribati are mostly natural and untreated materials, therefore decomposition and regeneration theories are present. Further exploration of the effects to marine life of these structures should take place, especially where local livelihoods are reliant upon the marine life. While many bungalows imitate the vernacular architecture of the Pacific Islands, many are becoming more Westernised to accommodate 'high end' tourist. Considering the community and the purpose of structures is essential for sustainable development, especially if the use for such a structure is intended for tourism and not local residents who may otherwise need accommodation. Deliberations, similar to marine life effects, should also take place between the interconnectedness of humans and the ecology for the same reason. Natural materials should be reinforced and celebrated to increase empowerment and decrease reliance on imported materials.



Figure 33 collection of bungalows in Tahiti (Eime, 2007)

Precedent Studies Summary

Passive design techniques, material selection and knowledge sharing are key themes throughout the precedents. NbS are also present, however some implementations have far stronger effects than others.

Climate:

The climate is considered in all the precedents, mostly through material selection. Local materials are used in all designs, however, Schoonschip opted for longevity of some non-local over the negative environmental impacts. The Dancing Rabbit and The Parkroyal Collection illustrates the great impacts that can be made when repurposing a material or structure is considered. This is relevant to the I-Kiribati community where they also repurpose products and materials.

Ecology:

Schoonschip by far shows the most considerations for the ecology out of all these precedents. Schoonschip also contributes positively to the ecology by implementing NbS through a kind of fish aggregation device where it encourages wildlife, flora and fauna to flourish. The other precedents include NbS also, for example rainwater harvesting is a part of all designs except the overwater bungalows. Likewise, greenwalls/roofs are present in many of the precedents for both human and ecological benefits.

Culture:

Homeground includes the most cultural consideration out of all the precedents, with the inclusion of many local indigenous shapes, imagery, and the inclusion of local parties (iwi). The Parkroyal Collection and the overwater bungalows do incorporate some cultural considerations through design and the ceiling and roof structures. Throughout all the precedents there is some sense of empowerment created whether it be through education, cultural considerations, materials or self-sufficiency.

Conclusion:

Passive design techniques are featured throughout all the precedents with different purposes, but all contribute positively towards the environment. NbS are also present throughout the precedents. They too, have different purposes, yet rainwater harvesting is a clear standout solution. Empowerment is shown in different forms through cultural considerations, education and knowledge sharing, construction and self-sufficiency.

Precedent Studies

Key findings

The takeaways from these case studies are:

Passive design techniques – airflow, shading, thermal mass considerations.

Passive designs where no energy is required to create a comfortable environment have positive or zero impact on the climate and ecology.

NbS incorporation – rainwater harvesting, green walls/roofs, wildlife aggregation, backyard gardens/container gardens.

The inclusion of rainwater harvesting decreases demand on local infrastructure and empowers the users, as do backyard gardens/container gardens. Green walls and roofs have climatic and ecological benefits by enhancing air quality and increasing biodiversity.

Materials Selection – locality, longevity, repurposability.

Careful consideration of materials, for example where local materials are more beneficial for the climate as they have a smaller distance to travel. Also repurposing materials for alternative uses extends the life of said material while also having zero impacts on the climate and ecology. Where local or repurposed materials are not appropriate, longevity of materials is a valid secondary consideration.

Education/Knowledge sharing – empowerment.

Educating and learning of cultivation and construction can increase self-sufficiency and therefore empowerment.

Culture/People - including people and considering the culture of a place throughout the different stages of design aids with acceptance and success of a project.

Chapter 4

NUWAO field work Introduction

Due to minimal available research about Kiribati regarding cultural values, community and general lifestyle, ongoing research with Nature-based Urban design for Wellbeing and Adaptation in Oceania (NUWAO), funded by a Marsden Grant, has been able to provide insight.

NUWAO have been conducting field research and have been in contact with the community of Nanikaai in South Tarawa where workshops were carried out to better understand local relationships to nature and what they want for the future.

The following chapter contains information from field work carried out by NUWAO's Maibritt Pedersen Zari, Luke Kiddle, Sybil Bloomfield and Tokintekai Bakineti who conducted field work in South Tarawa in 2023 and 2024 (Pedersen Zari et al ; Kiddle et al., 2024).

NUWAO field work Analysis & Findings

To better understand the information gathered, a Venn diagram was created (by the author) where the circles are the three main subjects of this thesis i.e: climate, ecology and culture. I used this Venn diagram to input the notes I took throughout the online meeting about the Tarawa research and noted where findings aligned with one of the three categories or where they overlap. As most of the notes taken were from relayed information from field work with the community of Tarawa, the diagram shows to an extent community values, how people feel about the environment in which they live, how they will live and how they want to live. This information is not available in literature.

The diagram shows that the community are not overly concerned about the climate in which they live, although they have thoughts that overlap between topics such as “How to support the environment to support human induced rapid changing, rather than impending doom”, “Environment will determine how they live in it”, “no need to control or intervene”, “respond to what happens”, and “trust in the ability to adapt”. This highlights that the community is accepting of the climate and surroundings and has faith that the atoll and ocean will continue to provide for them. The other note which is significant to all three topics is that the community has a clear vision. They know what they want and have ideas about what that will look like and how it will function.

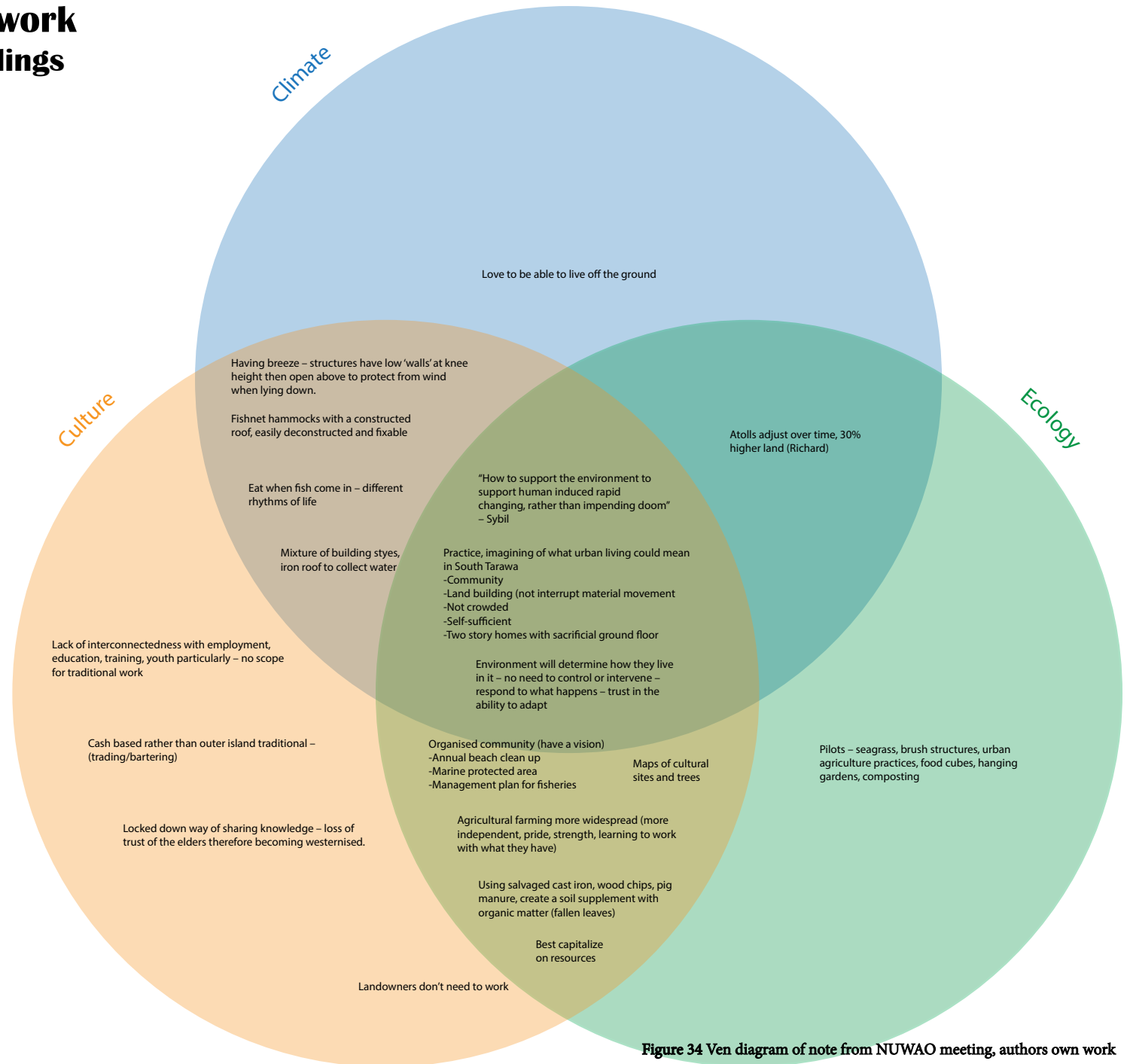


Figure 34 Ven diagram of note from NUWAO meeting, authors own work

NUWAO field work Analysis & Findings

The climate note is positioned closer towards the overlap of the circles because, the reasons for elevated structures are mostly due to the climatic conditions (storm surges and need for airflow for example) but have become a cultural norm. This note's relation to ecology is based on the topography of the land, where if the land were higher, then storm surges would not be such an issue and therefore posed the question, 'would structures still be built off the ground?' Answering this question with another note "having breeze...", was recognised as being important to the people of Tarawa due to the hot climatic conditions.

Notes relating to the ecology are not strong, however an interview with Richard Turpin Jr. (who was born in Kiribati and has spent much of his time there), was intriguing as he said the atoll has changed over time where now the aerial satellite images show a 30% total land increase since World War Two (due to the process of atoll accretion). This is interesting, as although there is significant erosion of the atoll, this suggests there is also accretion happening. The other ecological note is how the Kiribati Ministry of Environment, Lands and Agriculture Development (MELAD) are employing some NbS pilot projects which show promise such as mangrove revegetation on the lagoon shore of North Tarawa

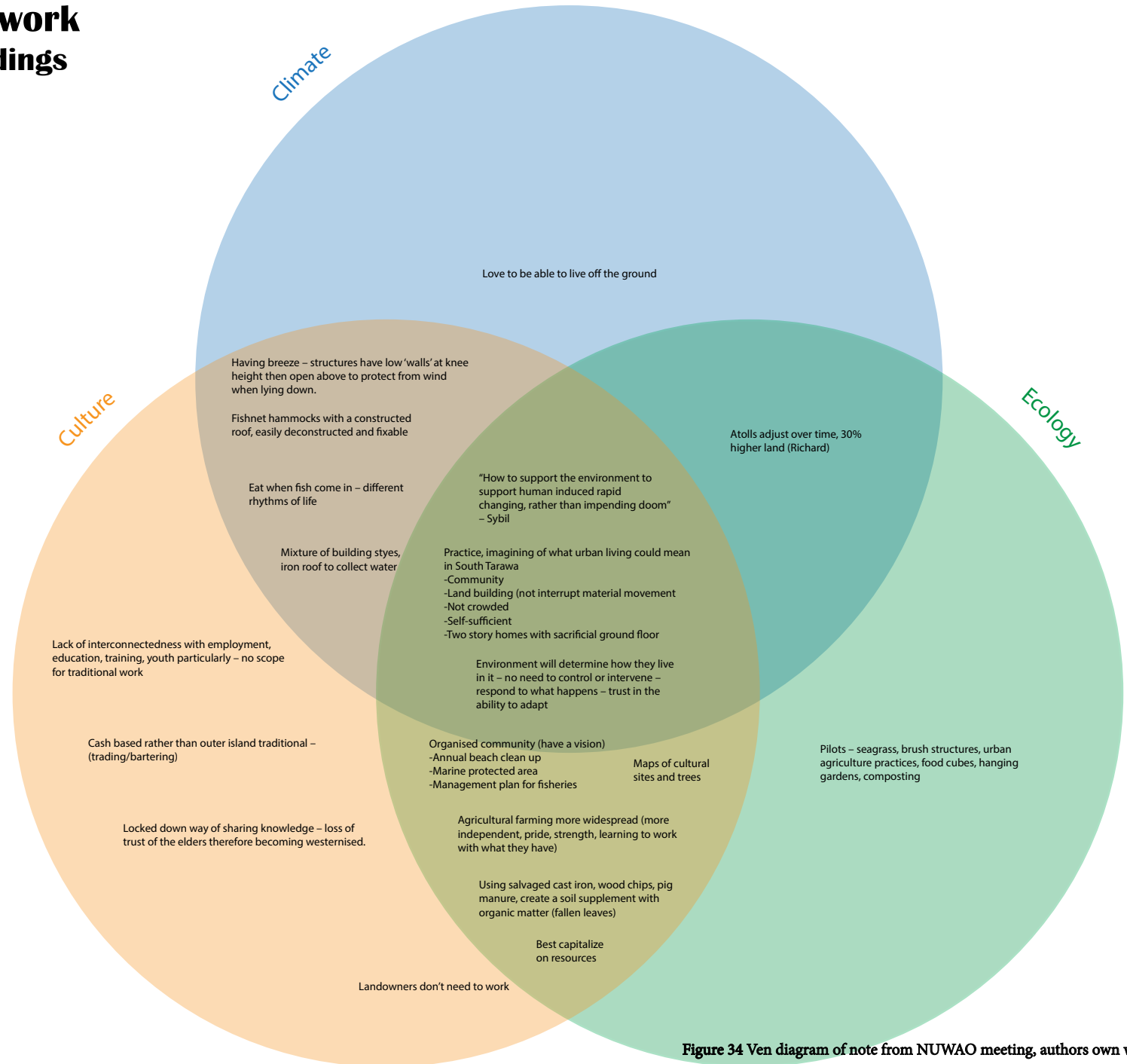


Figure 34 Ven diagram of note from NUWAO meeting, authors own work

NUWAO field work Analysis & Findings

The overlap between culture and ecology shows how the community is dependent on ecosystems. One comment from Bloomfield during the meeting was that the community recognises the holding capacity of the atoll environment and how they can best capitalise on it, which led to the ways the land is traditionally used for agricultural purposes. The community is learning to use what is available to produce what is required, like soil enhancement, though there is a dependence on food imports in South Tarawa (the urban area of Kiribati).

The information gathered from NUWAO field work and the visualisation of it using the Venn diagram has aided with understanding the community's needs, desires, and lifestyle beyond what is available in the literature. It shows what is most valued to them and what they are doing. Information that is scarce about the culture and community of Kiribati has come to light through these engagements and is very useful for this research.

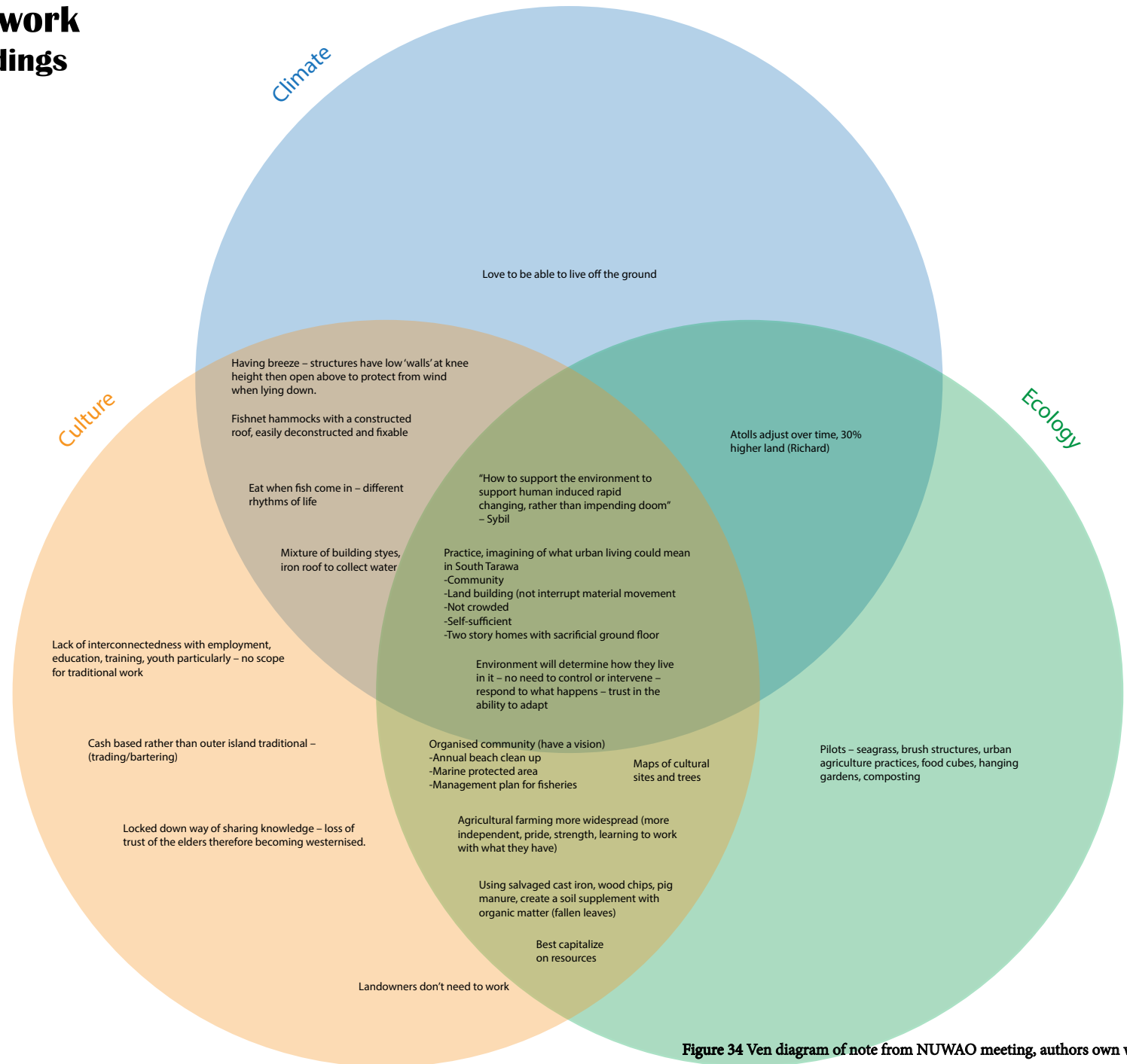


Figure 34 Ven diagram of note from NUWAO meeting, authors own work

NUWAO field work

Critical Reflection & Implications

This information is helpful in understanding the community desires from a bottom-up approach, which aids design work to be more of a success and has brought to light cultural values and understanding which was not prevalent through prior research.

- The community knows what they want:
- 2-story structures
- Sacrificial ground floors
- Self-sufficient
- Not over-crowded

The community also stated they are not for land building or reclamation as they do not wish to disrupt the natural environment or ecological systems in place.

Climate:

The Ven diagram shows the lack of comments relating to climate but there is a note that the **“environment will determine how they live in it”**. This comment alongside the community’s desires, where sacrificial ground floors are wanted, can be related to the climate with reference to climate induced storm surges and overtopping. This shows that although the community has not directly mentioned the climate, they are aware of it and the changes that are happening.

Ecology:

Bloomfield poses the question: how to support the environment to therefore support human induced rapid changes? The community is **respectful of the environment and does not wish to intervene with the natural order of things**. The community is organised in protecting parts of the environment by having marine protected areas and fisheries management, this could be built upon further by implementing customary resource management (a NbS) where restrictions to certain activities could be put in place to ensure growth, maturity or sanitation protection. This solution may not be well taken with the community if consequences are not fair and just though and is not entirely relevant to this paper where architectural intervention is the primary course of action.



NUWAO field work

Critical Reflection & Implications

Culture:

The most significant culture understanding I have taken away from this interview/information relay is that the I-Kiribati appreciate having breeze. Bloomfield described some structures having knee-high walls to allow for breeze to pass through while the occupant could still lay down and be protected from harsh winds. **'Having breeze'** may be culturally or traditional significant but the way in which one person Bloomfield and Kiddle spoke to about agricultural techniques does not seem to be of a traditional sense. This person told them of a rather alternative agriculture technique where a mixture of natural and man-made resources are used to form a soil supplement. Other growing techniques including **food cubes and hanging gardens as well as composting** are also key notes as moving forward this shows the community are **open to alternative cultivation techniques** and take 'pride' (Bloomfield) in being able to **produce healthy food for themselves** (empowerment).

From this interview/information relay a successful design outcome will consider the following points:

Community desires

Minimal impact to the climate, environment and ecology

Allow for breeze to flow freely

Incorporate traditional and alternative cultivation techniques



Chapter 5

Site Analysis Introduction

This chapter gives context to the site of the research where data, facts and other information is gathered, analysed, and summarized. This information is vital to design work for this research, especially where the climate, ecology and culture are considered, as in Kiribati, they are vastly different to the Westernised world.

The data specifies evidence of the population increase, occupations, imports and exports as well as climatic condition of the selected site (Tarawa). Understanding an atoll and its make up is useful in this research, as it aids with appropriate NbS implementation. Culture and structure are evidenced as key information also, as they provide understanding of the values, capabilities and local architecture of Kiribati.

Site Analysis

Introduction, Kiribati

Located in the Pacific Ocean is a collection of nations known as Micronesia. Kiribati is one of these nations. It borders the international date line and is the only country in the world that straddles all four hemispheres (Rowley, 2024). Kiribati is also the largest, most sprawled out country in Micronesia. Comprising of 33 atolls and islands. It spans an area of more than 3 million square kilometres (Scott et al., 1989).

Much of Kiribati's economic income comes from the exportation of copra (Trend Economy, 2024), but the main income is made from international fishing licences, and fees (International Monetary Fund Asia and Pacific Dept, 2024). The international port of Betio, located in South Tarawa on the Tarawa atoll, is where shipments are made domestically and internationally (Logistics Capacity Assessments, 2022).

As the country is dispersed across a vast area and within the Pacific Ocean, the climate varies from atoll to atoll (Turpin, 2024), but all are susceptible to the El Niño and La Niña phenomenon events (Kiribati Meteorology Service et al., 2015), which can cause problems with flooding and accessibility (World Bank Group, 2021).

Sufficient fresh healthy water is becoming a key issue, particularly on Tarawa, where the water sources are under threat due to climate induced storm surges, sea level rise, prolonged drought periods and anthropogenic and animal contamination (Kiribati Ministry of Infrastructure and Sustainable Energy, 2019). Salinisation and the natural nature of the soil is also a problem for some of plant species in Kiribati. Traditional cultivation techniques such as taro pits are becoming contaminated from sea water intrusion (Bowers, 2017) and the coral make-up of the atoll means the soil is not highly fertile nor does it possess the quality to hold water (Edis et al., 2017).

Due to the remote location of the atolls, the I-Kiribati understand how to best capitalize on the resources available to them (Bloomfield, 2024), for example the cultivation of coconut palm or the 'tree of life' where nearly every part of the palm is utilized (Travel Tour Guide, 2015).

Kiribati is heavily reliant on international aid for many things (Yates, 2019) and faces several challenges for survival, but it shows great resilience and adaptability in confronting them.

