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# Perceptions, impacts and adaptation of tropical cyclones in the Southwest Pacific: an urban perspective from Fiji, Vanuatu and Tonga

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## Abstract

To better understand perceptions, impacts and adaptation strategies related to tropical cyclones (TCs) in urban environments of the Southwest Pacific (SWP), a survey (with 130 participants) was conducted across three island nations: Fiji, Vanuatu and Tonga. The key aims of this study include: (i) understanding local perceptions of TC activity, (ii) investigating physical impacts of TC activity, and (iii) uncovering adaptation strategies used to offset the impacts of TCs. It was found that current methods of adaptation generally occur at the local level immediately prior to a TC event (preparation of property, gathering of food, setting up of community centres). This method of adaptation appears to be effective, however higher level adaptation measures (such as the development of building codes as developed in Fiji) may reduce vulnerability further. The survey responses also highlight that there is significant scope to provide education programs specifically aimed at improving the understanding of weather related aspects of TCs. Finally, we investigate the potential to merge ecological traditional knowledge with the non-traditional knowledge of empirical and climate model based weather forecasts to improve forecasting of TCs, which would ultimately reduce vulnerability and increase adaptive capacity.

## 1 Introduction

Home to 15 island nations and approximately 2.7 million inhabitants, the Southwest Pacific (SWP) is a vast area vulnerable to the impact of tropical cyclones (TCs). TCs account for 76 % of reported natural disasters within the region (World Bank, 2006) and have significant impacts on island economies (McKenzie et al., 2005), infrastructure (Handmer et al., 1999) and human life (Haque, 2003). Recently, TC Pam, a Category 5 event struck Vanuatu in March 2015. With winds reaching  $300 \text{ km h}^{-1}$ , wave heights exceeding 15 m and significant storm surge, this event is regarded as one of the worst natural disasters to impact Vanuatu. Eleven people lost their lives and a fur-

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ther 75 000 people were displaced, with damages expected to exceed USD 360 million (Nishijima et al., 2015). This is only one example of many devastating TC events that have occurred across the SWP.

The vulnerability of the SWP is heightened by the inherent spatial and temporal variability of TCs (Kuleshov, 2002; Ramsay et al., 2011), the unfavourable shoreline to land area ratio (Barnett, 2001) and relatively limited adaptive capacity of the SWP (PCESD, 2011). Many studies outline the need for adaptation strategies to cope with a changing climate (Mataki et al., 2006; Mortreux and Barnett, 2009; Rasmussen et al., 2009). However, the ad-hoc manner of which these adaptation strategies have been developed does not necessarily consider the uncertainty associated with the spatial and temporal characteristics of TC activity, particularly in the face of a changing climate (Barnett, 2001).

Personal experiences and knowledge of TCs (or any other natural hazard) from those living in the affected regions represents a crucial source of information. If utilised effectively, this information affords scientists, planners and social development workers the opportunity to incorporate a comprehensive insight into local-scale weather systems, impacts and coping strategies, as experienced and informed by generations of indigenous populations (Lefale, 2009; Green et al., 2010; Waiwai and Malsale, 2013; Chand et al., 2014). Given these benefits, the process of recording the experiences of Fijian, Ni-Vanuatu and Tongan people and developing an understanding into their perceptions of TC events forms the conceptual framework for this investigation.

The aim of this study is therefore to record TC related Traditional Knowledge (TK) from an urban perspective and assess the perceptions of TC activity from three Pacific Island nations, Fiji, Vanuatu and Tonga (FVT). In this study, the resource of human experience draws upon empirical observations and experiences and aims to provide an understanding based on three themes, (i) local perceptions of the processes that cause or are associated with TCs, (ii) physical impacts of TC activity, and, (iii) adaptation strategies currently used to deal with TCs across the FVT region.

## 2 Methodology

### 2.1 Choice of case study nations: Fiji, Vanuatu and Tonga (FVT)

The FVT region was chosen as the case study area for this study (Fig. 1) due to its susceptibility to frequent TC events (Chand and Walsh, 2009). Urban locations were sampled across the FVT region. In Fiji, Lautoka, Nadi Town and Port Denarau on the island of Viti Levu were sampled. In Vanuatu, Port-Vila and the village of Mele Maat on Efate Island were sampled. Lastly, on Tongatapu Island, Tonga, Nuku’Alofa was chosen.