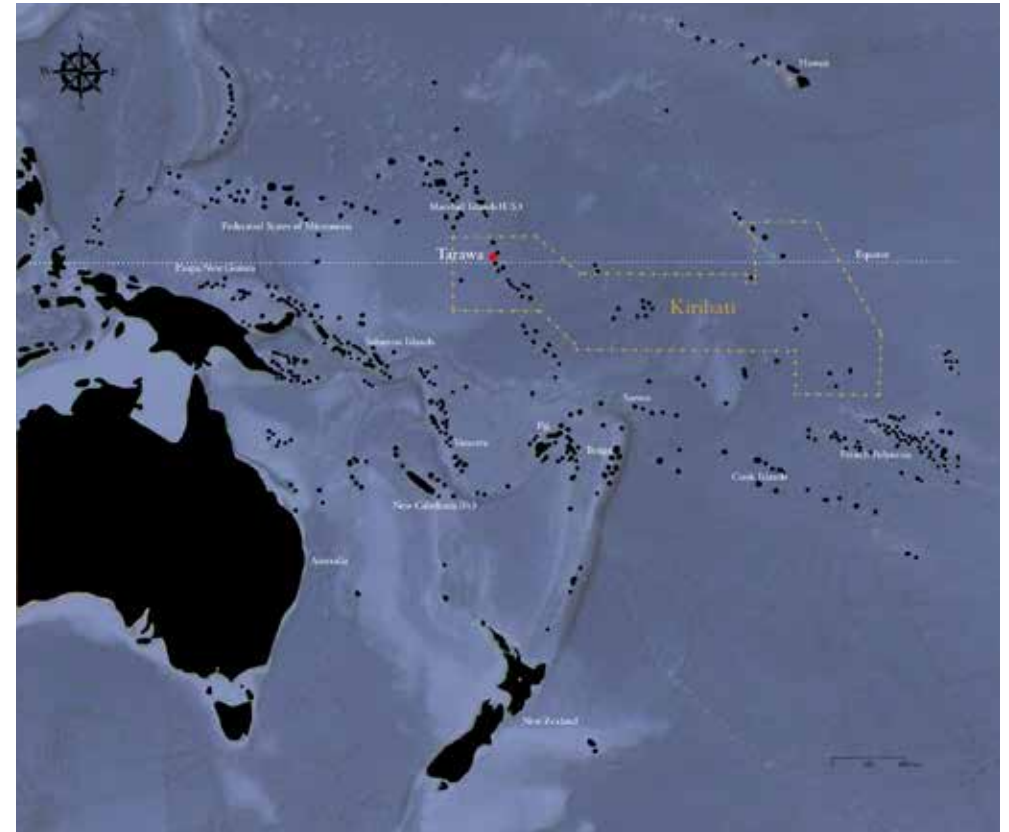


Figure 35 Map showing the location of Tarawa, Kiribati, authors own adaptation

Site Analysis

The land - atoll creation

atoll creation

An atoll is an underwater volcano (Seamount) which erupts with the lava piling up on the seafloor. When the volcano breaks the surface of the water it is then called an oceanic island. Small animals then form around the island called corals, which as a large mass create a reef. This is known as the fringing reef which surrounds the island just below the surface. The water between the reef and the island is called a lagoon. As subsidence occurs the sea erodes the top of the volcano into a flat manor, this is named a guyot. With the continuation of subsidence, the fringing reef then becomes a barrier reef. This protects the lagoon from the open ocean and harsh sea conditions. The limestone makeup of the coral decays due to less nutrients in the lagoon for the algae that the corals require, and this is why the lagoon becomes a vibrant teal or blue colour. Waves break apart the reef which then erodes into tiny grains of sand that are then deposited onto the reef. This is what is then moulded into islands or inlets and thus an atoll is formed.

- National Geographic Society, 2023

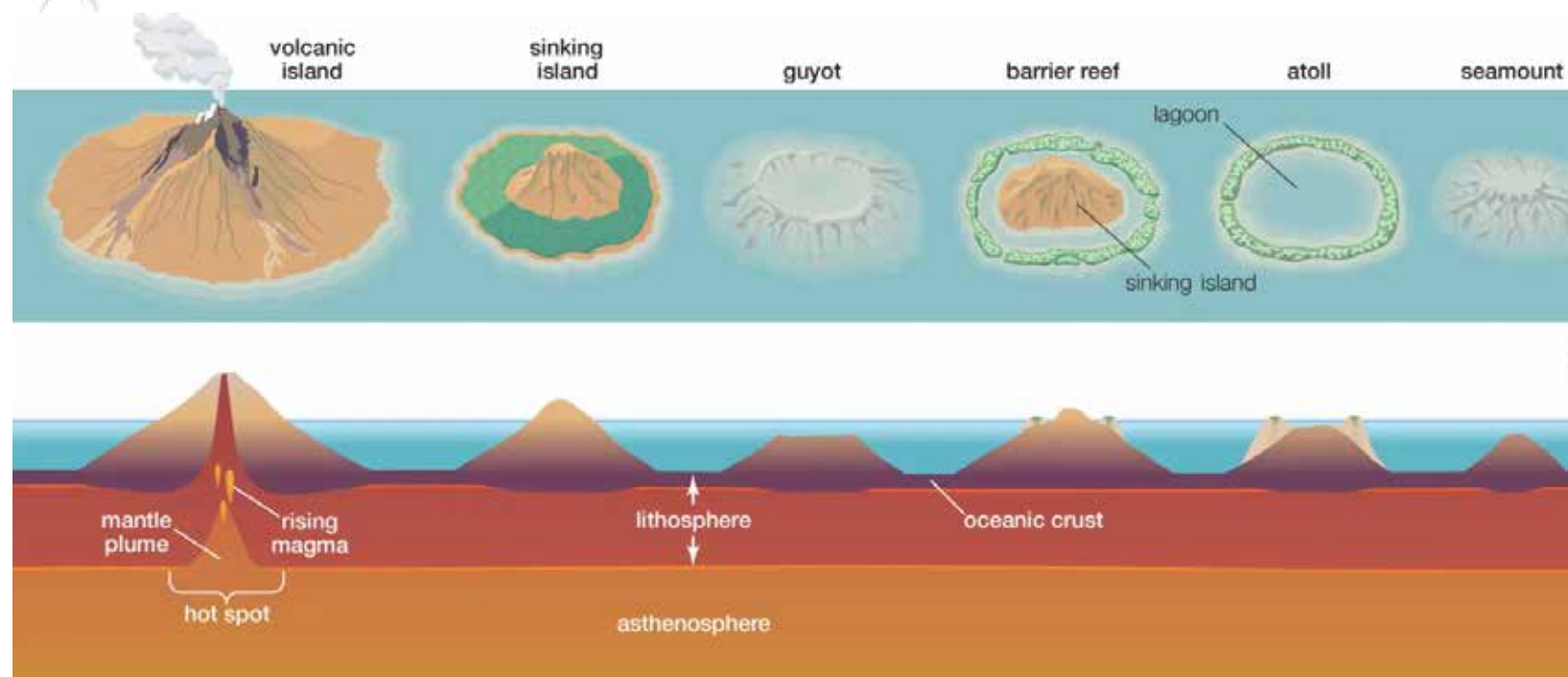


Figure 36 atoll formation (Encyclopaedia Britannica, 2012)

Site Analysis

The land - soil quality

Soil

Tarawa's coral limestone make-up means that the soils are typically sandy with no clay substrate, salty, highly alkaline and are low in nutrients (Edis et al., 2017). Encroachment of the sea and urbanisation are also problematic, especially in regard to traditional inground cropping, therefore threatening the economy (copra exports), health and livelihood of the community.

Some scientists (Edis et al., 2017) and locals (Ivan Ivelic) have explored ways to increase soil quality by exploring nutrient balancing techniques. Edis et al. discovered mixing ash from cooking fires or lagoon algae into compost increases the iron and potassium (coconut husks and shells also increased potassium) (Edis et al., 2017). Ivelic, a local i-kiribati, utilised local available materials to create a soil supplement composed of ground salvaged cast iron, wood chips, pig manure and other organic matter such as fallen leaves (Bloomfield, 2024).

The Pacific Soils Project (CISRO, n.d.) has been able to provide Kiribati (and many other Pacific nations) with education in soil quality and management. Between the years of 2019 and 2021 416 i-Kiribati participated in 4 workshops hosted by the Pacific Soils Project, where over 60% were youths. The workshop topics included soil testing, water and soil management, irrigation, plant health and why to become an agricultural scientist. The Kiribati Department of Agriculture presently runs a program that provides individuals with farming tools and organic farming workshop. The program also organises produce-growing competitions to encourage families to maintain their gardens and award a prize to the family with the best produce. (Cantieri, 2014).

The Kiribati Agricultural Strategy 5-year Action Framework (MELAD, 2022) includes a section on climate change where land erosion is mentioned, yet all the actions stated are related to the traditional inground agricultural system. The i-Kiribati people and more specifically the Kiribati government needs to lead the way into the future where traditional crops may not be an option.



Figure 37 Foodcubes in use (foodcubes, n.d.)



Figure 38 Hydroponic vegetable production in South Tarawa (Perez, 2004)

Site Analysis

The land - fresh water

Current Water Supply

Currently South Tarawa receives fresh groundwater from the reserves (freshwater lens') in Bonriki and Buoto for only two hours every second day (Ritchie, 2024). Some rainwater is harvested by residents but is not enough to provide a sufficient supply, especially during droughts (Kiribati Ministry of Infrastructure and Sustainable Energy, 2019). With the lack of clean water there are connections to health and hygiene issues, and increased sickness (Kiribati Ministry of Infrastructure and Sustainable Energy, 2019.; World Bank Group 2021). Studies carried out under Kiribati Adaptation Program Phase Two (KAPII) showed that inundation as a result of sea level rise could reduce groundwater yields from Bonriki and Buota reserves by about 20% by 2030 (Kiribati Ministry of Infrastructure and Sustainable Energy, 2019). This gives reason to aid the growing population with a viable long-term water supply and is being done with the help of the Asian Development Bank funding a desalination plant and solar photovoltaic farm.

Water has been contaminated by under-maintained sewage infrastructure, open defecation in close proximity to open water wells, storm surges, and lack of general knowledge about sanitation and hygiene (Kiribati Ministry of Infrastructure and Sustainable Energy, 2019). Contamination of fresh water supplies, the lagoon, and the ocean poses severe threats to Kiribati's environment and its people's way of life especially since the nation is reliant upon the land and ocean to provide sustenance and economic development (Trend Economy, 2024).

In 2018, the Global Environment Facility (GEF) Small Grants Program set out to reduce human faecal contamination by working with the community. Together they constructed forty public septic toilets (United Nations, n.d.), yet there is no evidence since completion that this project has resulted in any significant improvement.

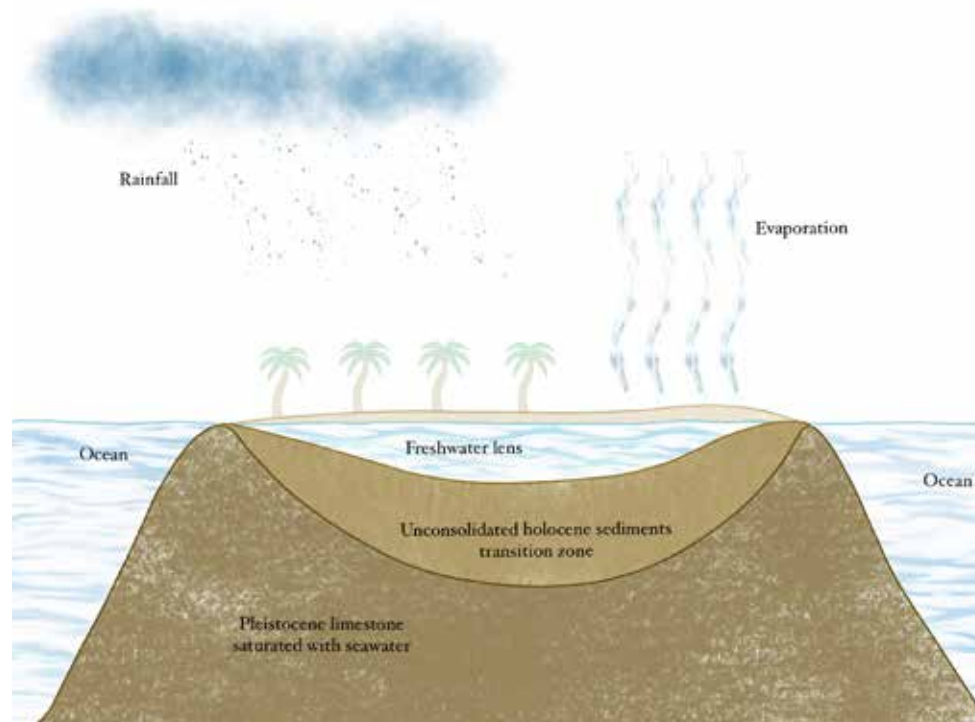


Figure 39 Freshwater lens, authors own adaptaion

"Water management in Kiribati is amongst the most complex and challenging in the world. Not only because of the pressures on the physical resource itself in terms of water quality and quantity, but also because of the increasing social pressures applied to the resource. Water resources are fragile, and vulnerable to drought, over-extraction and contamination. This is further complicated by issues of land ownership and water rights, and in the urban area of South Tarawa, a rapidly increasing population."

-Asian Development Bank, 2019

Site Analysis

The land - fresh water

South Tarawa Water Supply Project

The desalination plant being constructed in Betio, South Tarawa will have the capabilities to produce 4,000 m³/day with ability to double that (Kiribati Ministry of Infrastructure and Sustainable Energy, 2019). Other major components of this project include groundwater bores, a reverse osmosis system, filtration, brine return, chlorination systems, and storage tanks (Kiribati Ministry of Infrastructure and Sustainable Energy, 2019). The project also includes a training sector where the Public Utilities Board (PUB) staff will be able to learn how to maintain the reverse osmosis system (Kiribati Ministry of Infrastructure and Sustainable Energy, 2019).

In order to supply water to South Tarawa from the desalination Plant, new water storage tanks and booster pumps are required throughout the area with upgrades to the infrastructure. The project includes a new photovoltaic farm to supply the plant with the necessary power (Kiribati Ministry of Infrastructure and Sustainable Energy, 2019).

The Kiribati: South Tarawa Water Supply, Resettlement Plan (Ministry of Infrastructure and Sustainable Energy, 2017) is a thoroughly compiled report including analysis of potential water tank refurbishments, site analysis of the solar photovoltaic farm and effects on the community where work is to be carried out, particularly where private land is deemed to be optimal.

The project is set to be completed in 2028, with the goal to provide 100% of households in South Tarawa with healthy and sanitary water (Ministry of Infrastructure and Sustainable Energy, 2017).



Figure 40 Two woman carrying water vessels (Pacific Community, 2018)

Site Analysis

The ocean - waves

Waves & Storm surges

Waves and sea swells have a large impact on Tarawa. Where the port of Betio is considered, sea swells can affect the safety and efficiency of vessels, and 'down time' where important supplies may be needed, however, this is rare (Logistics Capacity Assessments, 2022).

Although the atoll is surrounded by waves striking it, research and data analysis has shown that during December through to March, waves tend to occur from the east and northeast, while through the 'dry' season between the months of June-September, waves are shown to come from the east and southeast.

Wave heights can range from 1m upwards to 2.5m in some recorded cases. During the wet seasons waves are often higher than the consistent 1-1.5m dry season waves (Kiribati Meteorology Service et al., 2015).

Bonriki Inundation Vulnerability Assessment (BIVA, 2015) conducted a statistical analysis and modelling of the waves around Betio and Bonriki on Tarawa. The data gathered was inputted into a model (SWAN) along with 34 years of historical wave data (1979-2013). The model was able to produce a wave rose diagram that shows the dominating waves coming from the east-northeast. Although the analysis and data are highly beneficial, they may now be outdated especially given climate change. Pacific-Australia Climate Change Science and Adaptation Planning Program also includes a wave analysis (fig.), but it, too, is now an unreliable source due to the changing climate conditions and the age of the document (Kiribati Meteorology Service et al., 2015).

More current wave and storm surge data would be ideal for designing and adapting Tarawa for the future, especially considering the atoll is already at the mercy of storm surges and sea-level rise. This information would benefit in the implementation

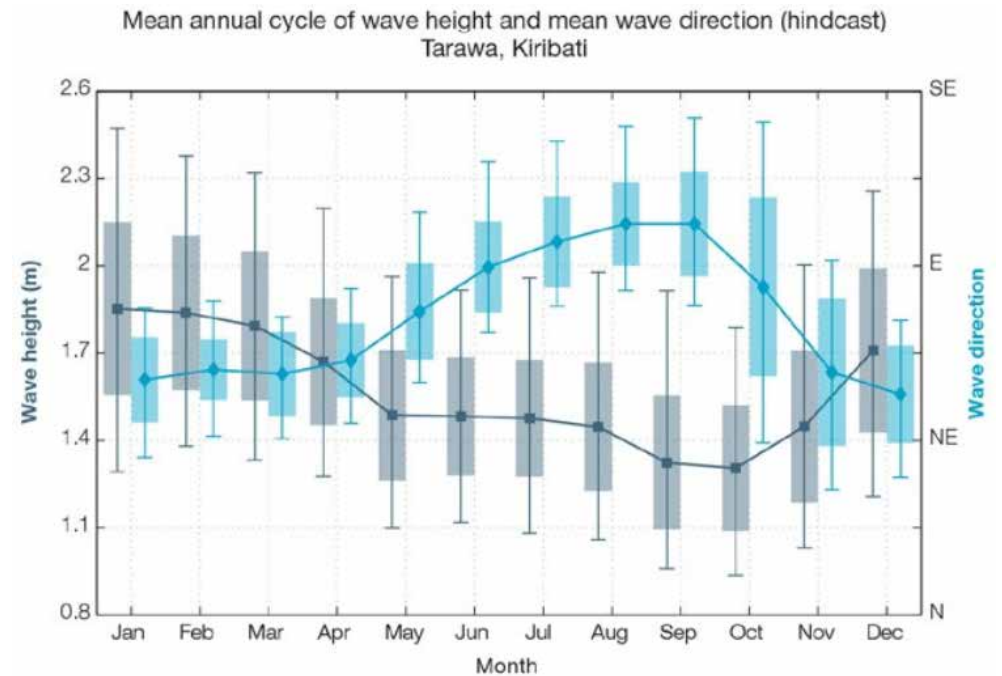


Figure 41 Wave height and direction graph (Kiribati Meteorology Service et al., 2015)

Site Analysis

The ocean - wind

Wind

With the location of Tarawa nestled between the South Pacific Convergence Zone and the Intertropical Convergence Zone, the wind directions and speeds seldom change in Tarawa; Easterly trade winds dominate throughout the year (WeatherOnline, 2024). Wind speeds increase from the month of November and begin to decrease from the month of April (Akitino et al., 2017). According to Weather Spark (2024) the winds are strongest between December and April with winds averaging 18.2 kms per hour. July is recorded as the calmest month, with average wind speeds of 15.7 kms per hour.

During an El Niño event winds typically weaken or blow in the opposite direction whereas a La Niña event the normal trade winds can become stronger (NIWA, 2024) which can bring on larger wave swells.

Due to these events, ocean surface temperatures also change and move causing the ocean wildlife to migrate to their desired living conditions (National Ocean Service, 2024) and therefore altering the fishing industries' productivity which Kiribati is reliant on for trade and food purposes. The wind directions are also linked to the elevation of sea level along the coastal and lagoon side of Tarawa (Sabūnas et al., 2021). The winds can also bring on salt spray causing harm to some structural elements, vehicles, soils and crops among other things.

“El Niño is a climate pattern that describes the unusual warming of surface waters in the eastern equatorial Pacific Ocean. Trade winds and atmosphere are also impacted by El Niño”

“El Niño has an impact on ocean temperatures, the speed and strength of ocean currents, the health of coastal fisheries, and local weather from Australia to South America and beyond. El Niño events occur irregularly at two- to seven-year intervals. However, El Niño is not a regular cycle, or predictable in the sense that ocean tides are.”

- National Geographic Society, 2023

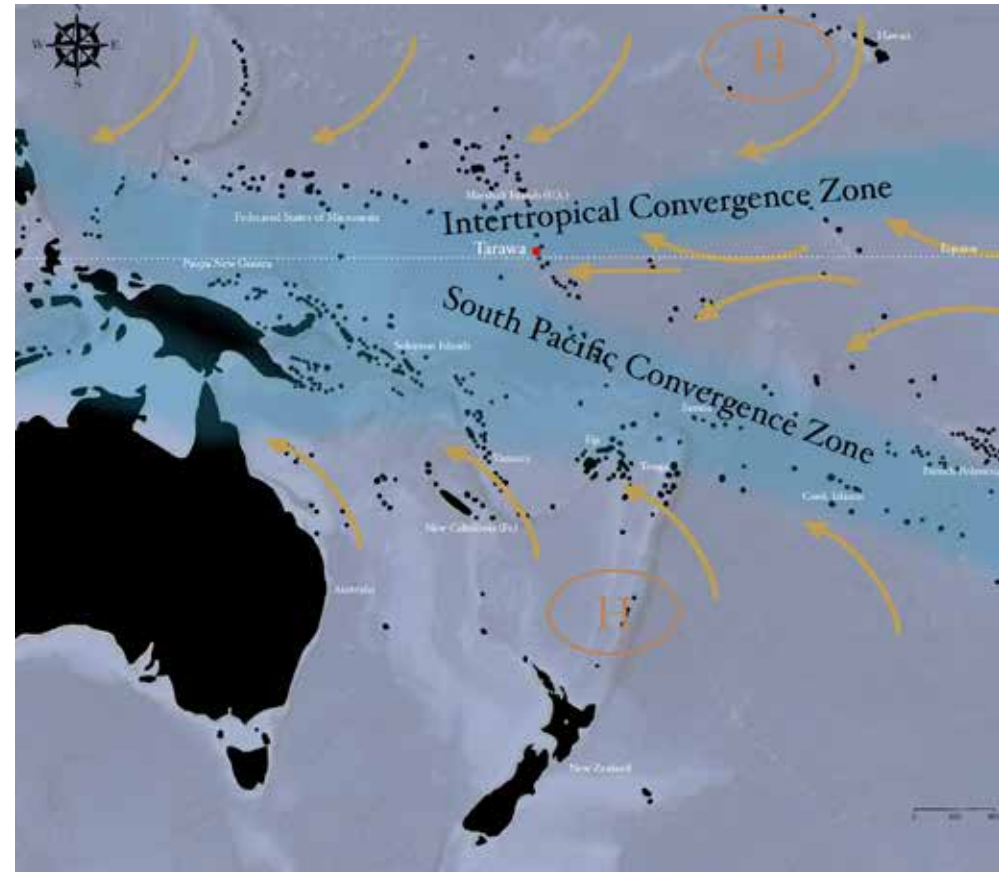


Figure 42 Map showing trade winds, authors own adaptation

Site Analysis

Climate change impacts

Rainfall

The 'wet' season often occurs during the months of November through to April. The rainfall periods are affected by the South Pacific Convergence Zone and the Intertropical Convergence Zone which extend across the South Pacific Ocean (Kiribati Meteorology Service et al., 2015). The months with the lowest mean rainfall for the year 2023 were September (79mm) and October (82mm) and the highest mean rainfall was in March which was recorded as 169mm (Weather Spark, 2024). During an El Niño event more rainfall tends to occur and sometimes brings on storm surges which in unison causes flooding events across the entire Atoll.

As with the temperature, infrequent and minimal rainfall are also factors in the soil degradation and lack of nourishment for crops. Coconut palms, a highly valuable plant to Kiribati, are naturally climatised to the conditions of the lower latitudes (Ritchie, 2024) and although the coconut palm can withstand a certain amount of drought-like conditions (as can figs), other important vegetation still require water.

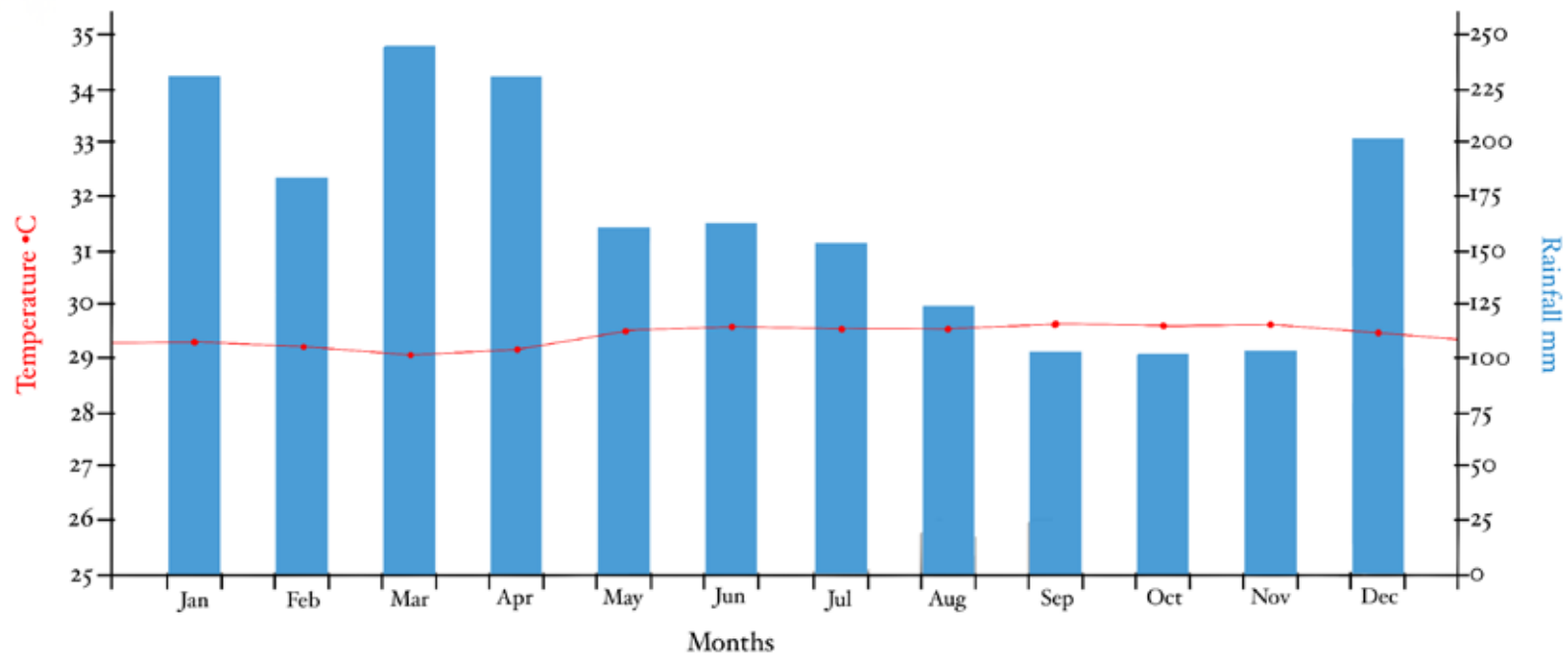


Figure 43 Temperature and rainfall chart, authors own work

Site Analysis

Climate change impacts

Temperature

The temperature of Tarawa is fairly consistent throughout the year where it maintains an average of 27°C with minimal decrease in degrees during the night (Weather Spark, 2024). Because of the hot and humid conditions, buildings (homes) tend to be open with only thin and flexible facades to allow for airflow (Whincup, 2010). The temperature has also contributed to soil degradation, where landscapes are too dry and coarse to maintain water and nutrients. This has led to the reliance on imported sugary foods which the World Health Organization (WHO) believes is a contributing factor to health issues such as, diabetes, high blood pressure and heart and lung diseases. (Kim, 2024).