### 2.2 Survey structure and sampling strategy

The survey is comprised of eight questions aimed to address the key research themes (see Table 1). Given the economic, social and cultural landscape of the FVT, a feasibility study of the most effective way of recruiting participants was conducted (considering options such as face-to-face interviews, mail out, online surveys or phone interviews). The research team established that a one-on-one verbal survey was most favourable, supported as by Anderson (2003) who stated that: “The preference is for “eyeball-to-eyeball” contact or “face-to-face” interaction, making meetings, discussion and personal interaction critical. This type of communication helps to determine trust”.

The survey was completed in public areas in a range of urban centres, for example, local markets, transportation hubs and around “central business districts”. Survey participants were selected based on the following criteria, (i) over 18 years old, and (ii) individuals’ willingness to take part in the study.

### 2.3 Knowledge elicitation

The FVT region is ethnically and culturally diverse, although all have English listed as one of their many official languages. At times conducting the survey offered challenges,

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due to a range of factors including, language barrier (poor spoken English) and cultural and gender inequalities resulting in varying levels of engagement.

A small number of respondents were unable to answer all of the survey questions asked. This may be due to the following reasons: (i) the participant did not understand the question, (ii) the participant did not know how to answer the question, and/or, (iii) social/gender differences between the research team and participants. At times the interviewer elaborated or simplified some questions to ensure the participant understood. In the case where participants were unable to answer a question, this was left blank.

### 2.4 Qualitative analysis

After data collection, responses recorded across the FVT region were transcribed into nVIVO, a qualitative data research software package (see Klint et al. (2012) for a similar methodology). nVIVO was used to explore relationships between words and identified key themes from the responses. Answers were subsequently sorted according to theme to enable analysis and interpretation.

For some responses, themes are presented graphically, and compared between island nations. Actual responses also appear in-text. Further, the impact of TCs on FVT is highlighted by the frequency of words, through the use of word clouds (e.g. McNaught and Lam, 2010; Kiem and Austin, 2013). Word clouds work on the premise of text size, with the text size proportional to the number of respondents using a particular word or phrase.

## 3 Results

Data was collected over a three-week period in November 2013 (note this is prior to TC Pam). Results of the survey are discussed in relation to the three research themes outlined in Sect. 1, including an insight into the demographics of the population.

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### 3.1 Demographics

A total of 130 participants took part in the survey across the FVT region. Table 2 summarises the demographics of the sample population (Questions 1–2, Table 1). A fairly equal representation of gender (52 % females, 48 % males), occupation and age is reflected in the sample population. The number of willing participants varied for each study nation. Given the various challenges listed above, including social and language inequalities, an unequal number of participants were recruited across FVT (Fiji = 47, Vanuatu = 25, Tonga = 58).

### 3.2 Local perceptions of tropical cyclones

Question 4, “what is your understanding of a tropical cyclone?” (Table 1) assessed participants’ understanding of TCs (to investigate if the population were aware of the physical processes and/or the impacts associated with TCs). Analysis of the responses highlighted two main themes that emerged from this question:

- i. respondents who associate a TC with the weather conditions (meteorological/oceanographic) experienced during a TC event (discussed in Sect. 3.2.1 below);
- ii. respondents who focused on the physical impacts and damage associated with TCs (upon people and places). In some cases these responses disconnected the weather phenomenon from the impact (further discussed in Sect. 3.3).

Respondents from Vanuatu and Tonga mostly associated TCs with their subsequent weather conditions (Fig. 2), while participants in Fiji were more likely to discuss the physical impacts of TCs rather than the conditions associated with TCs.