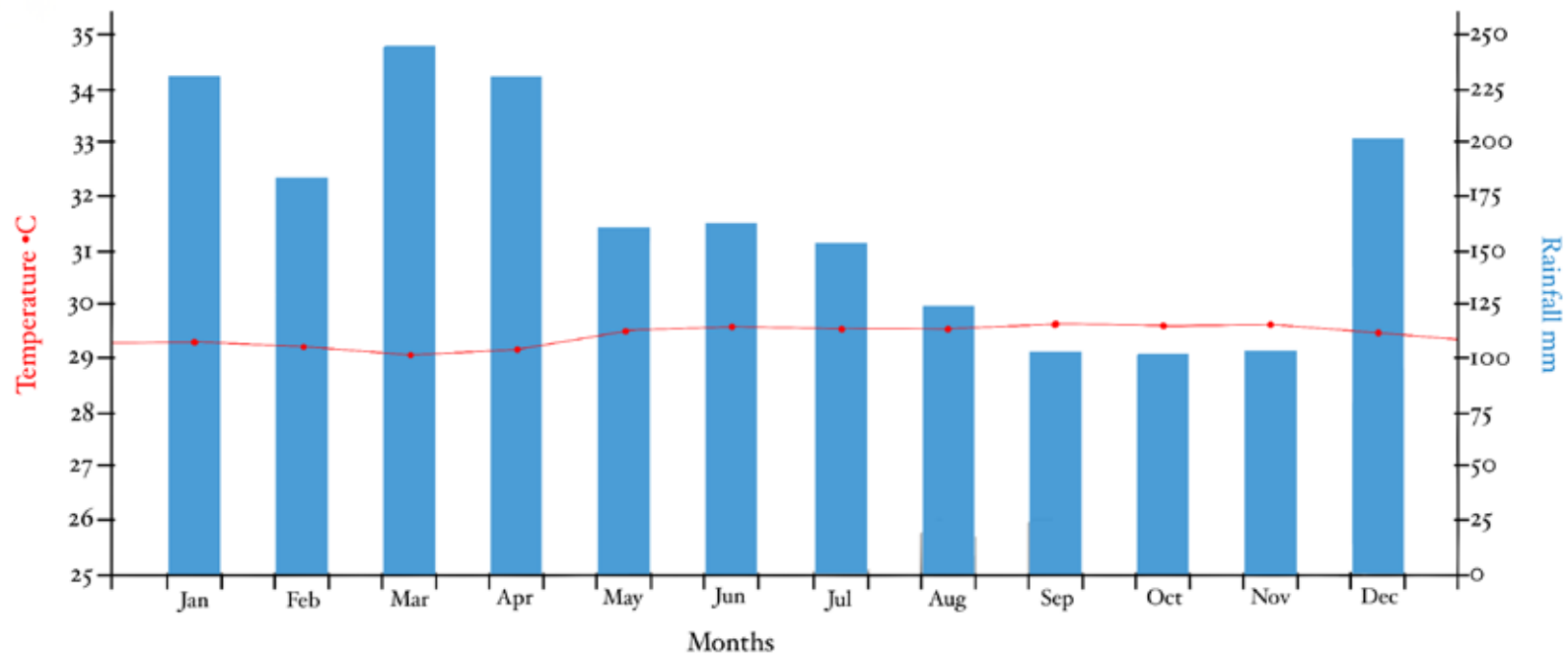


Figure 43 Temperature and rainfall chart, authors own work

Site Analysis

Climate change impacts

Sea-level Rise

As Tarawa's elevation from sea-level averages at 3m (Mulhern, 2020), the projected sea-level rise graphs give an indication as to how intrusive the ocean could become. As the ocean gains more mass, South Tarawa is at risk of losing more land where there is already very little to provide habitation, crops and other important infrastructure and vegetation.

A sea level rise model carried out in 2021 (Sabūnas et al., 2021) shows that under the RCP2.6 scenario a total of 29.5% of the Tarawa population will be affected. Isolating Betio, the sea level rise will affect 90.9% of the population. In comparison 58.5% of Tarawa will be affected according to the modelling against RCP8.5 with Betio's population being affected by 94.5% (Sabūnas et al., 2021).

The local government has taken to the idea of hard seawalls which are predominantly in place to protect public assets yet some of these are proving to be either ineffective, undermaintained or have adverse effects elsewhere (Duvat, 2013). Many locals are constructing seawalls out of locally sourced or scavenged materials to construct their own seawall defence (United Nations Development Programme, 2022).

Tarawa's seawalls are typically built from "coral rock, sandbags and concrete blocks" (Duvat, 2013). The impacts of these seawalls can cause beach narrowing, ecosystem degradation and biodiversity loss, which can also lead to loss of coastal inhabitations and cause food insecurity (Klepp, 2020).

It has been recommended that a combination of hard and soft seawall measures would result in a more beneficial outcome (Juillerat, 2012). Examples of these would be mangrove restoration and planting (soft). Mangrove roots help to bind sediments and protect from flooding (Waikato Regional Council, 2024). Constructed (hard) seawalls farther from the shoreline (breakwaters) could help with reducing wave energy and help with mangrove growth. Both of these examples are adaptations towards the encroachment of the sea but are not a long-term alternative where extreme sea level rise is considered, such as if the Western Antarctic icesheet goes.

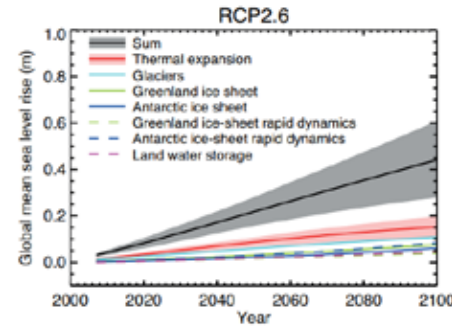


Figure 44 RCP 2.6 graph (Sabūnas et al., 2021)

RCP2.6 represents a peak in radiative forcing at approximately 3 W/m² mid-century before declining to 2.6 W/m² by 2100.

RCP 2.6 shows sea-level rise between 275mm and 600mm with a mean of 450mm

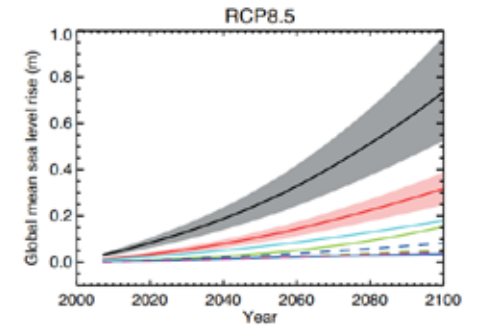


Figure 45 RCP 8.5 graph (Sabūnas et al., 2021)

RCP8.5 Represents a rise in radiative forcing to 8.5 W/m² in 2100.

RCP 8.5 shows sea-level rise between 550mm and 975mm with a mean of 737.5mm

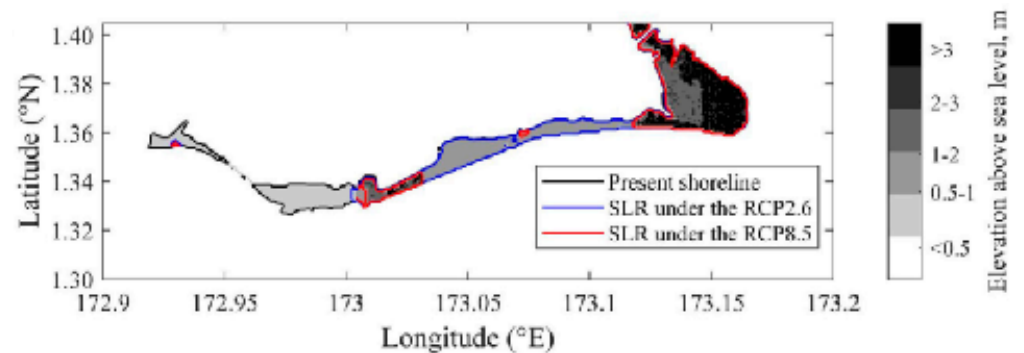


Figure 46 Map showing potential land loss (Sabūnas et al., 2021)

Site Analysis

Tarawa

Tarawa contains the international port of Betio and other important services which are likely reasons for large internal migration from outer atolls (Kiribati National Statistic Office 2022). North Tarawa is predominantly vegetation separated from South Tarawa by inlets and causeways. A virtual tour via Google Earth shows that South Tarawa is an extremely dense and built-up urban environment which is mostly housing. A mixture of construction methods can be seen, some of which may prove to be hazardous, especially in extreme weather events.

Betio, where the Port and the hospital are both set, is accessible from Bairiki and the rest of Tarawa via the Nippon causeway. Educational facilities are located in the region also, Bairiki hosts the Kiribati campus for The University of the South Pacific, and further east in Bikenibeu is the School of Nursing and the Kiribati Teachers Collage. The low-lying nature of the land and continual degradation of the coral reef due to sewage leakage (Asian Development Bank, 2011) and other influences (e.g. coastal erosion) continue to be an issue. Internally, on the lagoon side of the atoll, NbS are being employed by way of mangrove rehabilitation and planting (The World Bank, 2014). This method however has not been implemented on the external, ocean side of the atoll, shores of Tarawa, likely because of unpredictable sea swells which could destroy the plantings before they reach maturity.

Cultural and traditional beliefs are proving difficult to aid the citizens in modern cultivation techniques (White et al., 2004). Natural and climatic soil degradation has prompted the reliance on imports for sustenance (Kiribati Ministry of Environment, Lands and Agriculture Development, 2022). Traditional housing materials are becoming uncommon due to the lack of resources available as a fact of soil degradation due to coastal erosion and increased population and therefore demand (Whincup, 2010; Taboia Metutera, 2022). There has been a shift towards modern building material such as iron for roofing instead of thatch. Temperatures are consistent throughout the year (Weather Spark, 2024) as too are wind directions (Windfinder, 2024), yet rainfall is highly unpredictable and unreliable (Weatherspark, 2024). Wave directions are steady during the 'dry' and 'wet' seasons, with storm surges occurring more frequently (Kiribati Meteorology Service et al., 2015).

Kiribati has already lost two islands (Abanuea and Tebua) (Mulhern, 2020) due to sea level rise and predictions are not hopeful for the remaining ones. Water is scarce and often contaminated which has led to the Asian Development Bank funding the South Tarawa Water Supply Project (Asian Development Bank, 2011).

Many of the current sustainable projects in Tarawa include education for the locals so they can achieve and/or maintain such projects (Cantieri, 2014).



Figure 47 Map of Tarawa, authors own adaptaion



Figure 48 Map of Betio and Bairiki, authors own adaptaion

Site Analysis

Tarawa

Port of Betio

The port of Betio is accessible through the lagoon and a small opening in the reefs on the west side of the atoll. It is the main port-of-entry for all imports to Kiribati apart from some imports being able to cross dock in the Phoenix and Line islands. The Port is also a part of a trans-shipment operation where shipments arrive and then are distributed to the smaller outer islands.

The maximum draft of the channel at high tide is 11m yet the maximum draft at the dock is 8m with a maximum ship length being 200m. The weight limit of unloading on the dock is 25mt and there is a storage area where 400 forty-foot containers can be stowed. As there are limitations to the berthing of a vessel at the dockside, some ships are worked offshore.

- ShipNext, N.d.

- Logistics Capacity Assessments, 2022



Figure 49 Port of Betio (Kiribati Ports Authority, n.d)

Site Analysis

Culture

Community

The te mwaneaba is one of the most culturally significant structures of Kiribati and is a cultural system also. It is said to represent power and authority (Whincup, 2010). In this structure, village decisions are made and overseen by the Unimwane (old men) who know the traditions, the social norms, and the habits that must be maintained for survival and whose final decree is respected though some younger generations know that decisions could be better (Van Trease 1993). Since independence from the United Kingdom in 1979, a new young social class has developed who have developed technical skills and education, yet still practice and value the customs of the mwaneaba and are therefore allowed to speak with the Unimwane (Van Trease 1993).

The mwaneaba structure symbolises that collections of knowledge and expertise are required in order to survive as not one individual could make a mwaneaba. Traditional gender roles are still present throughout Kiribati. A female's role in the creation of the mwaneaba is to form the string that is used for the lashings and the males are the ones who build the structure (Whincup, 2010).

As with many Pacific Island nations, musical composition and dance are customary. Some of the Kiribati dance reflects that of the frigate bird (Stephenson, 2021) while others make the music which describes histories and myths (Whincup, 2005). Costumes that are composed of natural occurring materials are now becoming less common, with the involvement of plastic and other human-made materials (Whincup, 2005). Canoe racing is a well known and loved pastime of the people, alongside volleyball and soccer (Air Kiribati, 2024).

There are many taboo things when considering I-Kiribati customs; making direct eye contact especially with elders and speaking across another's conversation is also considered taboo (Kiribati for travellers, 2024). Many traditions and customs are passed down generationally. Some skills and methods are often kept secret from all but a limited circle of family members (Whincup 2005). There are however more open traditions such as rituals to yields and bring about rain (Jackson et al., 2021).



Figure 50 The traditional Mwaneaba(Whincupp, 2010)

Site Analysis

Culture

Community

Education and training are taking place in many areas of the nation, particularly cultivation. Due to the locked down approach of traditional knowledge sharing (it is not being passed down to the new generations in some cases) and youths may have a lack of connectedness and limited employment opportunities (Bloomfield, 2024). The Tarawa Technical Institute does offer courses in carpentry, computing, engineering and more (The American Association of Collegiate Registrars and Admissions Officers (AACRAO), 2024), however as with most tertiary education, this requires payment.

Tarawa hosts the University South Pacific's Kiribati campus as well as a teacher's college and two hospital clinics where early education in the health system is gained. Sadly, many nurses leave Kiribati to pursue further career opportunities abroad (Terubea, 2023). With the population increasing and ongoing health issues this movement is not ideal for the people who remain in Kiribati.

The latest census report for Kiribati shows that wholesales and trade are the most common industries for employment followed by agriculture, forestry and fishing. Educational jobs are fourth among this list, behind public administration. The statistics are further broken down into sex, roles and occupation. This data shows the greatest employment sectors and how gender roles are very traditional. It is also an indication as to where money is being spent and made.



Figure 51 Canoe sailing (Schutz, n.d.)



Figure 52 Household experiencing coastal erosion on South Tarawa (Government of Kiribati (2009))

Site Analysis

Culture - structures

Structures

Residential accommodation usually consists of three structures, one for cooking and eating, one for living and sleeping and one for storage (Trussel, 1979).

The traditional vernacular building structures of Kiribati are made predominantly of the pandanus and coconut palm trees naturally growing on the islands (Travel Tour Guide, 2015; Whincup 2010). As the islands do not contain the raw materials to produce tools similar to modern-day construction tools (hammers, nails etc.), the way in which the buildings are constructed involves no glue, nails or screws, instead the framing and other elements are bound together using specific lashing techniques and wooden pins (Whincup, 2010). The lashings are made from dried mesocarp from coconut husks and are knotted and tied in complex ways to ensure the structures are sound. Many components of a structure rely upon the efforts of others in the community; making of the 'string' is a woman's role while the male is to assemble the structures (Whincup, 2010). The lashing patterns also have cultural meaning.

The pandanus palm is used in its entirety. The trunks are typically the framework and roofing of a structure with much of the remaining elements being crafted from the coconut palm. Almost all parts of the coconut palm are utilised (Travel Tour Guide, 2015). The trunks are far softer than those of a pandanus and therefore are the least important part of the tree where construction is considered (Travel Tour Guide, 2015). The coconut itself serves many purposes to the community. The mesocarp is highly valued as it is used for cooking fires and crafting string, while the internal material of the coconut contains nutritional and economic value (Sheikh, 2024; Whincup, 2010). The ribs and leaves of both palm fronds are woven together to create flooring and walls which are most often covered by tightly woven palm leaf mats (Travel Tour Guide, 2015).



Figure 53 Lashings of a traditional structure (Travel Tour Guide, 2015)



Figure 54 Traditional floor coverings (pandanus and coconut fronds) (Travel Tour Guide, 2015)



Figure 55 Base structure of a traditional hut (Travel tour Guide, 2015)

Site Analysis

Culture - structures

“Inevitably, with the limited resources available and the imperatives of survival, an emphasis on functionality and simplicity of form has resulted.” (Whincup, 2010). The structures, unlike many other cultures for example Māori, do not incorporate carvings or detailing.

An individual expressed to Whincup (2010) their feelings about imported materials in constructing the traditional mwaneaba where they state, “if we do use them (imported materials) then we will lose our customs, values, identity and our way of life, particularly our upbringing as I-Kiribati... this will all be wiped away by these new materials”. Others have taken to the imported materials as they are shown to require less maintenance and less time consuming in the manufacturing sense of traditional materials (Whincup, 2010).



Figure 56 Village huts on Tarawa (Hinto, 2011)

Site Analysis Summary

Kiribati's geographic location in the Pacific poses many challenges but also opportunities, especially with the optimistic nature of the local communities. The research shows that Tarawa is facing the worst of the 'wicked problems' associated with Kiribati. Population growth and urbanisation is an alarming issue especially with regards to sanitation, hygiene, waste and infrastructure. The climate induced sea level rise predictions are also an issue for the nation and are already causing problems for many inhabitants of the atolls.

Temperatures are consistent, yet rainfall is unpredictable and at times problematic due to large weather events (El Niño and La Niña) either causing flooding or drought. The wind doesn't stray too much from the easterly trade winds, though they can increase in speed and in the case of an El Niño event the wind is said to travel in the opposite direction. The El Niño-Southern Oscillation (ENSO) also causes considerable storm surges, causing flooding throughout the atoll of Tarawa. These flood events destroy homes, businesses, and the land, as well as cause damage to the hard and soft sea walls. They also disperse debris (rubbish/waste) throughout the land and sea, therefore potentially causing harm to the corals and sea life ecology systems.

The predicted sea level rise is already causing issues for the atoll and the community due to the naturally low-lying land. The seawalls in place are doing little to mitigate the current storm surges and locals are doubtful about their success as many are not maintained or in place in areas that are suffering. This has led to locals creating their own barriers with discarded trees, shrubs and rubbish in order to hold the land together.

Site Analysis Summary

As the population increases, and climatic events continue to occur, ensuring the residents of Tarawa have access to healthy potable water is crucial. While the desalination plant will provide healthy water to all of Tarawa by 2028, a more immediate solution should be implemented as soon as possible.

Due to the nature of land formed through atoll creation, much of the land is not suitable for crop cultivation. There have been scientific discoveries that can enhance the soil qualities, but cultural and traditional beliefs are holding back this operation, which seems to be an issue for many of the potential solutions. Some young members now, however, have the education and expertise to combine with maintaining their traditions and are now in good graces with the local Unimwane in hopes to lead the way to improving their way of life.

The structures of the traditional homes are fashioned from local materials but with the increasing weather events and the accessibility to imported materials, many homes are composed of several different materials, such as corrugated iron for walls and roofing. This is not ideal with the temperature as the temperature retention of the material creates uncomfortable living conditions.

From this site analysis, it is clear that built environment designs need to address the issues of the population increase, climate events, healthy water availability, and food security. This can be done by focusing on resilient housing, sustainable water collection management and integration, and food security solutions, where practical within the climate of Kiribati, while still respecting traditional customs.

Chapter 6

Nature-based Solutions Introduction

This chapter is a brief introduction to potential nature-based solutions that could be implemented in this design research. Derived from the NUWAO Nature-based Solution guide (Pedersen Zari. M et al, 2024), a short explanation of the solution or system is outlined, followed by the advantages and barriers of the specific application, and an analysis as to whether it would be suitable for inclusion in architectural interventions meant for South Tarawa regarding this research's aims of food security, water security and sea encroachment as well as the topics of climate, ecology and culture.

Food Security:

Backyard, community & container gardens:

Having private backyard, community or container gardens can promote self-sufficiency with benefits of nutrition intake and generation knowledge and education, as well as numerous ecological and biodiversity advantages such as creating a sense of place, habitat provision, psychological wellbeing and of course food production.

Having such gardens requires access to water and time to maintain in order to ensure that crops don't go to seed and are used rather than discarded. Due to South Tarawa having major water security issues this could pose as an inadequate solution if water accessibility is not addressed. Space for gardens is also an issue in South Tarawa as land is used for housing, however, there are alternative solutions to this problem like the incorporation of vertical gardens and green walls.

These gardens can be incorporated or included in architectural interventions such as the case of the ParkRoyal Collection in Singapore. Including places for gardening within architectural structures provides the user of the garden and the structure a sense of place, opportunity, empowerment, improved air quality as well as food security.

Due to the soil conditions, ongoing sea level rise and storm surge issues, having one or all of these NbS included in future designs should be foremost.

Green/living walls:

Aside from the aesthetic appearance of green walls and roofs, they can also be utilized for air purification, thermal performance and biodiversity support.

Having vertical green structures with indigenous inputs can enhance the ecosystem and improve land management. Incorporating species that are capable of withstanding the desired infill and the climatic conditions could prove to be beneficial for food security, water scarcity and purification, urban heat island effect, and help with temperature regulation or reduction as well as psychological wellbeing, empowerment, waste management and sanitation, species maintenance and habitat provisions. Wind, heavy rainfall and saltwater exposure could lead to the failure of this solution. The green/living walls require strong structures to keep them upright and regular maintenance is also necessary. Having knowledge and time is essential to long-term success.

Green/living walls can provide cooler buildings and management of stormwater while also decreasing carbon emissions. Due to the conditions of South Tarawa, locating a green wall in any future designs will need to be carefully placed in order to prove successful.

Green/living roofs:

There are three main types of green/living roofs: extensive, intensive and semi-intensive. Extensive green roofs serve a functional purpose, usually installed for their effectiveness in stormwater management, roof protection, and thermal insulation. Intensive green roofs are designed to provide accessible green spaces for recreation, aesthetic amenity, and agriculture. Semi-intensive combine elements of both intensive and extensive green roof design and therefore have varying levels, depths and types of substrates. The functions of green/living roofs can be classified into the following five categories: biodiverse, biosolar, blue, blue-green and urban rooftop agriculture.

There are many climate, socio-cultural, ecological and biodiverse benefits to green roofs. Water collection, food security and thermal regulation are the most predominate in this case, but other advantages include air purification, soil erosion adaptation, empowerment and ecological wellbeing.

The types of green roof that are considered suitable options for South Tarawa are, 1. blue roofs, where water is collected and retained, it can then be utilized for agriculture or as a cooling device. 2. Blue-green roofs where plantings and water are interconnected. And 3. Urban rooftop agriculture which allows for the growth of agricultural needs atop the structure.

As with green/living walls, location and species selection needs to be carefully considered

Urban agriculture:

This is the process of growing, cultivating/harvesting and distributing produced in an urban area. A community garden is an example of this practice and so is a private garden on an apartment balcony.

Strong benefits of this solution are empowerment, resilience and self-sufficiency regarding food security. Others are carbon sequestering, reduction in urban heat island effect, pollination and education and knowledge.

Requirements vary with the size of the agricultural implementation; large scale gardens may require regular soil maintenance and pest control and higher water consumption whereas a smaller garden on a rooftop may not require as much water depending on the system.

The initial creation of an urban garden may be a bit costly or technical for example, constructing a planter box, but once it is established the money will be replenished with the unnecessary expenditure on produce. This solution provides resilience to the underlying theme of this research where food security is considered.

As urbanization in South Tarawa increases, including this strategy would be beneficial to the climate, ecology, and community. Providing spaces in structures where this could take place involves things like gardens and places where food can be 'processed' and then sold or traded, which could be done in an architecturally designed marketplace. The inclusion of this would empower the community who utilise it and much the same as community gardens, it can help to create a sense of place including that of traditional knowledge conservation. In a place such as South Tarawa, where the loss of land is in effect, having places within architectural elements where this solution can take place would be ideal.

Urban orchards/landscapes:

This is somewhat of a self-sustaining, open garden planted in urban space. Typically situated in an underutilised space with that anyone has access to.

In Te Moananui Oceania, many cultures practice this. Urban orchards/landscapes have historical/cultural value as well as the benefit of food security. Other likely advantages include biomass cover, increased air, soil and water quality, urban heat island effect reduction, empowerment, equality, and habitat provision along with many others.

There are many layers required to create a successful self-sustaining ecosystem, such as this one. High trees provide a canopy, fruit trees or desired edible trees form a sub canopy and ground cover helps create a strong root base.

The main issue with this incorporation this in South Tarawa is access to land as land ownership is an ongoing issue with many projects.

This solution is not so much of an architectural intervention, yet it still has potential to be implemented in design work. A sky bridge with edible trees is an example of how urban orchards/landscapes can be incorporated into architecture. Tall buildings are not typical of South Tarawa. However, a smaller scale intervention such as publicly accessible roof spaces or lower levels of a building could include gardens with nutritious produce.

Urban composting:

This is the process of transforming organic waste products into compost which can then be applied to soil, where overtime it releases plant nutrients.

The improvement to soil quality is a large positive impact of this solution as well as the minimization of pressures to infrastructure, like waste management and hygiene. Hot composting can have the ability to sterilise weed seeds and sometimes breakdown chemical residue. Successful composting requires the knowledge of material ratios, moisture content and temperature in order to avoid potential issues like odour and pests. Some pathogens and plants are large areas of concern where pathogens could be harmful to humans, the climate and/or ecology. Microplastics hidden in some bio plastics and composable packaging tend to be introduced into the environment via composting and should be carefully considered if they were to be included in the composting process.

As the atoll of Tarawa has poor soil for traditional agriculture, spaces in architectural designs where urban composting can take place should be considered to aid with soil remediation therefore enhancing food security.

Vertical Farming:

Vertical farming is the process of growing crops vertically rather than the traditional horizontal ground cultivation technique. Some vertical farming systems allow for levels, where multiple crops can be located over a small area, more often this leads to doubling or tripling the harvest.

There are many different ways for this solution to be carried out and all have requirements for propagation, seeding, harvesting, conditions/the environment and monitoring.

As urbanisation continues in South Tarawa, the benefit of vertical farming decreases the competition for land, provides food security, nutrient cycling, can reduce heat island effect and create a sense of empowerment.

Vertical farms could be structured into architectural designs in collaboration with green/living walls. Due to the encroachment of the sea, having this solution present in design solutions can show how agricultural practices can still take place and nutritious foods can still be accessible.



Water Security:

Biofilters:

Bio filters are specific water filtration systems and need to be layered at certain thicknesses and permeability. Particular plants are required where they can withstand heavy rainfall and heat.

Bio-filter systems can enhance the health of the ecosystem, prevent soil erosion, improve wastewater management and maintain aesthetic value.

Knowledge of the system and location is needed for this solution to be effective. Education and training can be implemented to maintain/initiate this solution.

This system can be used as a final (greywater) outfall from a structure to alleviate pressure from infrastructure while enhancing the ecology. Incorporating such a system in designs relevant to this thesis would be highly theoretical as the scientific requirements are site specific and reliant on the knowledge of the system.

Bioremediation / phytoremediation of water:

This system/s is eco-friendly, cost-effective and can serve as a water treatment alternative. It can aid with water security and pollution in a natural way. There are many benefits of such systems including coastal erosion, security of food production, saltwater intrusion to aquifers (in this case the freshwater lens), wastewater management and empowerment via biological control.

Having the proper plant species for the success of this system is vital, where there are requirements of the plantings (high biomass, rapid growth and strong capacity for absorbing pollutants). Other pH levels and climatic conditions as well as sites need to be carefully considered also.

As this is an emerging system, continual education and training would have to take place to ensure the system functions as intended.

With this solution, access to healthy water would decrease and, therefore, the roll-on effect to the ecology would highly benefit.

This emerging ecological technology would be beneficial to Tarawa where many water related issues pertaining to pollution are present. This solution could help to restore/enhance the waterways/ocean which the community of Kiribati are reliant upon.

Including such a system in architectural interventions can show adaptation towards climate change and create a more resilient community

Composting/vermiculture toilets:

This is a toilet sanitation system which does not rely on water. The most common vermiculture toilets use worms and small sticks of sawdust to essentially compost the waste. The waste can then be used to fertilize crops or other vegetation.

Due to the lack of or failing waste management systems on in South Tarawa and scarcity of water, this system could provide much needed hygiene improvements as well as nutrient for soils.

The requirements of this system are quite simple and there are some located on the atoll already. Some locals have complaints about the smell, this could be due to lack of maintenance, temperature, wind and high demand.

Maintenance, monitoring and education of the system would need to be continual to prove as a reliable alternative to traditional toilet systems as well as hygiene practices. Many of Tarawa's toilet systems currently use sea water for flushing which has caused issues with sewage infrastructure. Vermiculture toilets require no water, and the waste can be used for soil remediation, which is why this Nbs will be included in designs, with enhancements.

Rainwater harvesting:

This is the collection, storage and use of rainwater. It is one of the most common ways to create water security.

Collection and storage techniques may differ but the main reason for rainwater harvesting is to gather water and purify it with filtration systems to become a healthy potable water mass.

Aside from water security and self-sufficiency, other advantages of this solution are flood mitigation, reduced heat island effect, empowerment, food security, waste management and hygiene.

The technological requirements of these systems depend on the climate, intended use and therefore also size, collection surface area and storage capacity and capabilities.

To ensure long-term success and prevent future problems ongoing maintenance and education/training are required. Depending on the intended use of the system current water infrastructure systems may need to be included with designs which require local authorities to be cooperate with.

Some rainwater harvesting techniques are already in place in South Tarawa with education and training of the system taking place. Having this solution present is of great value, due to the freshwater lens becoming unreliable and the water infrastructure systems being inefficient.

Rainwater harvesting requires appropriate collection agencies, like iron roofing where rain can be directed towards water storage tanks rather than the traditional thatched roofs where water tends to dissipate on impact. Iron roofing tends to create a warmer internal environment, so if it is to be included, internal thermal comfort needs to be considered and can be mitigated through alternative insulation techniques or by increasing the roof pitch. Due to climatic conditions unpredictable and sparse down-pours occur but there is not enough storage to collect as much water as required to last until the next rainfall. Therefore, by including a rainwater harvesting system in designs, ample water storage capacity should be present also.

Sea level rise/encroachment:

Biofilters:

Bio filters are specific water filtration systems and need to be layered at certain thicknesses and permeability. Particular plants are required where they can withstand heavy rainfall and heat.

Bio-filter systems can enhance the health of the ecosystem, prevent soil erosion, improve wastewater management and maintain aesthetic value.

Knowledge of the system and location is needed for this solution to be effective. Education and training can be implemented to maintain/initiate this solution.

This system can be used as a final (greywater) outfall from a structure to alleviate pressure from infrastructure while enhancing the ecology. Incorporating such a system in designs relevant to this thesis would be highly theoretical as the scientific requirements are site specific and reliant on the knowledge of the system.

Should the ocean intrude upon Tarawa atoll, this solution could be beneficial towards sanitation of the surrounding waterways where structures are located. Improving the health of the water which can increase structural integrity.

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This emerging ecological technology would be beneficial to Tarawa where many water related issues pertaining to pollution are present. This solution could help to restore/enhance the waterways/ocean which the community of Kiribati are reliant upon.

Including such a system in architectural interventions can show adaptation towards climate change and create a more resilient community.

As with bio-filters, this solution could be beneficial towards sanitation of the surrounding waterways where structures are located. Improving the health of the water avoiding potential structural integrity.

Constructed Reefs:

This is a solution which needs knowledge, engineering and strategic planning on placement in order to be successful in the manner required; either reef rehabilitation or creation.

Some of the advantages of having constructed reefs include coastal erosion prevention, ocean acidification reduction, storm surge reduction, food security, and habitat retention or restoration.

Issues in order to carry out this solution are predominantly expertise, and financing, where many constructed reefs require funding and engineering knowledge.

The creation of constructed reefs can also enhance biodiversity, economic growth and tourist attraction for recreational activities though this may affect some of the other benefits of this solution.

Implementing this solution could increase structural security of structures situated along the coastline. The reefs could also serve as a fish aggregation device which would enhance self-sufficiency and therefore enhance wellbeing.

Flood resilient structures:

Flood resilient structures can involve things like sacrificial ground floors, elevated floors or floating buildings.

Material selection for the desired flood resilient structure is vital to success. Sacrificial ground floors would need to be water resistant and structurally sound and elevated structures would still require service connections as too would floating ones.

Having structures and/or services that are able to resist or adapt to water infiltration allows for flooding and disaster risk management, and shelter security.

Barriers to implementing some of these flood resilient structures in South Tarawa could be knowledge and skillset, costs for services infrastructure, material selection, availability and financing. Some of these barriers can be mitigated through education and financial aid.

Many traditional structures in South Tarawa are already elevated to allow for airflow but they also act as flood resilient structures. Many houses and their inhabitants are still at risk from storm surges and sea level rises, especially ones located along the coast and lagoon shoreline. Some of these are due to material selection for example, the coral rocks that are used as piles are not as common as they once were, and some locals may not be able to afford cement for concrete piles.

With many of the traditional housing already being elevated, and the atoll being susceptible to overtopping, designs that are elevated from the ground would be ideal, however it was expressed in chapter 4 by the community that having sacrificial ground floors would be welcomed.

Living crib walls / brush mattresses:

Typically made from natural and on-site materials, these walls are an alternative to hard retaining walls. Plants are securely placed in the materials laid in the foundation where the roots are able to take hold and stabilize the site.

The use of woven natural materials to form a 'covering' fit to withstand the climatic conditions, would be from indigenous knowledge providing the cultural benefits to this solution. This technique can be used to prevent erosion, flooding, wind/storm damage, disaster risks, and provide habitat and species regeneration.

Requirements of this solution depend on the size and location, as different soils require alternate combinations of materials and fixings. Plantings will need to be carefully considered, and education and training will need to occur.

Incorporating this solution into further design work would need knowledge of soils, site conditions and local support for implementation.

These structures would aid with structure security. While also increasing biodiversity.

The natural seawall could also acerate land which could be utilized for future construction, especially considering the population growth.

Living seawalls / biodiversity tiles:

Adding textures to existing or potential seawalls allows existing sea biota to cling to and/or create new habitats.

Indigenous knowledge passed down can give insight towards the dynamic of the coastal ecosystem which is important for this NbS to succeed. This includes things like species, season patterns and sustainable harvesting practices.

This solution can help adapt shorelines to coastal erosion, storm surges, ocean acidification, sea level rise, temperature increases, disaster risks, biodiversity health, purification and biological controls.

The new emergence of this solution is potentially why some are sceptical of its success, yet the economic value could increase dues to ecosystem and biodiversity habitat provisions being made.

The incorporation of the tiles is to rehabilitate degraded habitats and enhance biodiversity which encourages ecosystem resilience but could serve as protection and aid with structural integrity.

Living shorelines:

Unlike most hard seawalls, living shores protect the land against the sea while also providing habit and shelter for wildlife.

Living shoreline can incorporate traditional methods and usually natural materials like coral, rocks and local plant species.

Benefits of such a solution are not limited to habitat creation but also have coastal erosion prevention, soil erosion, disaster risk reduction, water security and quality as well as potential soil building opportunities, purification and species maintenance.

Assessment of the desired location needs to be made to ensure the land is stable enough to handle the response. Hard seawalls and wastewater management may need to be considered also.

The plantings will take time to reach maturity in order for them to be capable of being successful in their implementation. Research, planning and ongoing maintenance will more than likely need to take place where plantings and other services are to be considered. Costs for designs vary depending on size and site requirements.

The benefits of land protection, accretion and stability, are ideal for including living shorelines in designs for South Tarawa, yet the issue of time remains, as the solution would need time to reach maturity/optimal performance. Incorporating this NbS into designs would need careful site selection and analysis.

Mangrove Restoration:

Mangroves have the ability to grow in intertidal areas and have qualities to filter out the salt through their root system. They also help to reduce wave energy and are therefore an asset against storm surges.

Further benefits of mangrove forest are coastal erosion protection, biomass cover increase, ocean acidification decrease, disaster risk reduction, and habitat provisions.

There are several techniques to successfully introducing or restoring mangrove forests and are relative to the location of such a solution.

Some barriers that could pose a threat to success are oil pollution, biological invasion, insects and water transportation or inundation.

Mangrove rehabilitation or implementation could be beneficial for economic growth, as the ocean becomes cleaner the fish will congregate, waves from storm surges can be reduced once the mangroves have reached maturity and the coastline has a protective barrier against erosion. Due to these facts, mangrove plantation will be heavily considered in design work for South Tarawa where the site would prove successful.

Nature-based stormwater management:

There are several different types of stormwater management systems. Soakways and soakwells are two of them. They are underground pits filled with and store excess water during extreme flooding events, they can vary in size and shape.

Filter strips are vegetative sections of land that take in runoff and work best when densely planted. They can have filtration qualities depending on the species selection. Filter drains and infiltration trenches are simply above ground soakways, where shallow trenches contain gravel or rubble that allow water to dissipate beneath into the surrounding soils. Sustainable drainage systems (SuDs) store water during storm events and reduce surface water run off by simulating natural water management.

The vast number of benefits for SuDs include soil retention, flood mitigation, reduction of urban heat island effect, increase in water quality, waste management and hygiene, disaster risk and disturbance prevention.

Depending on the size of the selected system, some can be constructed with simple tools, others may require more invasive technologies where stormwater management and other biodiversity is considered, this being said plant selection also needs to be thought of.

Governing bodies are said to be one of the only barriers where they need to accept the effectiveness of SuDs.

Due to periods of heavy rainfall, soil quality, low cost and simple implementation, this water infrastructure would be suitable for South Tarawa.

South Tarawa suffers from extreme downpours and flooding; therefore, the inclusion of this solution in designs would be ideal as flooding events that can cause strain on infrastructure and structures can be minimized. This solution could be implemented alongside other NbS such as bioremediation or urban blue-green spaces.

Revegetation / renaturing:

This is the reintroduction or restoration of vegetation to selected areas. Where degradation or even erosion has occurred, this solution shows how nature can improve the soil, air and water quality.

This solution usually requires local knowledge of plant species and an understanding of the climatic conditions therefore it has high cultural preservation impacts. Further benefits of revegetation are biomass cover increase, reduction in urban heat island effect, food and medicinal production (depending on plant species incorporated), wastewater management, disaster risk reduction and habitat provisions.

Continual monitoring, maintenance and mulching may be required. Planning, understanding, and potential intervention of the soil and water will need to be met in order for the solution to be successful.

Limitations to suitable plants and seedlings could be obstacles as well as long drought periods and extreme weather events as well as pests.

With many benefits including indigenous knowledge this solution can foster strong human and environmental connection and therefore has the added psychological incentive.

Some Tarawa locals are currently applying this technique with mangrove restoration on the eastern side of the lagoon.

This solution could be incorporated in designs to revegetate the coconut and pandanus palms. This would aid with empowerment as these two palms are significant to the culture and economy of Kiribati, particularly with traditional structures. These palms could then be used for other architectural interventions once they have reached the appropriate age.

Te buibui (coastal brush structures):

Brush structures (Te Buibui) are constructed with unused or discarded natural materials such as palm fronds which are weaved through stakes to encourage sediment collection along shorelines.

Benefits are many with this naturally occurring raw material. Coastal erosion prevention, storm surges and wave reduction, sea level rise, disaster risk reduction and resilience, and empowerment are all said to be additional positive outcomes from this solution.

The technical requirements are limited to knowledge of materials (where to find them and how to best use them) to construct the brush structure. Locating the structure also requires some thought. The process of weaving or placing the fronds is as easy as that and therefore is simple enough for almost anyone to carry out.

As this is a strategy that is already being carried out in some locations of Kiribati, further implementation and investigation towards the success of it would prove useful with future design work. Te buibui also has the potential to accrete land while also decreasing wave energy, therefore protecting the land and structure which sit upon it.

Urban blue-green spaces:

This solution is defined as any vegetative area or water body in a city environment. There are variations in scales of this solution such as buildings with green roofs or walls. Scaling up to a neighbourhood size with an example being constructed wetlands and on an even larger scale (regional) coastal or mangrove restoration and river riparian are all considered urban blue-green spaces.

Depending on the solution, urban blue-green spaces promote the interconnectedness of all elements of the ecosystem. Benefits, depending on the solution, can be urban heat island reduction, air quality improvement, water quality improvement, increased biomass cover, human physical health and well-being, food production and habitat provision.

Locating the desired solution would require engagement from numerous parties especially where infrastructure is considered land ownership development and management of such spaces can be barriers towards a successful intervention.

If this NbS were to be included in designs for this research, the land ownership barrier may be an issue however if designs show significant enhancements the landowner may be more reciprocal.

Living/green walls and roofs would be ideal in South Tarawa, especially if they are capable of growing produce. They would also help to reduce heat island effects which is why they will be heavily considered in architectural interventions.

Water-caused erosion prevention:

In Lou of hard infrastructure, vegetation barriers and hybrid barriers are a more nature-oriented approach to the prevention of water caused erosion. Some vegetation can stabilize waterlines and potentially restore it depending where the selected solution is located.

Potential benefits can be erosion prevention, increased soil quality, storm surge prevention, sea level rise advantages, and habitat provision.

Technical requirements will depend upon location and size of the area and plant species will need to be considered also. Consideration needs to be given to the natural dynamic of water especially in places like shoreline where water cannot easily be controlled.

South Tarawa is already implementing natural seawalls, see (Te buibui), the inclusion of this solution also could enhance the effects.

By including structures or systems that are capable of 'controlling' the water, land and structural security can be increased. Such systems usually have the benefit of for flood prevention also. These reasons and the advantages are good reason for including this NbS in design work for this thesis.



Nature-based Solutions Summary

The NbS that will be incorporated into design work will be selected appropriately and shown in drawings and imagery to prove the need or use for it. Some NbS may be better suited or viable than others for South Tarawa.

NbS that show, through this analysis, to be highly suitable for incorporation into architectural interventions for South Tarawa are:

- community gardens
- container gardens
- green/living walls/roofs
- urban agriculture
- composting/vermiculture toilets
- rainwater harvesting
- flood resilient structures
- living seawalls
- mangrove restoration
- Te bui bui
- urban blue-green spaces
- water-caused erosion prevention

Carefully and considerately incorporating any or all of the above NbS in architectural designs would assist to answer this thesis's research question: How can urban nature-based solutions and climate adaptation in the context of architectural design, enhance resilience, ecology and human wellbeing in South Tarawa, Kiribati? As the benefits mentioned throughout the chapter relate to the themes of this research as well as the overarching topics of well-being and climate change.

Technological knowledge and understanding of necessary or incorporated systems should include an educational sector to encourage the local community how to best use such systems as well as maintain them, this will increase resilience and emote empowerment.

Chapter 7

Design Experiments Introduction

This chapter showcases design experiments which began prior to any significant site analysis. This is notable in some design work, particularly where cultural considerations are relevant. As research progressed, and community insights were shared, the experiments evolved.

The design experiments aim to answer the research question: How can urban nature-based solutions and climate adaptation in the context of architectural design, enhance resilience, ecology and human wellbeing in South Tarawa, Kiribati? As well as show an increase in food and water security while also reducing waste and issues of overcrowding.

The design experiments are shown in two stages; the idea stage, where initial thoughts and plans were formed, and the conceptual stage, where more thorough design thinking was used in order to formulate a more realistic or appropriate solution. Final evaluations of each design iteration were carried out using the devised theoretical framework (see chapter 3), made up of climate, ecology and culture sections to critique and improve the designs. This kind of reflection and criticism were key in assessing the most promising and least promising components of each design experiment and the progressing the design work to developed stage.

Design experiment 1.

Modules

The idea

As populations continue to increase in Tarawa so do households, some which do not have adequate space. This leads to extensions and in some cases inadequate housing.

This experiment considers modular living where more or less space could be easily added, taken away or repurposed depending on the size and needs of the extended family or community, while also keeping in mind the issues relating to the sea (sea level rises, overwash, and storm surges).

Local materials for this experiment were a dominating design aspect for the purpose of potential replication. Locals would be able to recreate the design 'easily' as they already possess the knowledge and materials to do so.

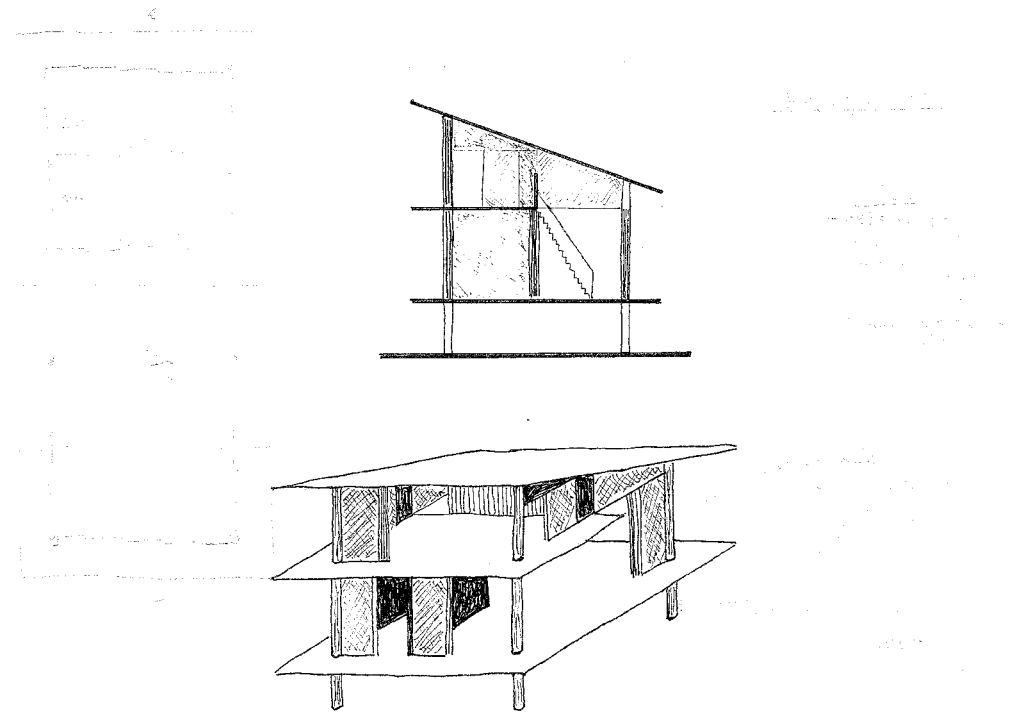


Figure 57 Sketch of modified traditional housing unit, authors own work

Design experiment 1

Modules

The Concept

From the research and site analysis, I determined that six modules would be required in order to create a functional and realistic structure. These modules are:

- Accommodation
- Sanitation/hygiene
- Horticulture
- Cooking
- Energy
- Water

The accommodation module is a 5 metre by 5 metre split level, private, open plan dwelling with its own dock. This open plan or flexi living is common in Kiribati as it allows space for large families and maximises air flow throughout.

Sanitation/hygiene are shared facilities. This provides safety and shared responsibility of the cleanliness of the space. One of these modules contains 5 showers, 5 toilets and 10 wash basins in each designated area.

The horticulture module includes vertical gardens and several container gardens with space for composting also. An alternative or additional idea for this module is a agriculture component where some livestock like chickens and pigs could be kept.

Traditional cooking in Kiribati is done over an open fire although some are now reliant on butane and camp cookers. The cooking facilities module includes 2 open fire pits for cooking, 2 refrigerators, 2 sinks and benches for food preparation as well as plenty of open space to facilitate many people for dining for other purposes.

Within the energy module there are generators to store and convert solar energy, laundry services and re-charging stations.

Lastly the most important module water. This module collects rainwater from the roofs of the energy and cooking modules stores and filters it. Once it has been filtered it is then able to be dispersed to the other modules (cooking and sanitation/hygiene).