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#### 3.2.1 Physical mechanisms

The majority of respondents in Vanuatu (80 %) and Tonga (70.7 %) discussed the weather conditions and related meteorological and oceanographic conditions experienced during a TC event. Many focused their answers on high windspeeds, significant rainfall, strong seas and potential storm surge. Many responses lacked detail, which the authors attribute to: (i) language barrier (see Sect. 2.3), and/or (ii) individuals are unfamiliar with the physical processes underlying TCs. Some respondents even associated tectonic activity as having an active role in TC activity. Although only 31 % of responses from Fiji discussed the physical mechanisms underlying TC activity, responses were considerably more detailed than those from Vanuatu and Tonga. Some responses noted that TCs are low-pressure systems and usually occur during hot and humid conditions. Many responses across FVT noted the TC season of the SWP (November–April).

### 3.3 Physical impacts of TCs on indigenous communities

Question 5, “How do tropical cyclones impact you and your community?” (Table 1) assessed the multitude of impacts respondents from FVT face in regards to TCs. Responses are summarised in a word cloud (Fig. 3) for forty of the most commonly used words across the FVT region. Responses from each nation are discussed in turn below.

#### 3.3.1 Fiji

The majority of Fijian responses (78.2 %) discussed damage to personal property and/or damage to housing/gardens. One participant commented, “The impact is very bad. The tropical cyclone destroys our houses, water tanks, gardens and falls all of our trees”. Other responses highlighted the potential impact falling trees can have on housing structures. A number of participants also noted the psychological impact of TCs, including shock, distress, disappointment and fear. Displacement and homeless-

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ness **was a** particular theme featured in many responses, **caused mainly by damage to homes or flooding that occurs after a TC event.** **A fewer number** of people mentioned the impact on infrastructure including, damage to roads, power cuts and prolonged damage to power supplies hampering the relief effort. Some respondents highlighted the severe damage that can occur across the **Yasawa and Mamanuca Island groups**, presumably given their high shoreline to land area ratio, low lying relief and relative isolation from the larger islands of Viti Levu and Vanua Levu.

The SWP Islands are very much reliant on subsistence farming (Mimura, 1999; Mataka et al., 2006), which was also reflected in many of the answers collected. Many respondents discussed the economic implications of TCs at length, particularly the impact of increased food prices. **Cassava**, a staple Fijian vegetable was used as **one such** example. **The price of the crop generally increases after a TC event, from its normal price of approximately USD 1.50 to USD 3.50 per heap.** The price driven upward by the destruction of arable land and subsequent shortage of crop. A similar scenario was noted for fish stocks, as fishermen are unable to go to sea, before, during and after a TC event because of dangerous and unfavourable conditions. This shortage of product, **in turn** increases the price of fish, another staple food in Fiji. Other economic impacts were highlighted, including, the loss of income (as it is common practice for businesses to cease paying their employees) during a natural disaster, or for the duration that trading has stopped. A discussion with a **Kava** producer and vendor in Nadi Market **highlighted significant economic losses after Cyclone Daphne, with a loss of earnings and damaged/destroyed crops totalling approximately USD 8500.** The sharp increase in the price of housing material after a TC event was also mentioned as hampering the rebuilding process.

### 3.3.2 Vanuatu

A significant number of Ni-Vanuatu respondents said that damage to housing and property was a serious impact of TC activity. Specifically, surveys highlighted recent TC induced flooding as a specific example of this damage.

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The economic implications of TC activity were not discussed to the same extent as responses from Fiji. **References were made to increased food prices, limited access to money and little or no insurance policies to help rebuild homes.** The recurrent nature of TCs, their variable temporal characteristics coupled with **limited income based mainly based on subsistence farming**, may help explain the very fragile conditions of homes and structures as observed in the settlement of Mele Matt. If little money is available to rebuild, stronger and more permanent structures may be out of the question, therefore the only alternative is to rebuild cheaper, weaker and less permanent structures. An example is seen in Fig. 4 an image taken in Mele Matt, which shows a typical outhouse building with tyres and other heavy objects on the roof to protect it from heavy winds. **This image provides an insight into the fragility of some structures, with similar buildings scattered throughout the village.** Only one respondent mentioned the impact on health, particularly during the subsequent flooding providing the necessary conditions for the spread of malaria, diarrhoea, flu and fever, which provides a challenge for the aged and incapacitated to seek help given the damaged infrastructure.

### 3.3.3 Tonga

Responses from Tonga incorporated many of the impacts discussed by respondents in Fiji and Vanuatu. A large emphasis was placed on personal safety, including fatalities, shock and disruption due to TCs. A particular focus was placed on the disruption and impact on family life. **Many responses** highlighted that houses are not strong enough to withstand the strength of TCs, with limited money to rebuild. The destruction of trees and plantations, specifically banana, breadfruit, mango and coconut were all mentioned.

### 3.4 TC related adaptation strategies

This section explores adaptation strategies across the FVT region by understanding (i) the delivery and quality of TC information, and (ii) how individuals prepare for a TC event.

#### 3.4.1 Delivery and quality of TC information

Question 6, “How do you get information when a tropical cyclone is about to hit?” (Table 1), aimed to understand how people receive TC related information and identify the source of this information. Findings from these results are presented in Fig. 5. Responses highlighted that radio was the most popular way to receive TC broadcasts. In such developing socio-economic nations, broadcasting updates through radio provides a cost-effective, participatory method of communication, for most, a necessity in delivering TC warnings. Other responses included; receiving information directly from the meteorological service of each respective nation, receiving text messages from mobile network providers or using the internet to track the TC event and follow TC warnings. However, these methods are dependent on having radio signal, owning a mobile phone and having network/internet access. These methods may not be suited to the more rural outlying islands across the FVT (which were not included in our survey sample).

Accessible disaster communication and management measures were noted throughout the FVT region. In Vanuatu, a map of the region with a reference grid (Fig. 6) is printed in the national phonebook by Telecom Vanuatu Ltd (TVL). This aid allows its user to locate a TC based on co-ordinates given, (often used in conjunction with a radio) and gives users the opportunity to understand the spatial extent of the TC event in relation to them. The national phonebook also summarises safety and evacuation procedures, provides a wealth of information about TCs including their seasonality, methods of preparation at the start of the TC season, the various types of cyclones and their potential impacts, provided by the National Disaster Management Office (NDMO). The national phonebook is distributed free of charge across Vanuatu. However this

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method of disaster communication is less (not at all) useful to those living in rural and remote locations due to limited radio services in outlying areas.

Question 7, “Is there any other information you need to be better prepared for a tropical cyclone?”, assessed whether respondents felt they need any further information to be better prepared and if they find the information satisfactory (Fig. 7). The majority of respondents in Fiji (63.8 %) stated that they are satisfied with the information they receive and they don't need any more information to be better prepared. Most stated that warnings are accurate and are generally issued in time to allow for adequate preparation. The remaining 36.1 % of respondents were not satisfied with the information and felt it could be improved, including more frequent TC updates and more accurate weather reports.

For Vanuatu, 47.8 % of respondents reported that they were satisfied with the TC information they receive. Those who highlighted more information was needed (52.2 %) made similar suggestions to those in Fiji and noted the need to improve communication in rural areas/outlying islands (though this was from an urban perspective). More educational programs on how to reduce the impacts of TCs and adaptation measures were suggested as methods that would greatly benefit the population.

The majority, 56.6 % of respondents in Tonga stated they needed more TC information to be better prepared. Many responses mentioned previously incorrect warnings often coming at the wrong time, or are not given in ample time to allow for the necessary preparation. It was also suggested that site specific information be tailored to each village/community as their needs in the face of a TC may be significantly different. A number of respondents also highlighted that the utilisation of technology, for example, social media and text messages could be used within Tonga to inform the population of a possible TC warning.

#### 3.4.2 Preparing for a TC event

Question 7, “What do you and your community do to help reduce the impacts of tropical cyclones?”, aimed to understand how respondents prepare for a TC once a warning

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has been issued. Most responses were very detailed, outlining the step-by-step actions taken when a TC warning has been issued. Responses across the FVT region were comparable, and as such this section discusses the actions taken by the FVT community as a whole in how they prepare for a TC event (see schematic in Fig. 8).

5 The majority of responses discussed the measures the respondents take in order to prepare their property, making it “TC ready”. Initially, preparations begin outside. Gardens and small areas of vegetation are cleared primarily to ensure no loose objects are picked up by high winds. Also, any crops that may be of use are saved, which can be consumed or sold for income later. Secondly, given the fragility of many houses, participants discussed the process of tying down their roofs and securing their houses at length. Depending on the conditions of the roof, heavy objects (such as tyres or sandbags) are often placed on top to help protect the roof from strong winds (see Fig. 4). Shutters may be placed on the windows to protect them from high winds and flying objects.