The arrangement of the modules was determined by the importance of water and how life revolves around it; Positioning the water module in the centre with the other aligning modules dispersed from there. This configuration shows the public spaces being more central, allowing for community engagement and interaction, while the outer modules provide necessary privacy.



Figure 58 3D visualisation of modified traditional housing unit, authors own work

Key:

- Red - private accomodation
- Yellow - Sanitation and Hygine
- Green - Agriculture
- Blue - cooking facilities
- Cyan - water and energy stroage

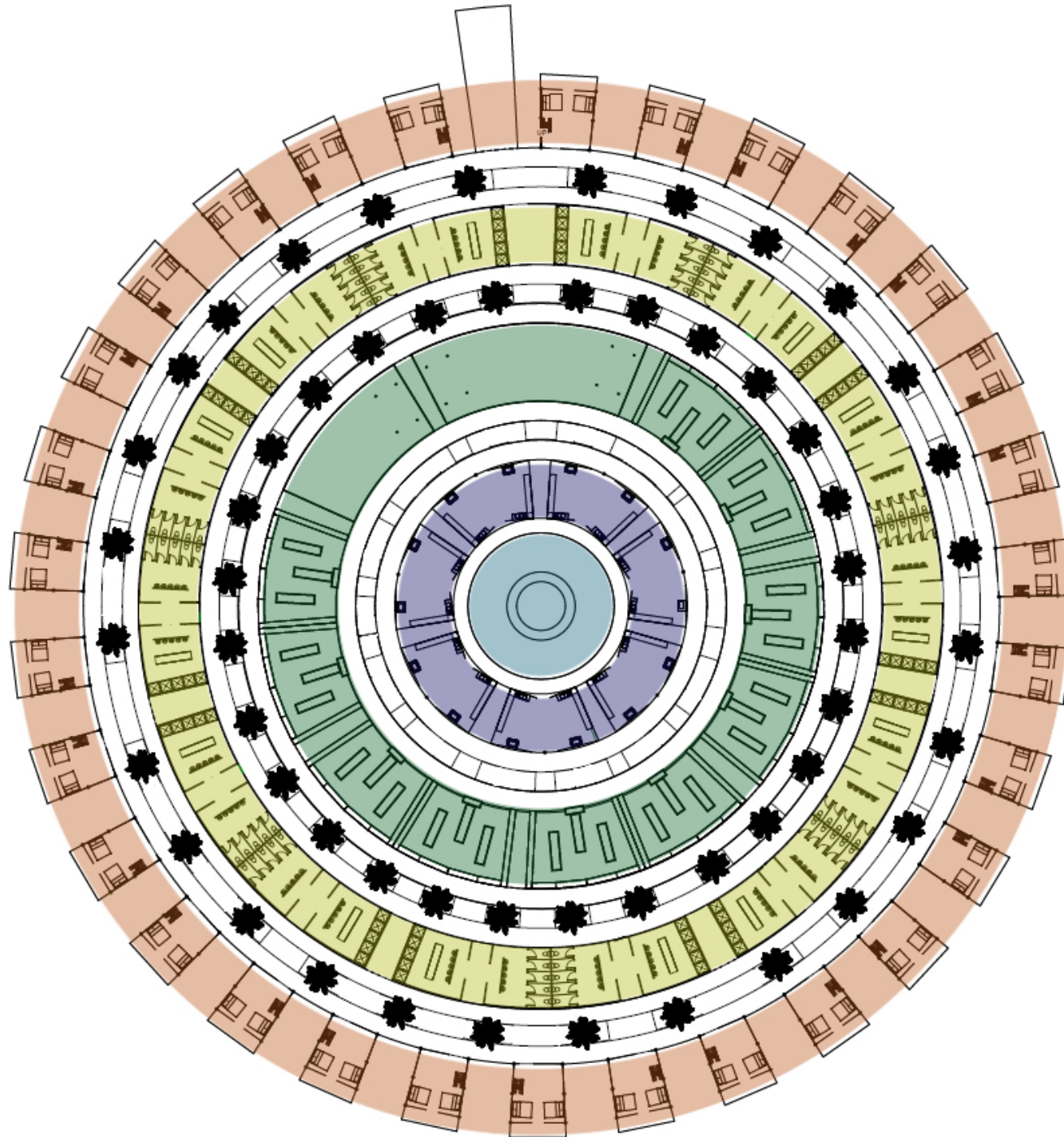


Figure 59 Urban plan showing all modular components radiating outwards from the centre, authors own work



Design Experiment 1

Modules

Critic

This experiment contains the necessary survival structures and systems, including community, connectedness and cooperation. The main structural materials are sourced locally and, in some areas, require local/traditional knowledge.

Climate:

Local materials are used throughout the modules and traditional knowledge of systems and material connections are required. The opportunities for education or training would ideally need to take place while the modules are being constructed and the traditional knowledge holders would have to be willing to share their knowledge, then, through maintenance, training could continue.

The elevated nature of the entire structure acknowledges adapting to the rising sea levels, while also being disaster resilient against the persistent storm surges. The elevation and location (over the lagoon) of this experiment means that the infrastructure would need to be sufficient enough to support it without having negative effects on the environment. This is possible, but maybe costly and difficult to maintain unless expertise and training are provided.

Ecology:

By including these NbS of rainwater harvesting, urban agriculture spaces, solar energy power and natural materials, this design shows consideration of climate induced sea level rise where traditional water collection is becoming impractical and unsanitary, soils are at risk of degradation and energy is a more commonly required resource.

As mentioned above, the impact on the environment and therefore ecology is minimal with this design so long as the proper systems are in place to protect it. With this design the connection between humans and the ecology are not strong but are present as there is access to the sea all around which the i-Kiribati rely on for sustenance and economic stability



Figure 60 Perspective section of half of the urban plan, authors own work



Design Experiment 1

Modules

Critic

Culture:

The living arrangements and traditional cooking methods are present within this design; however, the vertical horticultural method is somewhat new to Kiribati and may not be accepted or quite understood. The cultural values of the community are thought of and are shown through community gardens and shared facilities, but many cannot be addressed through design work. Empowerment of the community for this experiment would come from the community's engagement between each other and the services that would be needed to keep this design operational along with participatory design methods.

Conclusion:

The size of this experiment is rather incomprehensible for Tarawa Lagoon, however, the design could be constructed in sections as indicated by this design experiment's title 'modules'. The infrastructure required is foreign and would need to be carefully considered and training would need to be provided to ensure longevity.

While there are NbS present, they are minimal and are more beneficial to the humans and less so to the ecology.

The westernised nature of some of the components might prove to be essential (sanitation/hygiene) yet they may not be deemed acceptable or relevant. Walls are not common in many traditional structures or are made where they can be retracted but this design has failed to include such absence of walls and therefore the breeze is unable to travel freely throughout and provide a cooler more comfortable living environment.

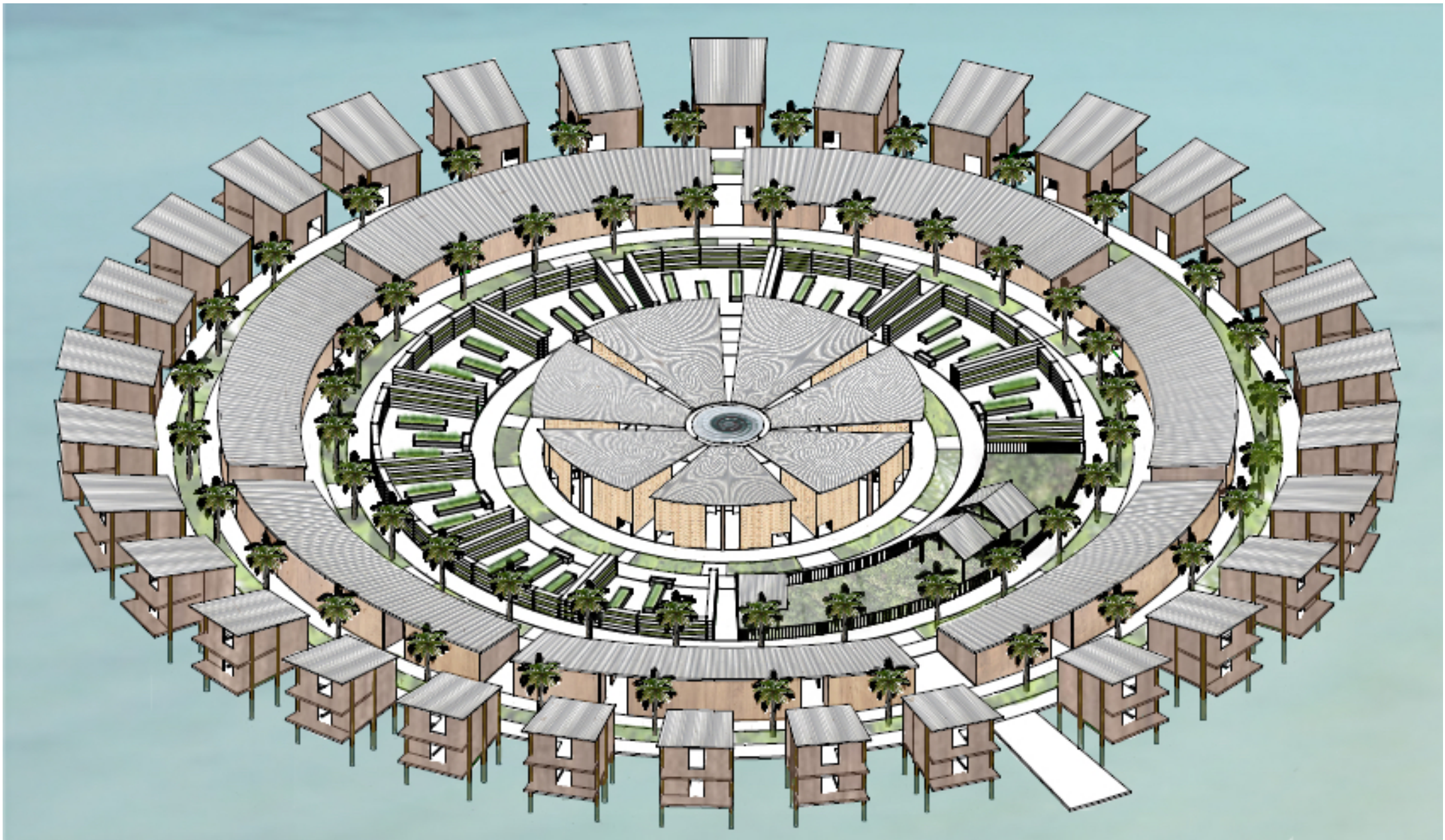


Figure 61 3D image of entire design experiment, authors own work

Design experiment 2

Shipping containers

The idea

This design is similar to the module experiment, except this experiment's structural component consists of shipping containers. This was chosen because a virtual walk-through of Betio showed that many shipping containers are situated throughout the area.

This idea was formed early on in this research, through quick start design work, before any site analysis was carried out. As more information was uncovered the idea evolved from the room structure with full kitchens, living rooms, bathrooms and bedrooms to the more traditional structure of Kiribati of three open plan structures.

The idea is that these shipping container rooms would sit upon an anchored floating structure made from locally sourced pandanus palms, which could then be easily replicated.



Figure 62 shipping container concept based of Western paradigms, authors own work

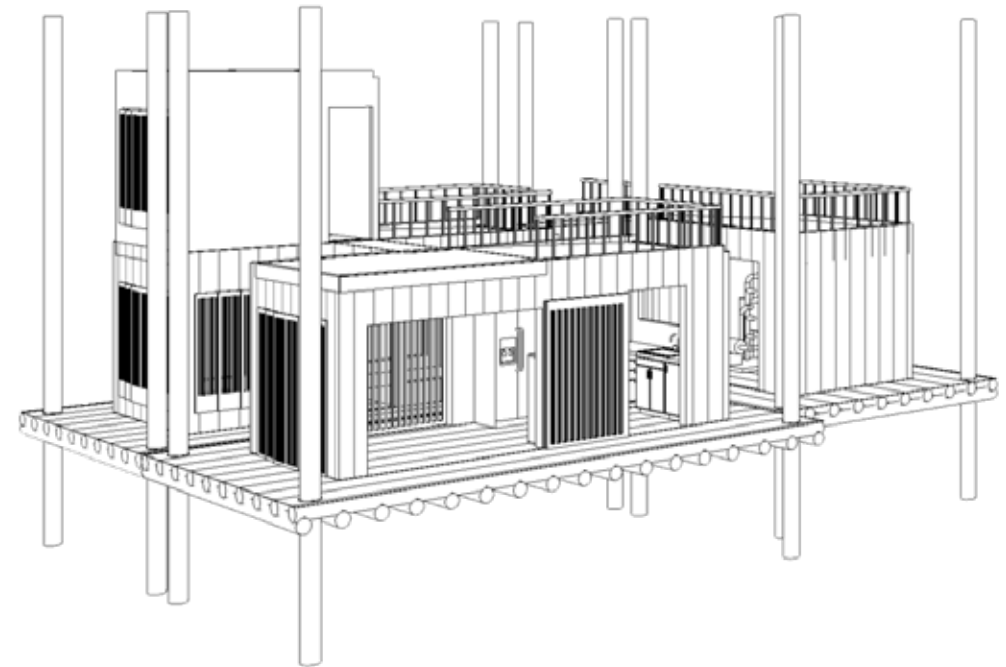


Figure 63 Shipping container modular living components on a floating structure, authors own work

Design experiment 2

Shipping containers

The Concept

Cultural analysis of the main uses of spaces in the traditional housing structures informs this experiment. The spaces/shipping containers are divided into 4 main areas which are as follows:

- The main space, on the lower level, is where cooking, hosting and sleeping would take place.
- The secondary space, located on the second level above the main space, would be considered the area best for sleeping as the height allows for air flow as well as privacy.
- The third space is for sanitation and hygiene which contains two showers, two vermiculture toilets and the appropriate infrastructure below. The last space is for agriculture which is situated between the stacked shipping containers in a courtyard-like formation.

The material and structure of this space allow it to float when storm surges occur, or the sea level rises to an unwarranted height thereby protecting the crops from sea water inundation.

The main and secondary spaces are flexible spaces within this design, as traditionally some houses/huts of Kiribati are singular and are subject to the sole room changing based on what is required of it.

The location of this structure is land based but can be elevated if need be. The location of this particular experiment is set back from the ocean enough to allow for mangroves to be planted, which would provide protection for the structure as well as for the ocean. The mangroves are provided nutrients from the excess liquid from the vermiculture toilets. The rooftop is split between iron roofing for rainwater collection and rooftop gardens which allow for further cropping and also serves as a kind of additional insulation (heat reduction) for the secondary space below as soil has a high thermal mass. The green walls in this design also offer a similar benefit; crops may grow, and the heat island effect is lessened while direct sunlight is prevented from hitting the building structure and therefore heating it up.

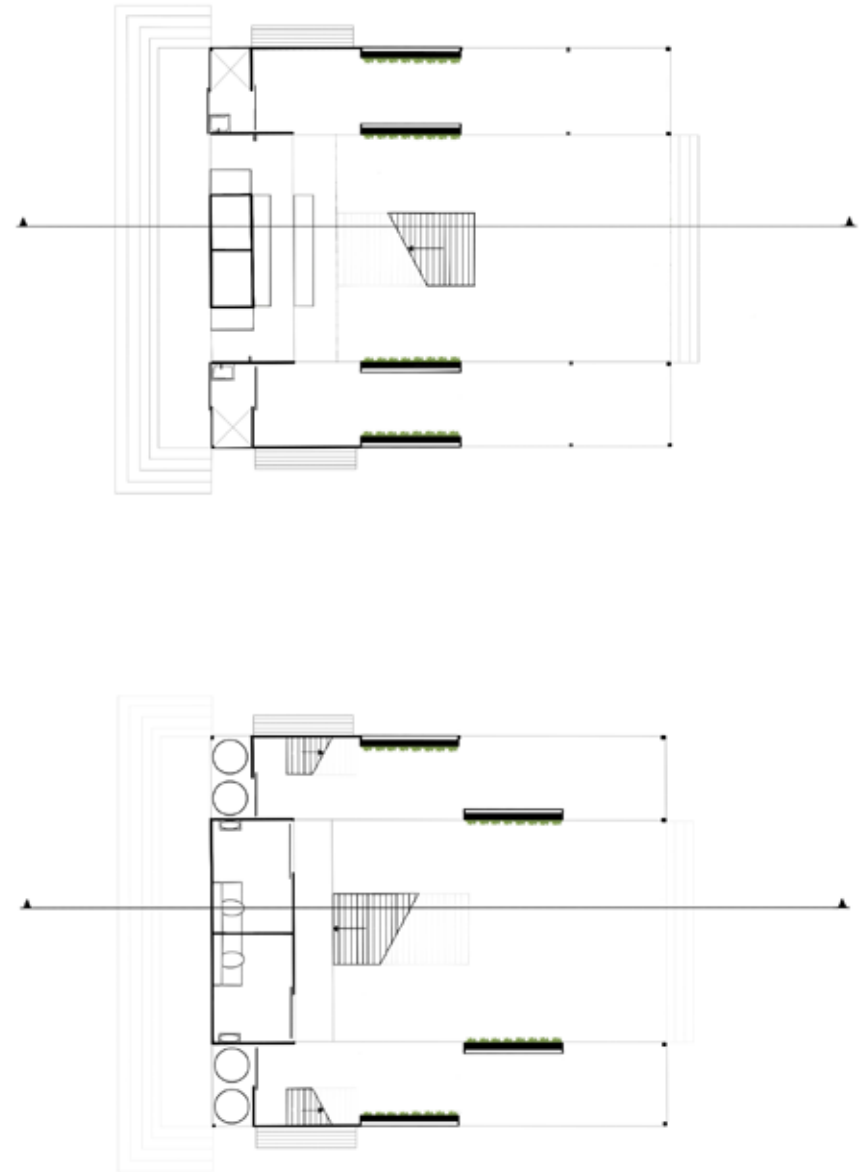


Figure 64 Plan of iterated shipping container modules lower (bottom) and upper (top) levels, authors own work

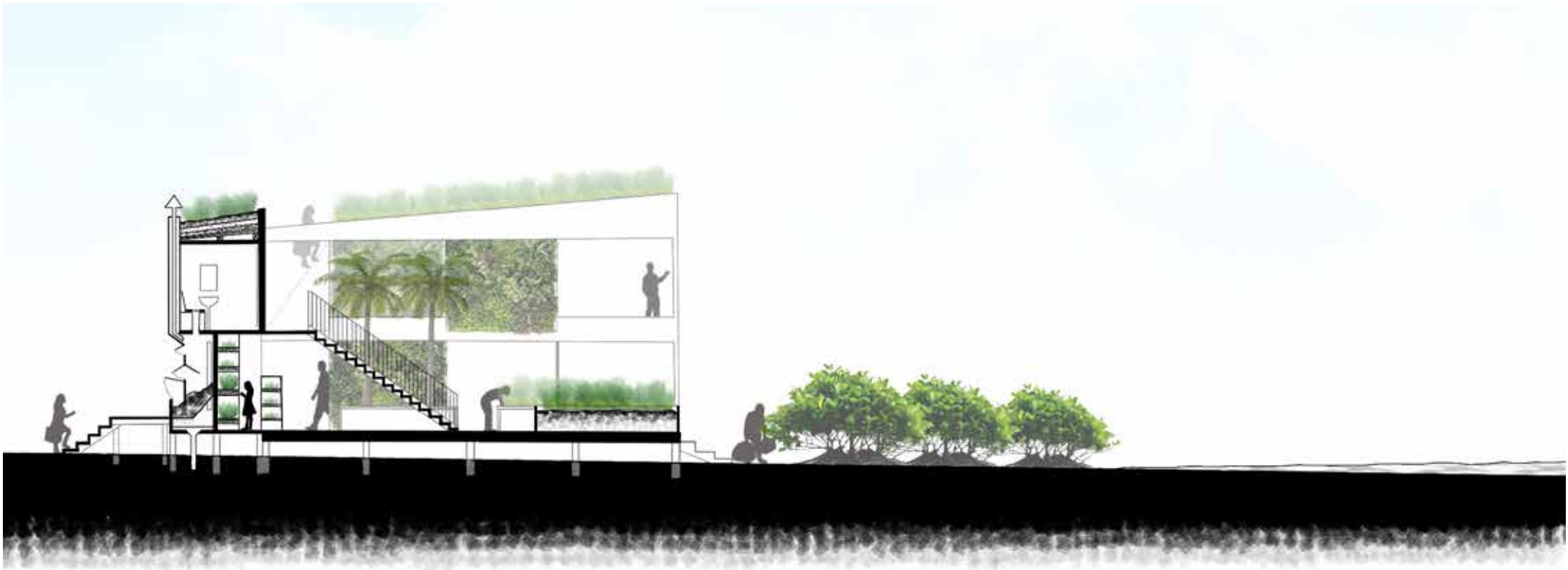


Figure 65 Section of iterated shipping container module design, authors own work



Design experiment 2

Shipping containers

Critic

This experiment responds to the research question through an elevated design to account for rising sea levels, incorporating NbS such as green walls, roofs, container gardens and vermiculture toilets. The design also acknowledges cultural understanding of the i-Kiribati living arrangements more effectively.

Climate:

In this design, local materials are used in the traditional sense, for privacy. Local knowledge of plant species is vital to the green roof as the plants located there will be exposed to the elements of wind and sun. While the floating courtyard garden is adaptable to storm surges, king tides and rising sea levels, the shipping container structures are stationary. The shipping containers will eventually corrode, and structural integrity will be at risk if over-exposed to seawater. This corrosion could be harmful to the environment and the ecosystem. The inclusion of vermiculture toilets has the potential to enhance the ecosystem if used correctly.

Ecology:

Mangrove restoration is the dominating NbS with this design, although it may require other interventions for it to be successful. By creating a temporary protective barrier like Te buibui could help the mangroves to reach maturity. Including green walls and a floating base for food production is a response related to the rising sea levels and helps to reduce heat island effect.

Impacts on ecology are minimal, although the transportation of the structure (shipping containers) would be considered harmful due to the high carbon emissions produced. The eventual corrosion of the shipping containers also has potential to cause harm to the ecosystem where metal and the shipping container coatings may leech into the environment and alter the ecosystem negatively unless correctly maintained. The connection between humans and nature is present through the vermiculture toilet producing a food source for the mangroves, which in turn provides the residential structure protection



Figure 66 3D image of iterated shipping container design, authors own work



Figure 67 Render of iterated shipping container design, authors own work



Design experiment 2

Shipping containers

Critic

Culture:

Having open flexible spaces allows the users to interact with the space how they see fit. This is a normal practice in Kiribati, where the spaces are used for more than one purpose. The cultural values of community and equity are present through the layout of the design where common space is centred, and the private spaces are equal in size. Water and breeze are highly valued in Kiribati, which is why the design includes rainwater collection and storage and is constructed without walls which allows for airflow. Traditional covered mats are intended for floor coverings. The cultivation of the garden, and the maintenance of the toilets are the main sources of empowerment intended with this design as the inhabitants would have to maintain them.

Conclusion:

The Corten steel used to make shipping containers is said to withstand direct saltwater exposure for 100 years with protective rust (Amardeep Steel Centre, 2021). After this it could cause significant damage to the environment and ecosystem, however, alternative materials should be explored. The elevation of the structure is important in providing protection against rising sea levels and storm surges and should be included in any further design work. Including a system in which humans work in tandem with the shoreline, mangroves enhance the resilience of the structure and, ecosystem and provide a unique human and ecological connection. Further designs should provide more elements where community empowerment is present as the architecture itself does not strongly show this. Self-sufficiency and empowerment could be achieved by including more local materials in the designs which would allow for local knowledge to be applied, and any maintenance would be able to be done without outside intervention.

Design experiment 3

The Canoe (te wa)

The idea

The traditional canoe (wa) is important to the I-Kiribati way of life, providing a vessel for fishing and recreational sports. This was used as an inspiration for this design experiment by exploring how this vessel could be architecturalised.

By visualising the main structural components from the wa as a base for this design, the idea that this experiment could also have the means to become buoyant, when the need, arose. This could solidify sovereignty for the residents of Tarawa as the sea continues to rise. This is important because people want to stay there, and also because inhabitation is connected to fishing rights, a key source of income for i-Kiribati.