15 Next, the preparation of provisions; food, water and other consumables were discussed. Dry food including; biscuits, flour and sugar and long date goods, such as tinned foods are collected. A working radio, first aid kit, torch and a cyclone tracking map were also identified as important necessities when waiting out the storm, defined as a 72 h kit in Tonga. Safe public buildings on higher ground, such as, churches, schools and community centres, are generally open to residents if they feel their home cannot withstand the impact of the TC. The research team noted a sincerity with the population and a definite sense of community spirit who were very much focused on helping others, particularly those with a disability or those of age who were less able to prepare.

## 25 4 Discussion

This discussion addresses the wider significance of the findings with three key objectives, (i) to understand the varying perceptions of TCs, (ii) to uncover processes

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of preparation and methods of adaptation, and (iii) discuss the potential of merging weather related traditional knowledge (TK) with non-traditional knowledge (NTK) of meteorology and climate science, with the potential of developing a new forecasting tool for the region.

### 5 4.1 Understanding the perceptions of TCs

Limited knowledge of the mechanisms and basic science surrounding TCs emerged from the survey results. A study of weather related TK conducted in Samoa (Lefale, 2009) also highlighted significant ecological knowledge but limited knowledge of weather phenomenon, with Samoans generally unfamiliar with the processes underlying weather and climate phenomenon in the South Pacific.

10 Recent work has been carried out to enable capacity building and increased awareness of weather related issues through education programs in the region (though none are specifically focused on tropical cyclones). Two such programs, “Cloud Nasara” and “Climate Crabs” are a collaboration between the Red Cross and the Australian Government’s Pacific-Australia Climate Change Science and Adaptation Planning (PACCSAP) Program. These animations aired on TV and during community education outreach programs explain various weather extremes caused by El Niño/Southern Oscillation (ENSO) in the Pacific. Cloud Nasara is specifically for ni-Vanuatu people, translated into Bislama, French and English (PACCSAP, 2015). Interestingly, none of these educational initiatives were mentioned by respondents, which may indicate that more effort and time or alternative education programs are needed to reach the wider population. While the ultimate success of these programs is yet to be determined, a similar framework may be applied to provide education on TCs which could then be distributed to a wider audience.

## 4.2 Uncertainty and adaptation: identifying processes of preparation and methods of adaptation

The temporal and spatial uncertainty associated with TCs makes planning for TC events extremely difficult, made even more challenging by the developing nature and insularity experienced by each island nation. Islands' increased vulnerability and low adaptive capacity (IPCC, 2007), makes planning for such events and preparing for the upcoming TC season incredibly important. Results highlighted a significant awareness amongst the population of what to do in the face of a TC, the steps that must be followed to become "disaster ready" and how to prioritise each task (see Sect. 3.4.2). The developing nature of the FVT region, coupled with the spread of islands over a large geographical areas, means that cost-effective, accessible communication is required to enable successful disaster management and adaptation strategies. This section provides an assessment of some of these measures.

As noted in Sect. 3.4.1, numerous responses stated they received text messages to warn them of a TC. The recent telecommunications boom in the South Pacific has seen a recent exponential growth in the use of mobile technology, earning the title "[the] Digital Islands" (Cave, 2012). In a study of the use of mobile phone technology, approximately 60 % of the population in the Pacific had, or had access to a mobile phone (as of November 2013), with increases predicted for the future. In 2009, it was reported that three of every four households owned a mobile phone (Vanuatu National Statistics Office, 2009). Utilising this form of technology is one innovative method of easily communicating TC warnings to almost two-thirds of the population. In the case of TC Pam, text messages with updates on the TC were sent by the Vanuatu Meteorological Service every three hours while the TC intensified, and every hour as the TC approached Vanuatu. It is believed that this measure (combined with others), helped keep the death toll relatively low for such a major event (ABC News, 2015).

Fiji has implemented a range of methods to improve the country's resilience to extreme events and TCs. One example of this in action is a publication by the Fiji Build-

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ing Standards Committee (1985). This report outlines numerous design upgrades to homes in a bid to build stronger, more wind resistant housing that can withstand TCs, for example, external roof tie down systems. However, given the characteristics socioeconomic characteristics of the region, costly technical guidelines in the document are inaccessible to many. In a post disaster assessment after TC Evan in 2012, many residents stated they would like to use disaster resilient materials to rebuild their homes, however a lack of financial support stopped this from happening. The Fiji National Provident Fund (FNPF) is one such scheme that is available to TC affected victims, whereby USD 500 is allocated to qualifying households to help rebuild. However, the limited resources mean people cannot adequately rebuild and TC proof their homes. Instead, other programs such as Housing Assistance and Relief Trust (HART) are busy relocating impoverished families to secure accommodation after a TC event (GOF, 2013). An increase in population and the potential of more intense TC in the future (Lavender and Walsh, 2011) will see increasing financial pressure placed on these projects, highlighting the potential for more sustainable climate change adaptation practices in the South Pacific.

Capacity building through community engagement programs is the most successful way to educate vulnerable communities of climate extremes and how to adapt (PCESD, 2011). In Fiji, a program named "Building the National Resilience to Disasters" teaches schoolchildren how to be disaster ready through a booklet containing games and exercises. From 2012, Disaster Risk Reduction (DRR) was made compulsory in the Fijian school curriculum at both the primary and secondary level. Selby and Kagawa (2012) note the innovative student centred approach Fiji takes to DRR, with routine (three times per term) emergency drill practices and the annual National Disaster Awareness Week. Vanuatu also practices DRR education, however Kagawa and Selby (2012) noted the haphazard structure of DRR in the current curriculum and the limited knowledge of the subject area amongst teachers. SPREP (2013) also highlight that DRR has been introduced into Tonga's national curriculum.

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Forward-thinking methods of disaster resilience and adaptation planning have been developed by the Vanuatu Meteorological Service (VMS). Specifically, tracking maps have a range of benefits giving users the opportunity to visually track the TC event whilst listening to the radio. Also, the forum in which it is published (national telephone directory) makes it accessible to the wider public of urban and peri-urban areas (as the phonebook which is distributed throughout Vanuatu is free). Fiji's National Disaster Management Office (NDMO) has also released a similar cyclone-tracking map, which is also freely available. However, considering the spatial extent of the region, the cyclone-tracking map is effectively useless without a radio, a reality in more remote locations across the area. In these more remote locations, TK (further discussed in Sect. 4.3) is used as a valid source of weather related information.

### 4.3 Traditional knowledge vs. non-traditional knowledge

Whilst speaking with survey participants about their experiences with TCs, a common theme emerged relating to changes in plant and animal indicators preceding TCs, for example, changes in mango and breadfruit outputs (Whan et al., 2014). This is an example of TK that could be useful in improving prediction of TCs in the region. Indeed numerous studies have demonstrated the usefulness of TK in improving understanding of environmental prediction and meteorological phenomenon in the South Pacific (e.g. Lefale, 2009; Waiwai and Malsale, 2013; Chand et al., 2014), which is also believed to be a cost-effective, participatory and sustainable method of adaptation (Robinson and Herbert, 2011). If utilised effectively, TK affords scientists, planners and social development workers the opportunity to incorporate a comprehensive insight into local scale weather systems, impacts and coping strategies as experienced and informed by generations of indigenous populations. Therefore, given the significant contribution TK can make towards the preparation and adaptation to TCs, this section discusses the potential of utilising the NTK of weather and seasonal climate forecasting alongside the TK of indigenous people.