Figure 68 Sketch of traditional Kiribati canoe, authors adaptation

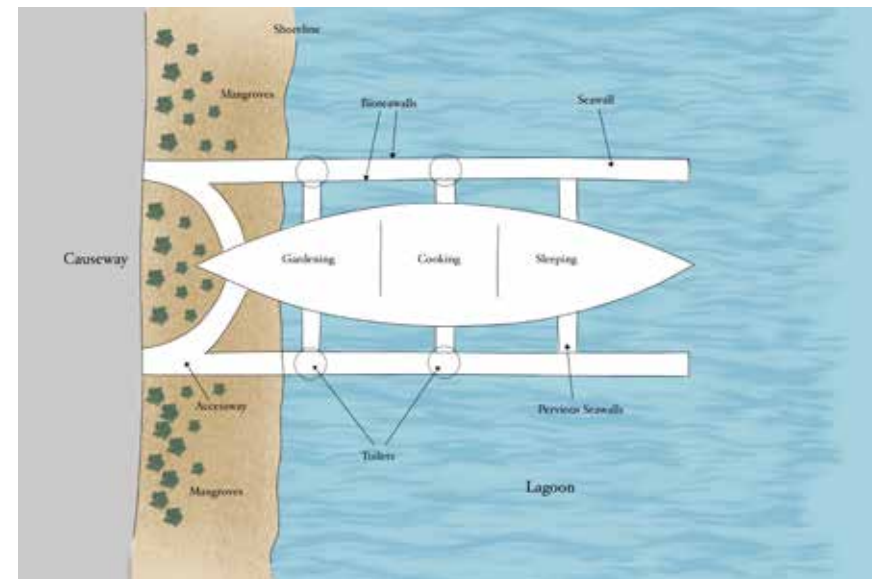
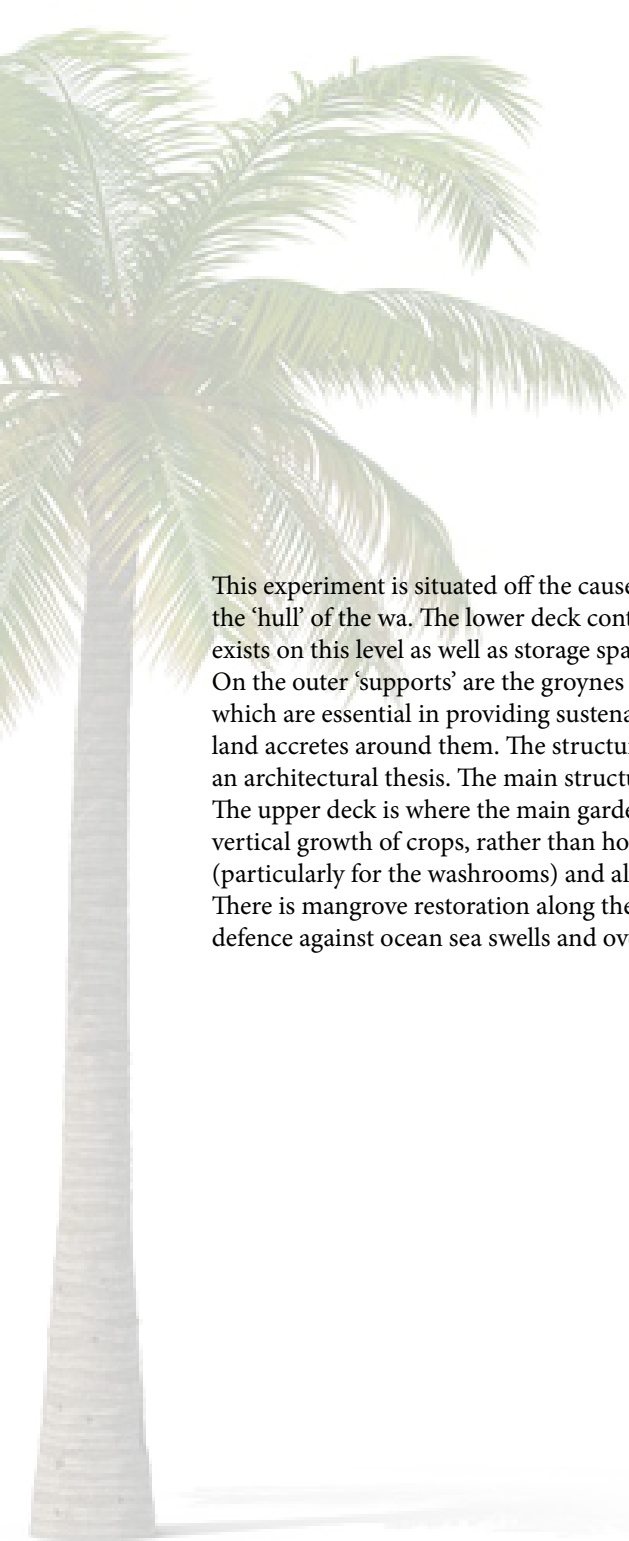


Figure 69 Sketch of how a canoe could be architecturalised, authors own work



Design experiment 3

The Canoe (te wa)

The Concept

This experiment is situated off the causeway on the lagoon side with the intention that the causeway will serve as a seawall. The design has two main spaces, or decks, which are the 'hull' of the wa. The lower deck contains the cooking area which can also double as the sleeping area or be closed off to create two separate spaces. A small washroom also exists on this level as well as storage space.

On the outer 'supports' are the groynes with biodiversity tiles and brush structures to support biodiversity. These groynes also house the vermiculture toilets and palm trees which are essential in providing sustenance, construction materials and support the economy. The concept is that these supports would be able to be built upon or extended as land accretes around them. The structure itself would affect water currents and therefore land accretion but understanding the exact implications of this are beyond the scope of an architectural thesis. The main structure would also move further into the lagoon.

The upper deck is where the main gardening space is allocated as well as the water collection and filtration facilities. Both upper and lower decks contain living walls to allow for vertical growth of crops, rather than horizontal. This allows the horizontal spaces to be used for other activities. The green walls also provide some sense of permanent privacy (particularly for the washrooms) and also aid to reduce temperatures.

There is mangrove restoration along the causeway, and this should continue to regenerate if the groynes do accrete land as expected. These mangroves would serve as a secondary defence against ocean sea swells and overwash should the causeway fail to do so.

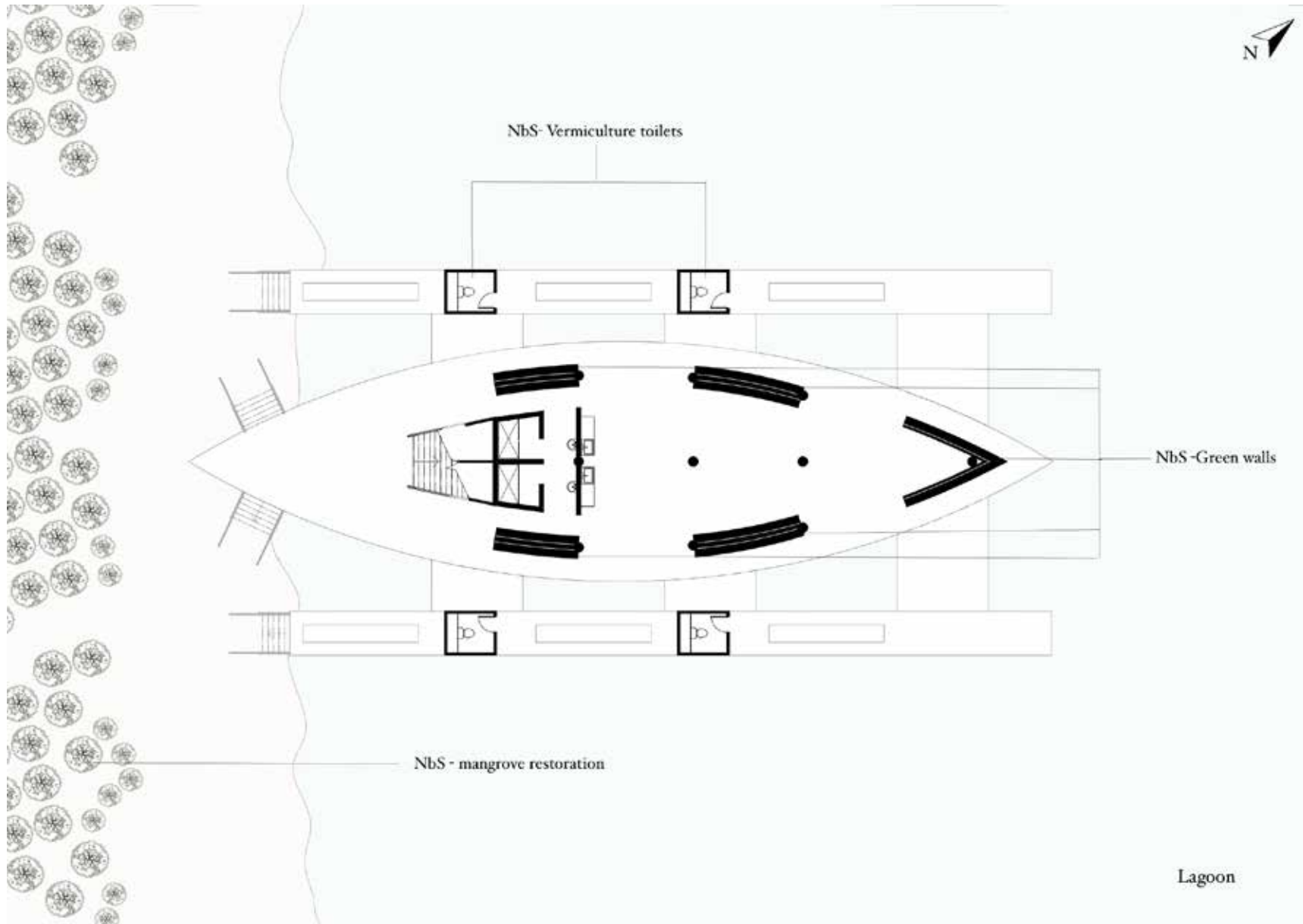


Figure 70 Lower level plan of canoe design experiment, authors own work

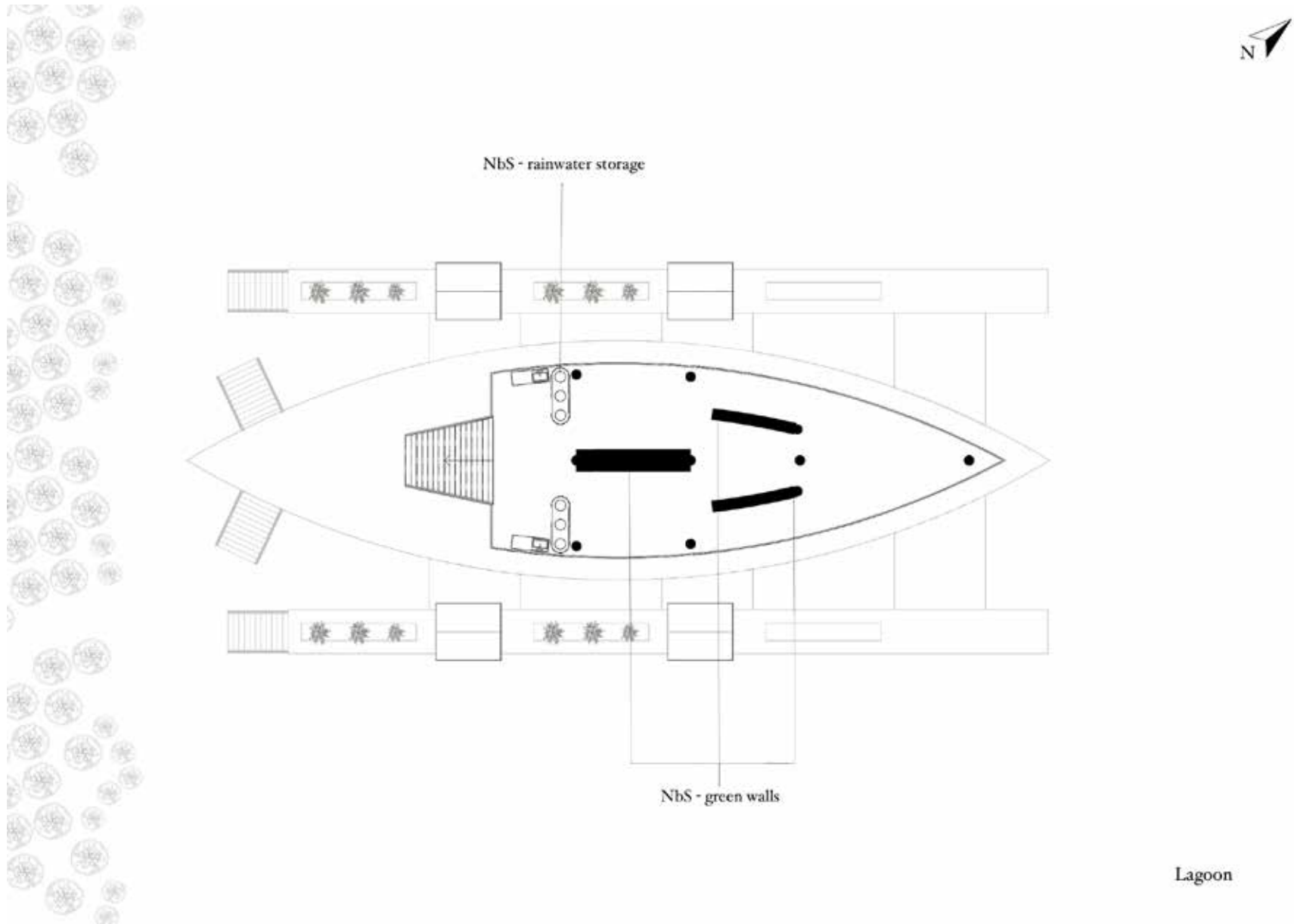


Figure 71 Upper level plan of canoe design experiment, authors own work



Figure 72 Section of canoe design experiment, authors own work



Design experiment 3

The Canoe (te wa)

Critic

The wa experiment acknowledges the rising sea levels, environmental and ecological impacts and shows better understanding of the Kiribati lifestyle/living arrangements. However, some areas could be improved upon, particularly where human and ecological interconnection is considered.

Climate:

The main structural materials would need to be buoyant in order for the floatable function of this experiment to operate. These materials could be sourced locally in Kiribati (Pandanus palm) but may require greater understanding of material integrity and longevity for the size of the structure. As this experiment would have the ability to float and expand as necessary, it does show climate adaptation in response to rising sea levels. Positive environmental impacts are created as the mangrove restoration increases air and water quality while also acting as a land stabiliser.

Ecology:

The included NbS promotes self-sufficiency, environmental enhancement or restoration and encourage biodiversity growth. The green walls can provide sustenance where the atoll may not be suitable, while also increasing air quality. The biodiversity sea walls, and mangrove restoration promote healthy lagoon conditions. Considering a hybrid design for the groynes where the infill could be similar to Te buibui would have fewer negative impacts to the lagoon ecology than a typical concrete one. This would provide the lagoon with improved water quality and the wildlife in it with potential homes/food. In this way the interconnection between humans and the ecology is present but would be made even stronger through further NbS incorporation.



Figure 73 3D image of canoe design experiment, authors own work



Design experiment 3

The Canoe (te wa)

Critic

Culture:

This experiment shows understanding of cultural values in the way living arrangements are considered. The open flexible spaces where breeze can flow freely through the structure are paramount with this design, as the community of Kiribati values having breeze highly. Including space for coconut palms to be planted is a cultural consideration for this design as the reliance on the coconut palms is vital to i-Kiribati people. The inclusion of green walls and water harvesting systems gives people a sense of self-sufficiency, which in turn gives feelings of empowerment. Empowerment (and security) can also come from the fact that the structure is able to withstand rising sea levels and storm surges due to the floatable nature of the design.

Conclusion:

This experiment demonstrates a thorough response to climate induced sea level changes where the design can adapt accordingly. The materiality of this particular part of the design would need further consideration of the structural integrity, buoyancy, longevity and stability of materials are considered. The groynes' seawalls would need to be refined further in regard to structure, strength, and durability to ensure minimal impacts on the environment, especially if the Te buibui concept is to be applied. Increasing human and ecological connection would elevate this experiment and could be done with further incorporation of NbS where ecological impacts are strong and positive. The design layout is credible when measured against the cultural values and lifestyle of the I-Kiribati, particularly where air movement is considered. Traditional knowledge, use, and importance of the coconut palm can continue to be shared as the design includes space for this plant.



Figure 74 Rendered image of canoe design experiment, authors own work

Design experiments

Extractions

Design experiment critical reflections highlight the following:

1. Food and water security
2. Modular design
3. Nature-based solutions
4. Ecological connection
5. Cultural considerations

1. All of these design experiments show alternative and shared agriculture techniques and rainwater harvesting which aim to increase food and water security. These techniques should carry through to developed design as the inclusion of such ideas provides not only food security but also feelings of empowerment.

2. Design experiment 1 – Modules, and design experiment 2 – Shipping containers, both showcase ideas of module-based design. Although Experiment 1 is rather large, it considers the current local living arrangements; separate spaces for different activities with separate components/structures for each. Experiment 2 also shows this, but it is done on a much smaller scale, with a system that is already module based and has the capacity to increase vertically. The potential to increase a structure vertically is appealing in the context of urbanisation and sea level rise, therefore this part of the shipping container experiment will be considered in future design work.

Design experiments

Extractions

3. Nature-based solutions are present in all experiments however the benefits related to the climate, ecology and humans vary with the specific NbS incorporated. Green walls are present in Experiments 2 and 3. They provide food security and also aid with reducing the heat island effect, particularly in Experiment 2 where the materials used are prone to conducting heat. Including green walls allows space to be used efficiently when there is little available or when it is required for another purpose. Therefore, continued inclusion of green walls is warranted in any further design work for South Tarawa.

4. Experiment 3 begins to show a deeper human and ecological connection through the use of biodiversity tiles along the seawall which could be further be enhanced in conjunction with other NbS, such as fish aggregation devices. Mangrove restoration and regeneration are also present in Experiment 2 as well. Incorporating this NbS has benefits for the ecology, architecture, and humans. In both experiments, the mangroves are reliant on humans for supporting nutrients and humans are reliant on the mangroves to provide protection and seawater filtration. Mangrove restoration/regeneration should continue as a standard NbS in design work for South Tarawa, particularly where lagoon-adjacent designs are considered. Not all areas are suitable for mangrove planting in South Tarawa however.

5. Cultural considerations are present in certain aspects of each experiment. Experiment 1 shows this by having separate spaces for certain activities and including fire pits for traditional cooking methods. Experiment 2 and 3's design layouts provide flexibility of spaces where the I-Kiribati use one space for many purposes. The open plan arrangement alongside the openness of the structure also recognises cultural understanding, where breeze is able to flow through the structure with minimal obstructions. All experiments include green spaces for coconut palm cultivation, as this is a significant source of food, material, income, and a significant traditional knowledge base for i-Kiribati.

Design experiments

Key extractions



Key takeaways from these experiments that should be included in further design work are:

1. Rainwater harvesting systems are important to increase water security
2. Green walls are useful to increase food security in an urban setting and reduce the heat island effect
3. Designs should be modular as this preserves the ability to increase in size easily
4. Designs should have a strong ecological connection – co-dependency or respect between ecology and humans is culturally significant
5. Cultural understanding and norms should be incorporated, and air movement should be at the forefront of design decisions alongside traditional knowledge continuity.

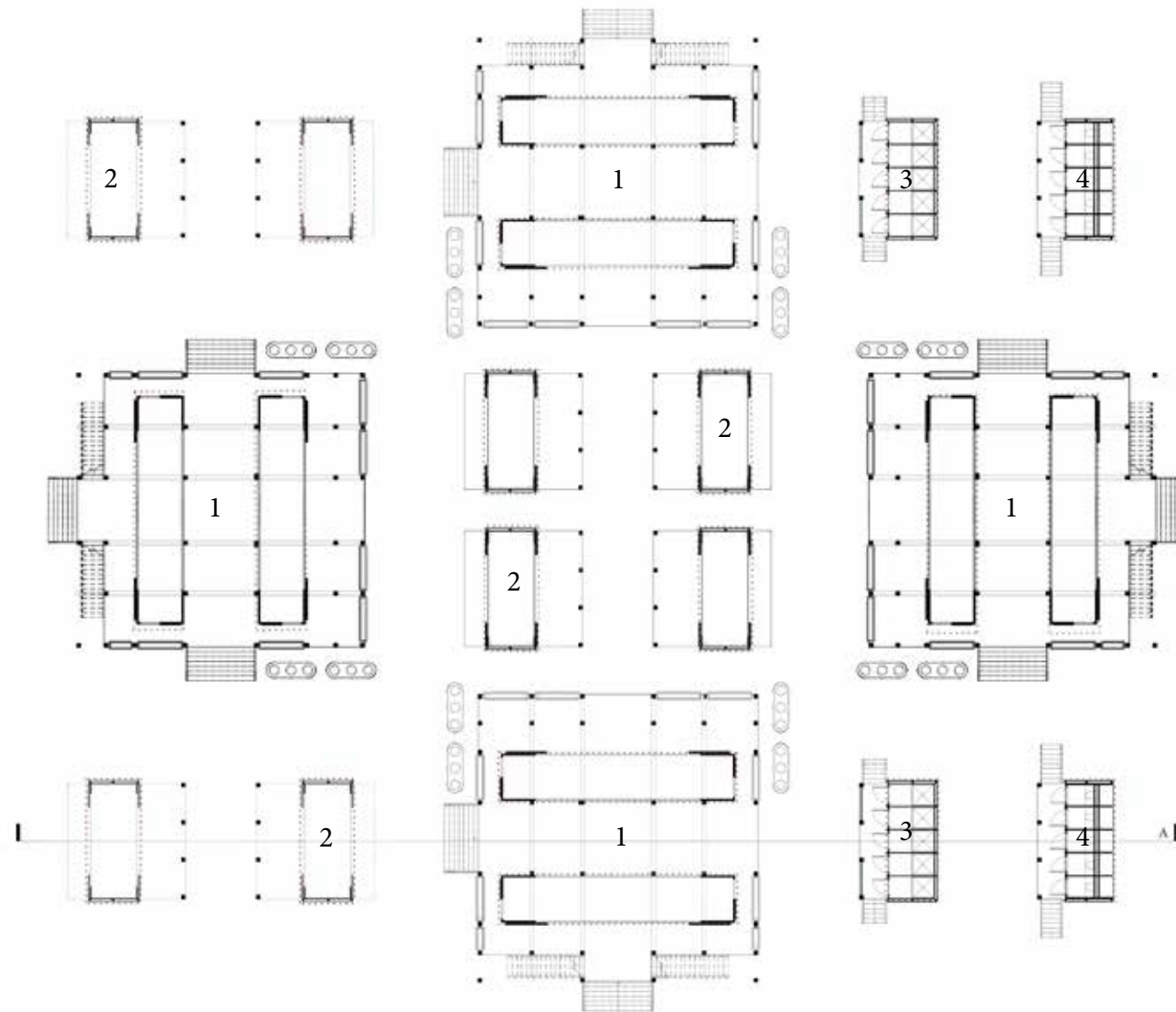


Chapter 8

Design Development Introduction

This chapter presents a design developed from the previous chapter's experiments. The developed design takes elements from all three experiments but is derived mostly from design experiment no. 2 which focused on shipping containers. This is for the reason that shipping containers are accessible to South Tarawa, and they are multifunctional; they can serve as the storage and shipment space for the construction materials required, then be altered for another purpose, in this case accommodation. Analysis, discussions, and conclusions follow with references to precedent studies, NUWAO fieldwork, meetings, and the theoretical framework for this thesis.

Plans



Key:

- 1 - accomodation/main living space
- 2 - cooking area
- 3 - shower module
- 4 - vermiculture toilet module

Acoomodation/main space shipping containers are 40ft all others are 20ft.

Dotted outline shows placement of shipping containers.

Figure 75 Lower level plan showing where the shipping containers are located and potential layout for all modules, authors own work

Plans

The upper level shipping containers are placed perpendicular to the lower level. This creates a court-yard like setting in the middle.

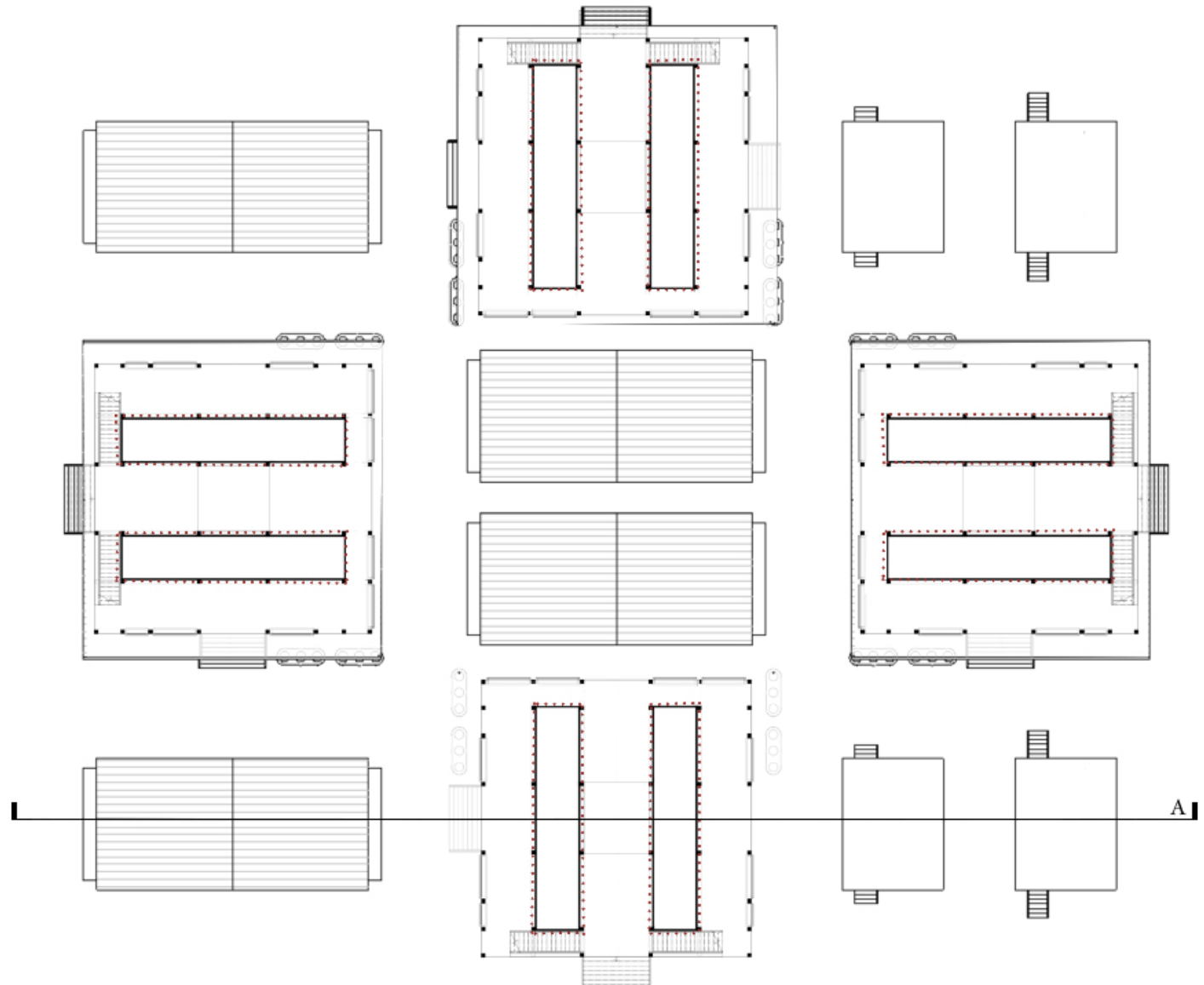


Figure 76 Upper level plan showing top floor layout and shipping container location, authors own work

Programmes

Key:

Blue
- accomodation module

Red
- cooking module

Green
- sanitation and hygiene module

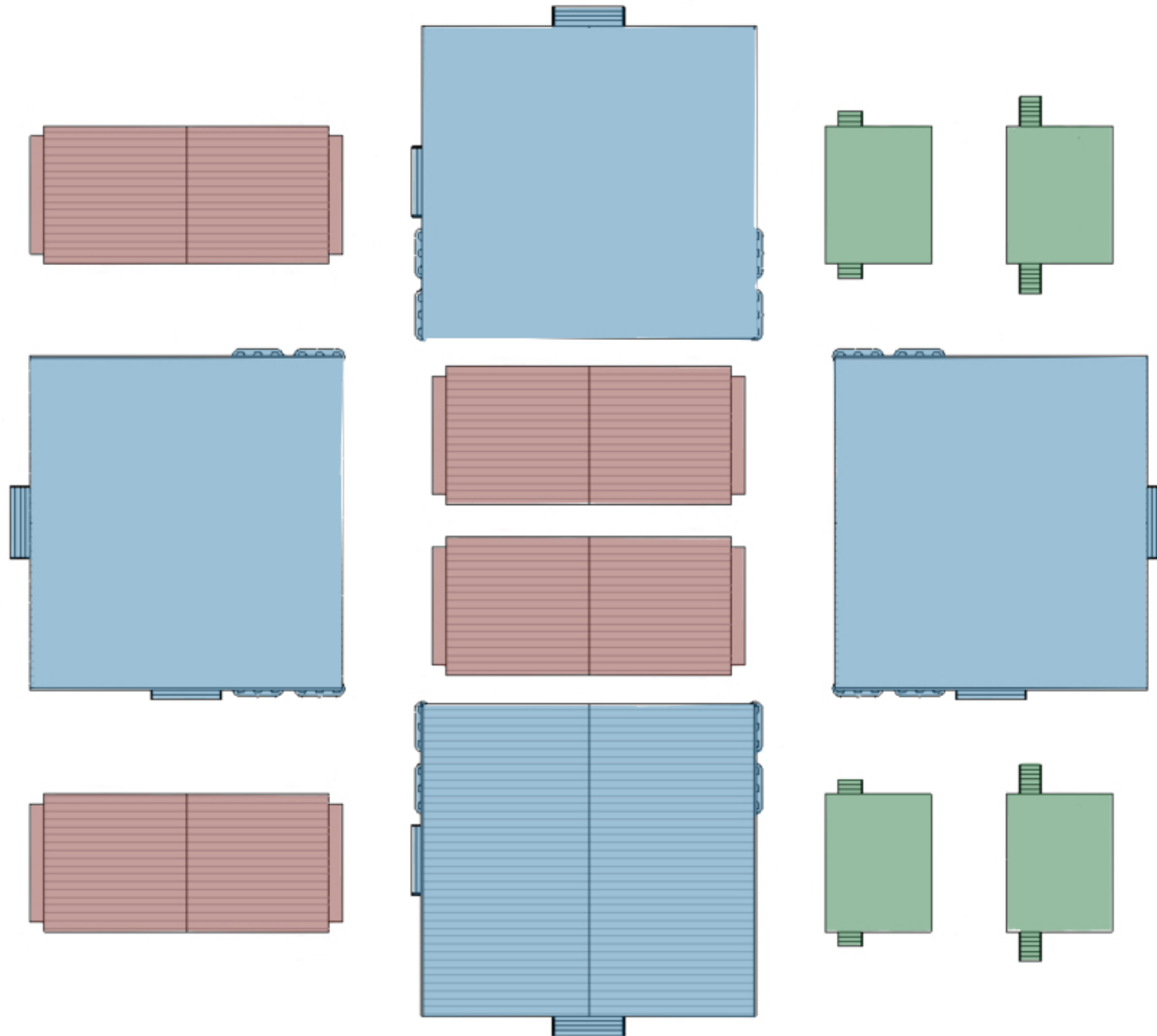


Figure 77 image showing programmes of each structure, authors own work



Figure 78 3D image of potential layout for all modules, authors own work

Location

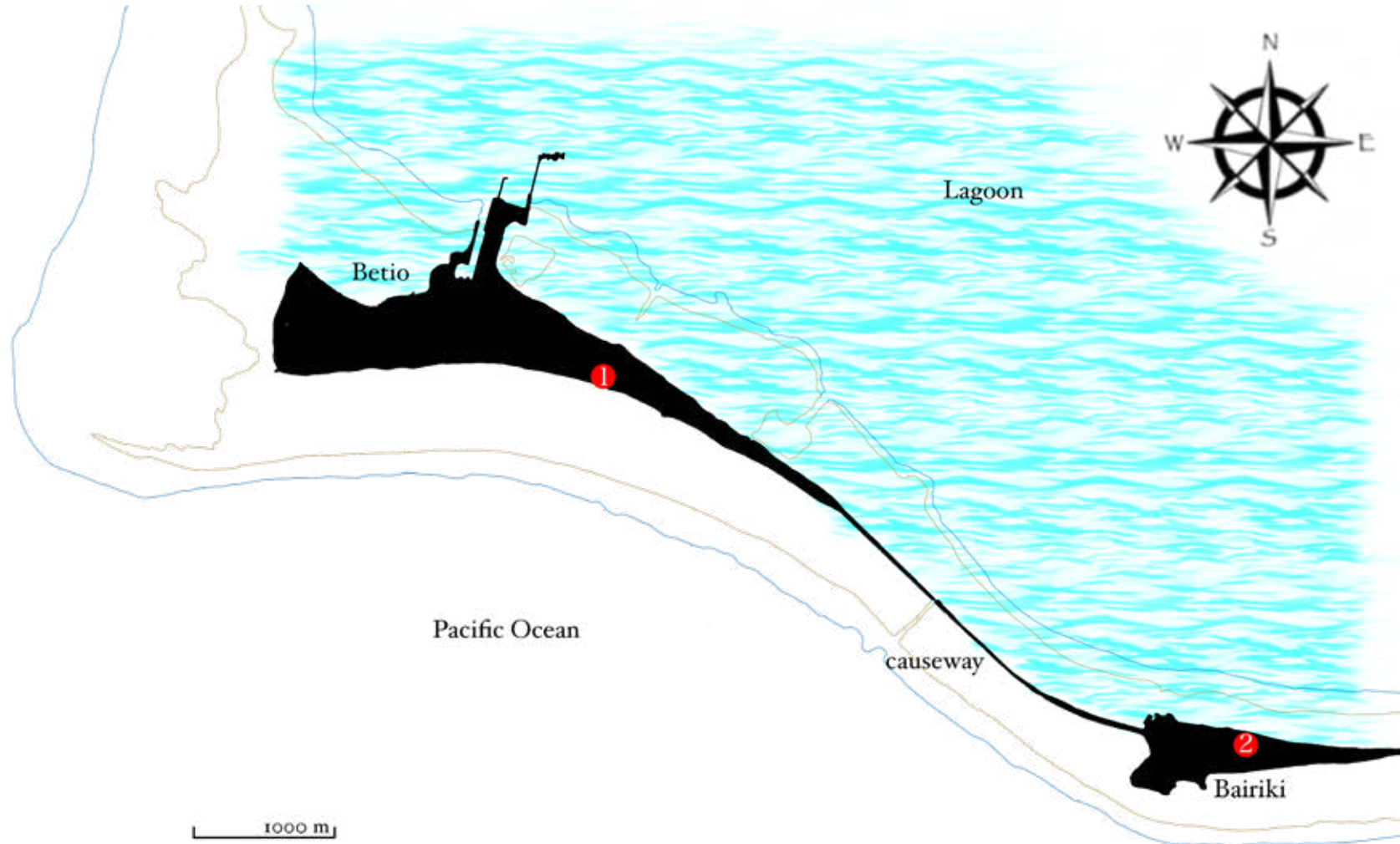


Figure 79 Map of Betio and Bairiki showing site locations, authors adaptation

Location - site 1.

Site 1. is located on the ocean side of Betio, where the density of people is high and the housing is in very close proximity.



Figure 80 Structure positioned on site 1. authors own work

Location - site 2.

Site 2. is situated on the lagoon side of Bairiki. This location has the available area to situate one of each of the modules without displacing any living beings as this is bare land (currently used as a 'boat ramp') The vegetation is spaced in such a way that allows for the construction of the structures without impacting either the plants, or local wildlife.

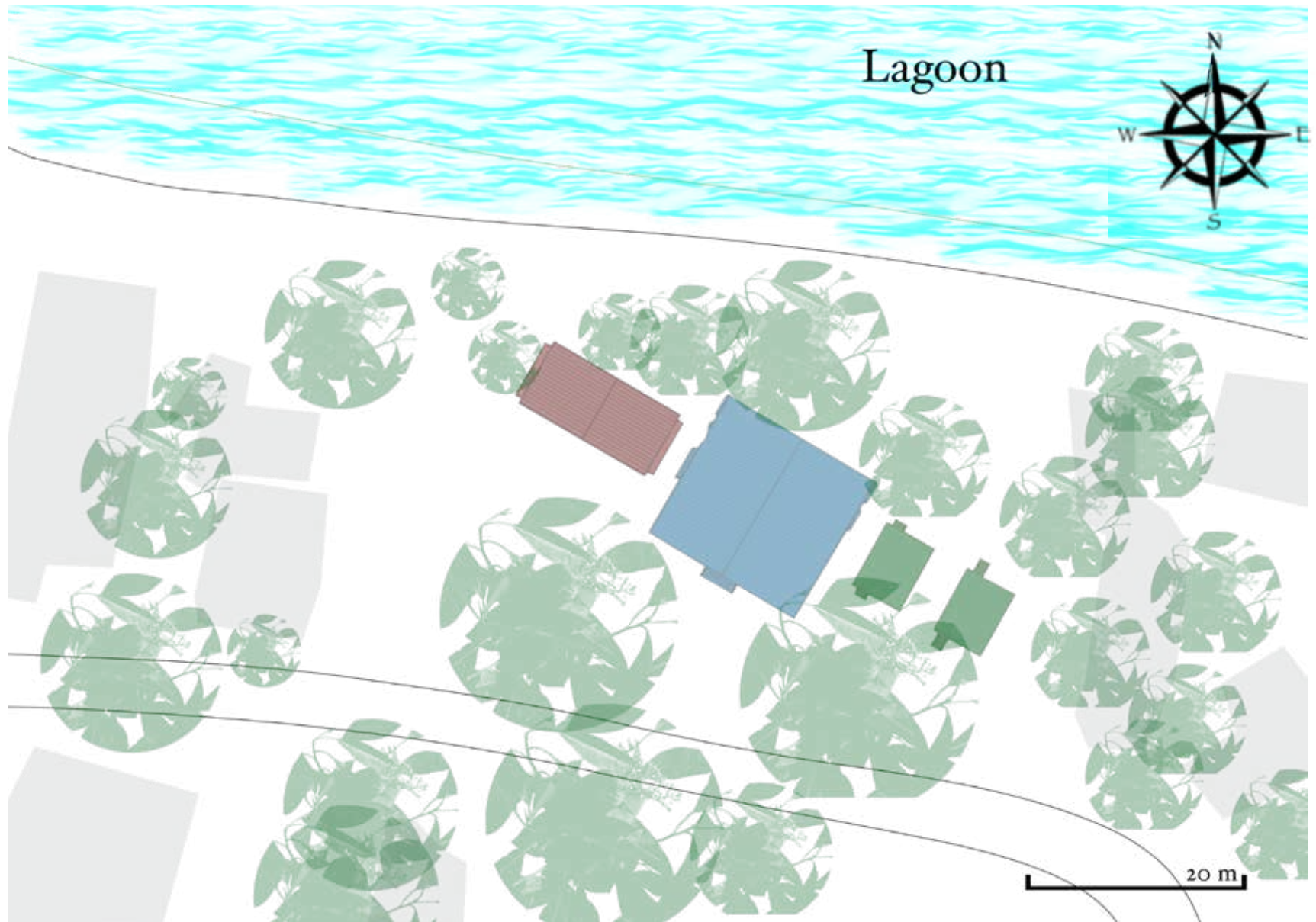


Figure 81 Structures positioned on site 2. authors own work

Materials and Construction

The stages of construction involve several different techniques, knowledge and structural understanding. The footing for the shipping containers, which would have a height above ground of 1 metre minimum, will need to be made of marine grade quality timber in order to be able to withstand continual overwash and potential sea inundation due to sea level rise. These will need to be placed prior to the shipping container arrival.

The framework that envelops the stacked shipping containers is comprised of cross-laminated timber (CLT) columns and Glulam (GLT) beams which are connected together using marine grade steel joinery and bolts. These materials have been selected as they have low environmental impacts, high durability and the prefabrication ability aligns with the vision for this design, where the locals are able to create their own space.

The framework (bearers and joists) for the flooring would be provided in this design, however, due to the cultural value of airflow, the intended floor covers would consist of locally sourced materials, which allows further air infiltration and is traditional in Kiribati.

Container gardens intended to create the double skin façade are also a kitset design, this is to make best use of the space in the shipping containers upon shipment of all construction materials, while also encouraging education in construction. The green walls can be placed in lieu of the container gardens or louvers to help increase air quality and reduce the heat island effect. Lightweight timber louvres, in this design layout, are placed on the upper levels and have the capability to be adjusted which gives the inhabitants control over airflow quantity.

The rainwater harvesting tanks used in this design have been selected for their size a capacity, as the dimensions of the water tanks allow them to fit into shipping containers.

Roofing iron is becoming a more commonly used material for construction in urban Tarawa due to ease of access and the rainwater harvesting qualities. Both of these reasons are why it has been chosen for the roofing in the design on the accommodation and cooking modules. Gutters are also incorporated to enhance water storage capacity.

Most materials will be shipped in the six shipping containers used to create one accommodation, and one cooking module. The hygiene (shower) and sanitation (toilet) modules would be constructed off site in such a way that the exterior would still resemble a shipping container, therefore making shipment easier. Upon arrival, doors, hatches and other implements would need to be positioned as per the design.

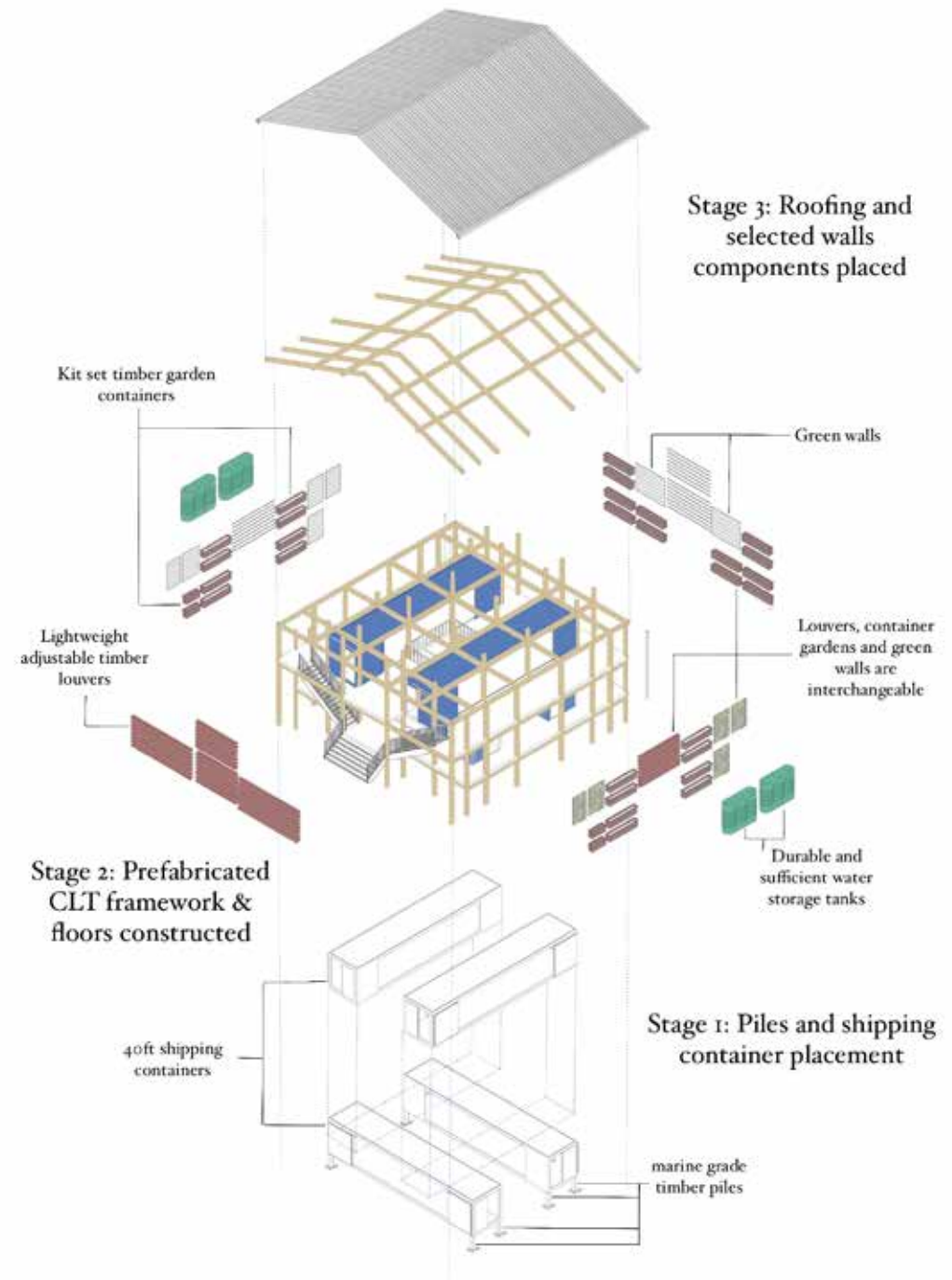


Figure 82 Exploded view of structure, authors own work

Details & Assembly

A combination of CLT and Glulam framing would be the main structural elements with metal brackets and commercial grade bolts used to secure connection between the necessary structural elements.

The selection of these materials and construction techniques allows for deconstruction, adaptation and additions to be made without the need for major structural changes.

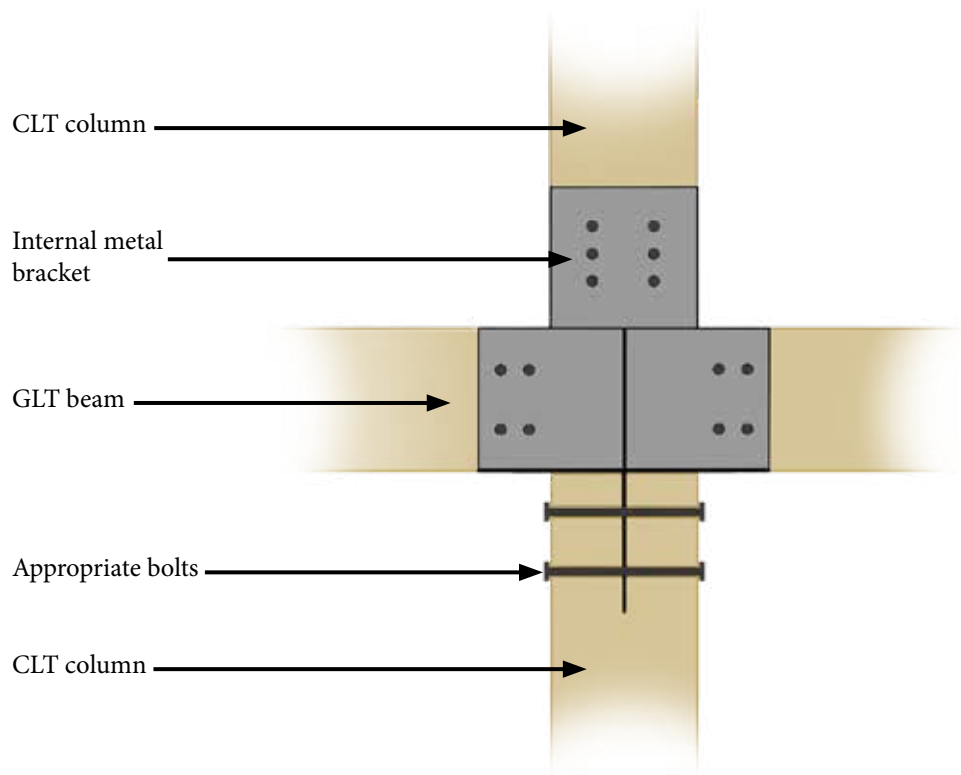


Figure 83 Detail of column-beam-column connection, authors own work

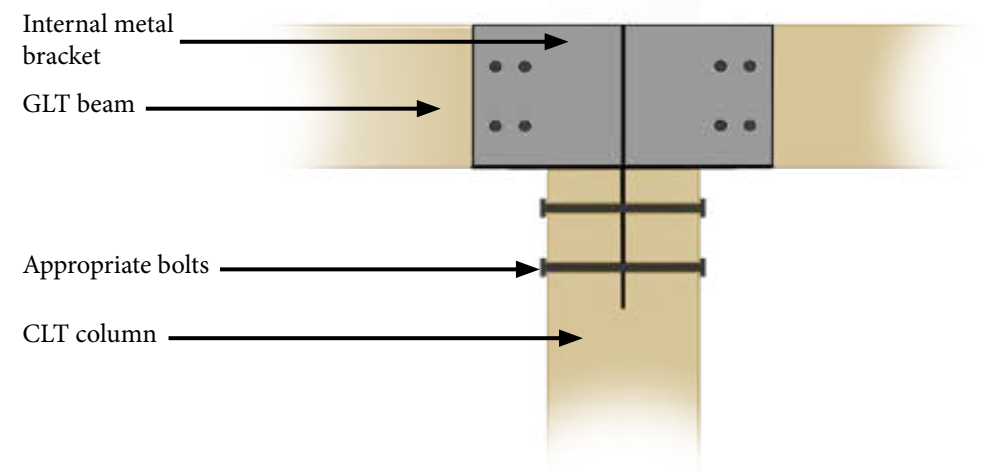


Figure 84 Detail of column-beam connection, authors own work

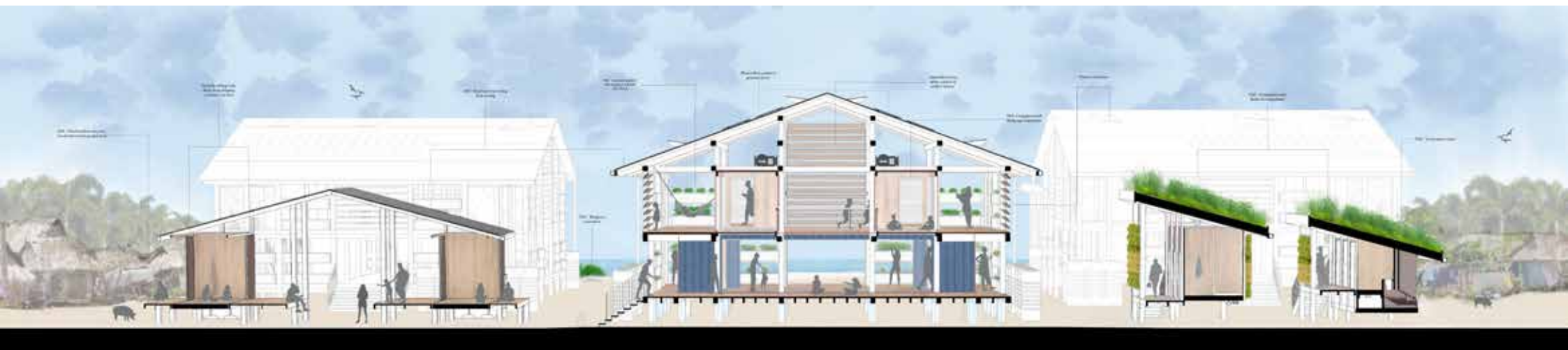


Figure 85 Perspective section (A) showcasing NbS and programmes, authors own work

Cooking module

Common cooking practice in Kiribati involves open fires or butane camping stoves. Other 'normal' kitchen appliances are also not common.