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Moller and Berkes (2004) discuss how utilising TK and non-traditional knowledge (NTK) can be complimentary in many ways. Summarised in Table 3; the qualitative data of TK and the quantitative NTK can benefit and improve our knowledge in the following ways, (i) the merging of relatively long (TK) datasets with shorter datasets (NTK), (ii) combining the notion of averages (statistical basis of NTK) and extremes (TK) is particularly good at highlighting extreme events and changing patterns, (iii) cross-pollination of qualitative (TK) and quantitative (NTK) ideologies, (iv) hypotheses (TK) vs. mechanisms (NTK), and (v) objectivity (NTK) and subjectivity (TK) (Table 3). Recently, Kijazi et al. (2013) demonstrated the potential of utilising plant related TK to forecast rainfall in Tanzania. This study compared forecasted rainfall with observed conditions, which produced coherent results. In the SWP, a similar longitudinal study in a controlled environment could also uncover ecological TK in predicting weather. Specific to the South Pacific, numerous predictors of TC activity are used. When talking to survey participants the research team noted similar findings listed in Lefale (2009) and Chand et al. (2014) in relation to plant and animal indicators for upcoming TCs. Examples include; early and more abundant flowering of mango and breadfruit in the harvest season preceding a TC, the mass movement of birds across a non-native area (Breuner et al., 2013), changing animal behaviour (Acharya, 2011), and the depletion of fish stocks are only a few examples. Large-scale changes in barometric/hydrostatic pressure, temperature, winds and humidity are believed to drive these differing plant/animal responses.

The question is however, what is the most effective, consistent and economically sustainable way to integrate TK with NTK? The Climate and Oceans Support Program in the Pacific (COSPPac) is also working to explore TK and the potential ways in which it could be utilised to inform seasonal prediction in the region (Chand et al., 2014). Figure 9 synthesises the proposed framework emerging from the findings of this work and highlights the potential of amalgamating the TK of the people of the SWP, with the NTK of climate science and weather forecasting. This multi-disciplinary approach could potentially lead to the development of multi-dimensional TC forecasting tools for Small Island States (SIS). This improved forecasting capability has a number of societal

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implications particularly regarding disaster preparedness and climate adaptation and could lead to improved “decision led” adaptation measures and a bottom-up planning approach.

However, the question of how to navigate the incompatibilities between TK and NTK still remains. Here we propose a conceptual framework that may be applied to utilise weather related TK with the NTK of climate science and weather forecasting.

- i. Depending on the application, a country-by-country assessment of weather related TK is needed to uncover plant/animal indicators specific to each country.
- ii. Ground-truthing of forecasted conditions using plant/animal indicators (identified in point 1) with observed conditions and identification of the most effective indicators.
- iii. **Continual** (real-time) data collection. Examples can be drawn from Waiwai and Malsale (2013), whereby free mobile phones were distributed to select groups in outlying islands to collect weather related TK. A similar scheme could be introduced, in this case, a continual real-time reporting system. Other methods of data collection could include a periodical meeting of individuals from various communities to relay changing environmental conditions.
- iv. Amalgamation of weather related TK and climate models to provide a multi-dimensional forecasting tool for SIS. Developing a methodology to translate the qualitative TK data into a homogenous quantitative scientific format and to incorporate it into existing forecasting tools is a significant challenge. More work is needed to establish appropriate strategies of integration for these two distinct entities, appropriate to the SIS of the South Pacific.

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## 5 Conclusions

There is no questioning the substantial impact of TCs upon the SIS of the South Pacific. Yet, the forecasting of, and adaptation to TC events is inherently challenging. In response to this, our study contributes to this research sector by, firstly, better understanding the perceptions of TCs in urban communities. A notable finding was the divide in respondents who associated a TC with an extreme weather event and those who only discussed the secondary impacts and subsequent damage to people and property. The study also revealed a number of successful adaptation methods, such as the TC tracking map in Vanuatu and the inclusion of DRR in the school curriculum, particularly in Fiji. However, it was also highlighted that no single adaptation method is accessible to the entire of population of the FVT, due to spatial, social and economic limitations. Most significantly, this study has highlighted the useful wealth of knowledge that the indigenous people of FVT possess to inform weather related/TC prediction.

The study revealed a lack of consensus across the FVT region in regards to the quality and accuracy of TC forecasts that individuals receive (noting that we only sampled from urban areas where communication methods are likely to be better than for rural or remote areas). In this paper we propose a conceptual framework of collecting weather related TK and explored how this can be used in conjunction with climate models and forecasting tools. Not only could this aid improved forecasting accuracy, but it could also result in more tailored adaptation measures and improved planning, which may reduce the potential risk of death and financial disaster for the FVT region and be used as a template for other SIS and nations across the world.