Two 20ft shipping containers are the base for this module and like the accommodation module, a roof extends between them, providing additional shaded space from the sun and increases water harvesting capacity. Once positioned atop the prepositioned piles, the sides of the containers would be carefully cut out, as outlined in the kitset information which would be provided. These cut out panels would then be used to create barn door-style sliding walls that would be situated on the exterior of the shipping containers where the material original was located. This allows the users of the ability to close the space if needed, for instance if there are strong winds which affect the cooking fires.

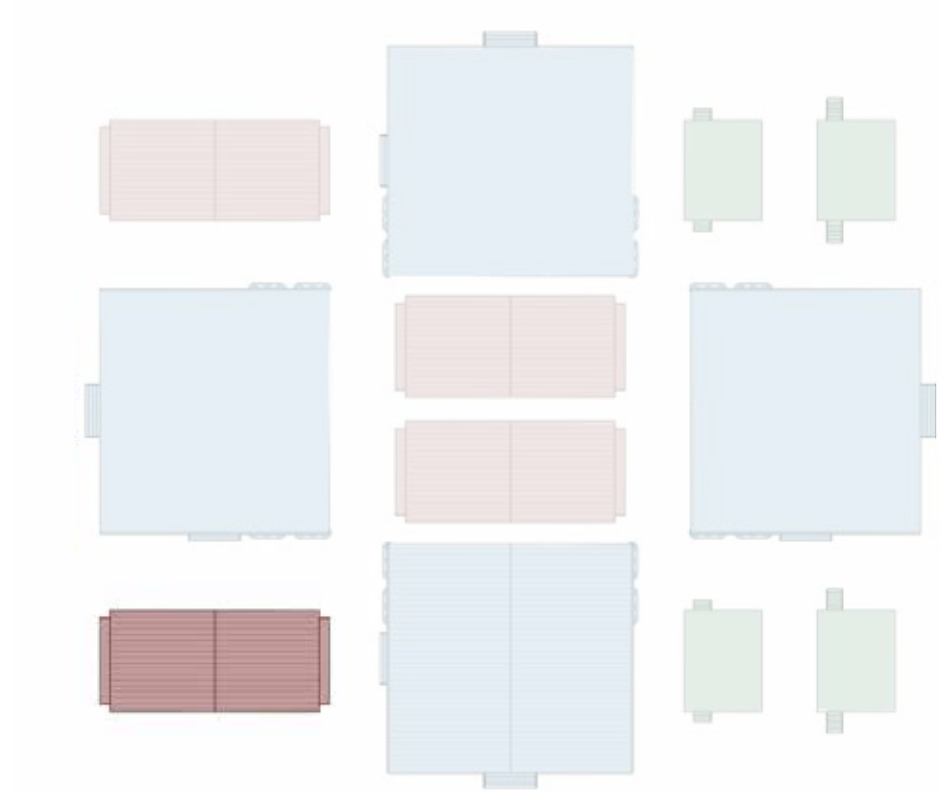


Figure 86 Adaption of figure 76, highlighting the cooking module, authors own work



Figure 87 Portion of figure 83, showcasing the cooking module, authors own work

Accommodation module

This module is the main component of this design as it hosts the most functions and NBS elements.

The exterior of this module's design has large verandas, on both levels, acting as a double skin façade with container gardens, green walls and adjustable louvers providing food production and necessary shading while still allowing airflow. These elements, as mentioned in the materials and construction section of this chapter, are interchangeable, which gives the occupants the power to choose whichever façade they desire.

Internally, the four 40ft shipping containers would have the same quality as the cooking modules, where the exterior facing walls would be cut out and replaced with the same material but transformed into sliding panels. This is useful when trade winds may be stronger than usual. It also provides flexibility and adaptability of the space.

A feature created by positions of the shipping containers and the roof covering, is the double height internal courtyard. This space is designed for communal use but can be transformed if needed. For example, if the main sleeping areas reach capacity, the courtyard could be converted to provide additional sleeping space. The double height and roof design aid with passive cooling and airflow. Where hot air rises, it is able to be released via the operable openings in the roof.

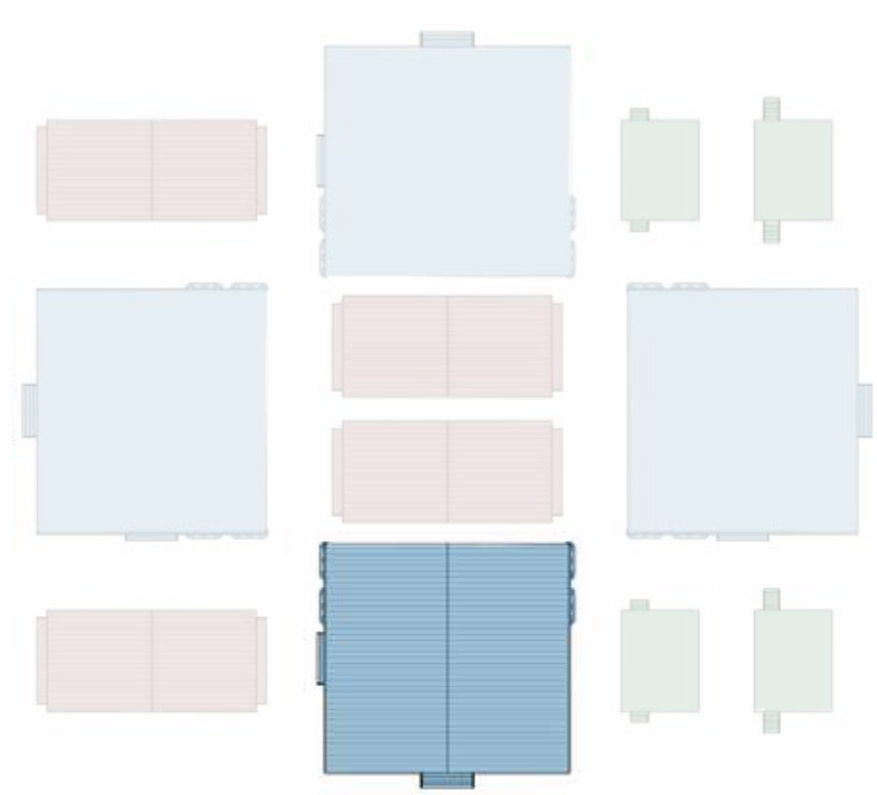


Figure 88 Adaptation of figure 76, highlighting the accommodation module, authors own work



Figure 89 Portion of figure 83, showcasing the accomodation module, authors own work

Hygiene and Sanitation module

This module is comprised of two separate modules, one for hygiene (showers) and the other for sanitation (toilets). Both of these modules would be constructed before being shipped to the site. This would be done in a way which still allows for safe secure and proper shipment of the shipping containers.

As shipping containers are made of corten steel, which has a high heat conductivity, this needed to be addressed. By incorporating green walls and green roofs this would aid with thermal regulation, especially where the vermiculture toilets are considered and help to reduce the heat island effect.

The vermiculture toilet system is a key feature of this design, as sanitation is one of the largest problems facing urban South Tarawa. This module is designed to be a standalone component, allowing it to be placed independently of the other two modules if desired. As this NbS requires no water, it is an ideal option for the population of South Tarawa, which faces several water related issues.

The system operates as a composting system. Faecal matter is deposited in the main collection chamber, which is set at such an angle that encourages material movement, sticks, twigs, and excess natural materials for example coconut husks, are then placed on top. Addition of worms aids with the waste to compost transformation. The end product (the compost) can then be placed on vegetation where culturally acceptable and enhance the environment. The inclusion of the system would be most beneficial to health and wellbeing of South Tarawa and the surrounding ecologies, as it encourages locals to avoid defecating in the lagoon or around the shoreline, which is currently an issue.

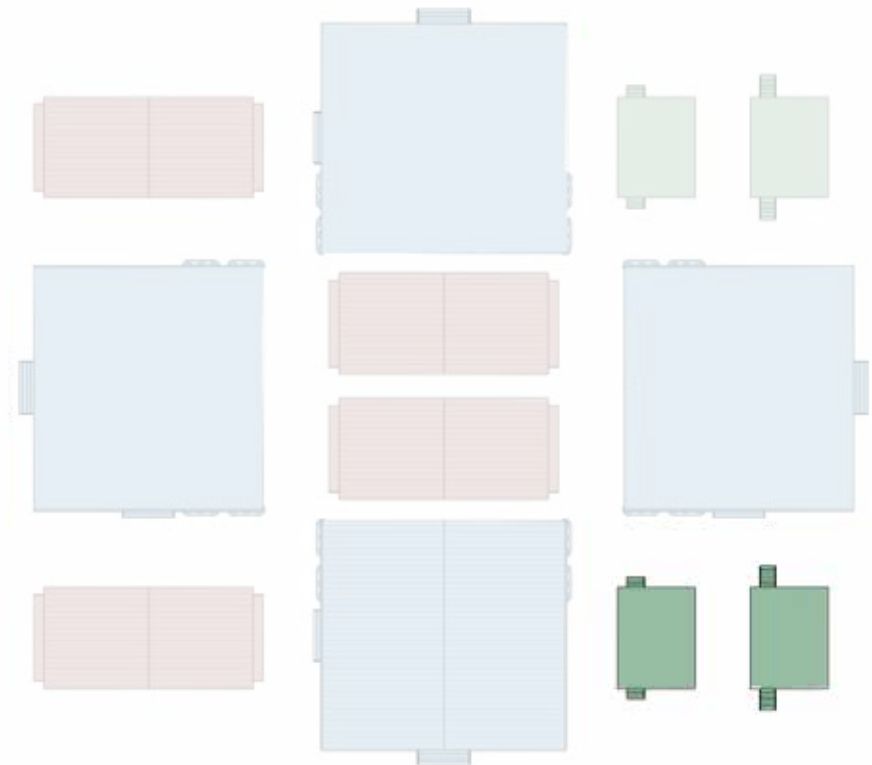


Figure 90 Adaptaion of figure 76, highlighting the hygine and sanitation modules, authors own work



Figure 91 Portion of figure 83, showcasing the hygiene and sanitation modules, authors own work



Figure 92 Authors visulisation of sanitaion module



Figure 93 Authors render of sanitation module



Figure 95 Adaptation of figure 83, depicting the year 2100 under the RCP 8.5



Figure 96 One of each module on site 2. authors own work



Figure 97 Site 2. in the year 2100, authors own work



Figure 98 Upper floor of accomodation module, authors own work



Figure 99 Upper floor of accomodation module with external door closed, authors own work



Figure 100 Upper floor of accomodation module, showcasing container gardens, authors own work



Figure 101 Visualisation of accomodation and hygiene block in accordance with RCP 8.5 sea level rise projections, authors own work



Figure 102 3D visualisation of all modules as would be situated on site 1, authors own work



Figure 103 3D visualisation of 3 modules situated on site 1, authors own work

Design Development Critic

Climate:

Materials for this design are not locally sourced; this is due to the structural requirements of the building. However, there are opportunities for local materials to be incorporated, such as woven mats to provide extra shading or as room dividers. This along with the construction of the structure allows for cultural knowledge sharing and education. The shipping container base components of the main space/accommodation design element would provide the transportation of the materials required to build the desired structure. This 'kitset' solution provides opportunities to increase skillsets while also enhancing empowerment perhaps for locals as they build their own structures, with the kit being flexible enough to be put together in different ways to suit different groups, sites, or programmes. With the most extreme sea level rise projections showing an increase of 975mm by 2100, this design is elevated at 1 metre above ground level as a response to these increased dead levels and more frequent overwash, but also to allow for increased airflow under the building to make more comfortable living conditions in the heat. This elevation could be increased further if desired to extend the occupant's ability to cope with the rising seas. The impacts on the environment are minimal as the systems incorporated like the solar photovoltaic panels and rainwater harvesting tools, function internally although the materials selected may not have the most positive impacts on the environment during manufacturing, for example the iron roofing and the metal bodies of the shipping containers themselves, they have been selected for longevity, durability against saltwater and salt laden winds and to make inclusion of NbS more practical and effective for example rooftop rainwater harvesting.

Design Development Critic

Ecology:

The NbS included in this design are to increase food and water security, positively impact the climate, but mostly to adapt to it, benefit and increase ecological wellbeing, and to create a comfortable living environment for people. NbS could be included to further the positive effects, such as nature-based stormwater management strategies and bio filters where excess water from downpours would be guided away from the structure to increase structural integrity while also positively impacting the ecologies (water harvesting and infiltration for example) and the climate (reduction of heat island effect for example). To significantly increase the effectiveness of the proposed NbS a more thorough understanding of the site and plant species capable of performing in such a location, and cultural relationships to these martial elements would be needed and would be based on interdisciplinary and local collaboration.

The inclusion of the vermiculture toilet system can positively impact the ecology through the composting capabilities. The final composted product can be used to enhance soil quality. Enhanced soil can be placed around mangroves, palm trees or other culturally acceptable vegetation. The vermiculture toilet system also reduces the need for sewage infrastructure because there is no water used. This would benefit the ocean and fresh-water ecologies in and surrounding South Tarawa as the current damaging, polluting, or difficult to maintain infrastructure (or just absent infrastructure) would be replaced. The vermiculture toilet system also illustrates and enhances positive connections between humans and local ecologies through the enhancement of soil quality, reduction of pollution, and increased ocean water quality.

Design Development Critic

Culture:

During a design crit with Naakori Taniera, a recent Master of Architecture graduate from the University of Auckland, NUWAO team member, and i-Kiribati person on the 3rd of October 2024, the importance of flexibility and was reiterated. Taniera implied that designs which allow the user the freedom to create spaces as they desire would be best accepted by locals. This design allows for that ability. The design lacks 'normal' household items such as ovens and segregated/specific rooms is typical of traditional architecture in Kiribati and allows the inhabitants to use and create the spaces as desired; whether that be closing the exterior shipping container doors to create a more internal space or crafting woven mats to hang between columns acting as walls. This open and flexible design allows for breeze to flow as needed while also giving control to the inhabitants over how much sunlight is permitted in and enables control about how to divide the spaces as required.

Community involvement and connection is active within this design, particularly within the accommodation module. The shipping containers are placed close enough to each other to enable a roof covering to span between them which creates an internal double height courtyard. The intention for this space is for communal whereas the shipping containers themselves would serve as more private spaces. However, the interchangeability and flexibility of the spaces when needed, is still present. For example the space could serve as a sleeping space where the private spaces are at capacity. This mimicks the mwaneaba setting, where visitors are able resided temporarily therefore aligns with the community and cultural values of the i-Kiribati.

The flexibility of spaces with this building structure gives power to the user. Empowerment is further enhanced with the incorporation of the double skinned façade comprised of container gardens containing of local edible plants. This incorporated NbS not only helps to reduce internal temperatures, but also aids to increase food security. The rainwater harvesting system can also provide feelings of empowerment as the occupants are able to collect their own water for use instead of relying on the public utility board, which is currently not able to supply fresh water (by filling local tanks) on demand.

Design Development Critic

Conclusion:

The design aligns with the sections of the theoretical framework devised in this thesis. The climatic impacts (GHG emissions) are minimal with the most likely element to have effects being materials manufacturing of the shipping containers and roofing in particular. This could be improved upon by selecting alternative, more climate friendly materials as they become available, however, in the case of the Schoonschip precedent examined earlier, these materials may not be economically sound. Projected sea level rises are responded to with the elevation of all structures in a way that has minimal impact on the environment. A thorough life-cycle analysis of the impacts of any module would need to take place, specifically where trees and other flora and fauna are considered to further tweak the design.

The NbS incorporated enable more effective climate adaptation, have positive impacts to the ecology and create connections between humans and ecologies to improve human-nature relationships. As discussed, further NbS could be included to increase structural integrity, disaster risk and flood resilience, particularly between and around multiple modules if they were built.

Understanding of the local lifestyle and culture has been considered carefully as possible given available resources. The flexibility and open nature of the accommodation module aligns with local values like having breeze and prioritising the flexibility of spaces. The separation of major programmatic spaces such as accommodation, cooking, and sanitation and hygiene aligns with traditional spatial arrangements. This separation also allows the user to locate the modules as desired. The vermiculture toilet module is design so that it could be placed appropriately anywhere in South Tarawa, meaning this module is considered a standalone design. The 'kitset' design would give the user a sense of empowerment and increased skillset, by enabling them to create their own space the way they want it. The integrated NbS that address food and water security would also increase the feeling of empowerment and self-sufficiency.

In conclusion, the design illustrates how the inclusion of thoughtfully chosen NbS in architectural design can enhance resilience, ecology and human wellbeing in South Tarawa, Kiribati, in the face of the changing climate while also considering local cultural values.

Conclusion

It is imperative that architecture can adapt to the impacts of climate change. This design research responds to the increasing urbanisation of South Tarawa, while demonstrating how to improve water and food security using NbS. South Tarawa has become a highly urbanised area and is already suffering from climate change induced events. By employing selected NbS in this extreme case, this research serves as a guide for how humans and nature can work in tandem, as the benefits to the climate and ecology are many and the climatic conditions continue to evolve.

The final design has been guided by chapters describing the theoretical framework, precedent studies, NUWAO fieldwork, and site analysis. This part of the work forms a foundation for a successful design outcome for this thesis. In order for the design to be successful it needs to align with the theoretical framework. The final design has been influenced by precedent studies that have components which align with the framework and could be positioned on the site of Tarawa. The NUWAO fieldwork highlights cultural values and community desires which are a key section of the theoretical framework and are expressed in the final design in several ways, for example with the segregation of spaces and incorporation of passive systems to control and allow for cooling breezes to flow through the spaces. Finally, the site analysis formed the basis for understanding what kind of structure would be best suited to the site taking into account location, climate, ecology, and appropriate materiality.

Precedent studies carried out in this thesis were analysed using the devised theoretical framework, which was formulated specifically for this thesis but has the potential to be used for other design work perhaps where climate, ecology, and culture are of high importance for a successful design outcome. These precedent analyses influenced the research and the final design outcomes by demonstrating that the inclusion of passive design techniques, NbS, and community engagement in construction and operations of a structure is possible and successful.

Conclusion

Due to minimal published material relating to culture and day to day life in Kiribati, the NUWAO fieldwork filled many gaps in knowledge and was a key contributor in ensuring cultural considerations were upheld and celebrated in the final design. It was also vital to build understanding of what the locals might want when it comes to the future of inhabitation of the atoll and structures to support this. This is vital knowledge for this design-led thesis because the values of i-Kiribati relating to structures differ greatly from that of Aotearoa New Zealand. Therefore, without this knowledge, the architectural outcomes of this thesis may have been significantly different.

A thorough site analysis was required due to the unique climatic conditions of the atoll, the remote location in the Pacific Ocean, the nature of the atoll and accessibility to materials for construction. Further research could be carried out to better understand which specific plant species would be best suited for the climate in relation to the buildings proposed and spaces around them. Soil remediation is being carried out to some extent by locals and international aid organisations. Such practice and knowledge could be brought into the fold of this design if it were to be implemented.

This research and design illustrates one potential answer to the question, 'how can urban nature-based solutions and climate adaptation in the context of architectural design, enhance resilience, ecology and human wellbeing in South Tarawa, Kiribati?'. However, further research to enhance this design outcome would be associated with additional research into materials selection, understanding local skillset in construction, and specific plant knowledge; for example, which crops would grow best in the current and future conditions, and a more in-depth cultural understanding and real collaboration with locals beyond the scope of a masters thesis.

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Appendices Presentation

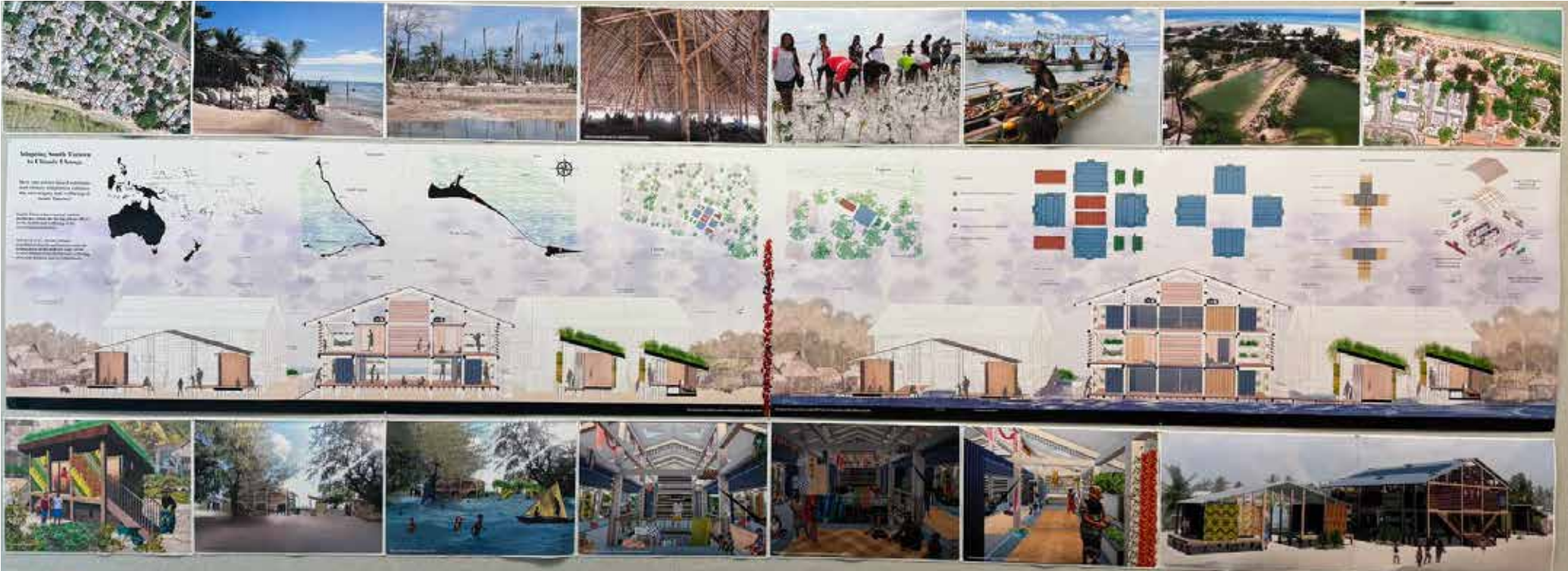


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