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**Table 1.** Survey Questions.

Question number	Question	Section/key areas
1	Occupation of participant	Demographic
2	Age of participant	
3	How long have you lived here?	
4	What is your understanding of a tropical cyclone?	Local Perceptions of TCs – process vs. impact
5	How do tropical cyclones impact you and your community?	Physical impact of TC activity
6	How do you get information about when a tropical cyclone is about to hit?	Adaptation strategies in use across the FVT region
7	Is there any other information you need to be better prepared for a tropical cyclone?	
8	What do you and your community do to help reduce the impacts of tropical cyclones?	

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**Table 2.** Demographics of participants.

		Fiji	Vanuatu	Tonga
Number of participants		47	25	58
Age	18–30	17	7	16
	31–40	12	9	19
	41–50	7	6	8
	51–60	8	2	11
	60+	3	1	3
	Mean	39.5	37.8	38.8
Gender	Male %	60	36	43
	Female %	40	64	57
Occupation	% Unemployed/Retired	12.5	16.7	17.6
	% Primary e.g. fishermen	53.1	41.6	50
	% Secondary e.g. carpenter	0	4	2.9
	% Tertiary e.g. shop worker	31.3	37.5	29.4
	% Quaternary e.g. researcher	3.1	0	0

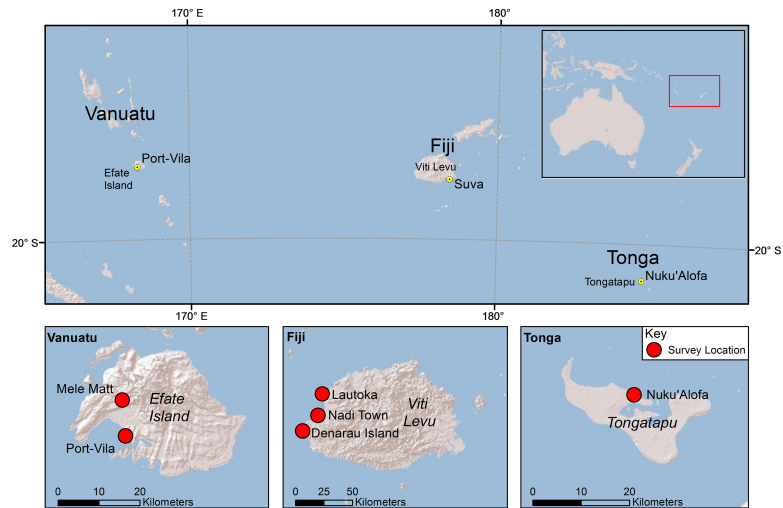
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**Table 3.** Summary of the differences between Traditional Knowledge and Non-Traditional Knowledge (adapted from Moller and Berkes, 2004).

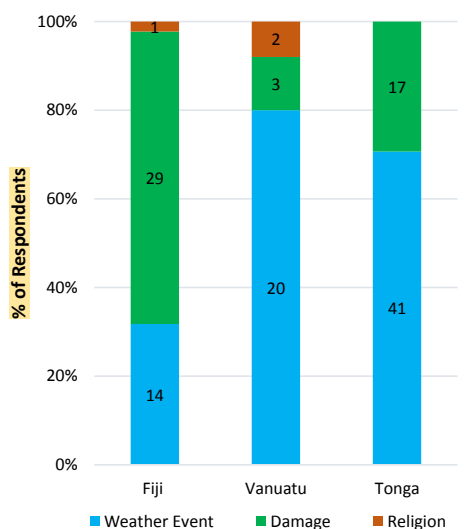
	Traditional knowledge	Non-traditional knowledge
Duration of dataset	Shorter datasets	Longer datasets
Statistical Quantification	Averages	Extreme events and changing patterns
"Type" of dataset	Qualitative	Quantitative
Hypothesis vs. Mechanisms	Hypothesis	Mechanisms
Objectivity vs. Subjectivity	Objective	Subjective

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**Figure 1.** Map of study location and urban survey locations across Fiji, Vanuatu and Tonga (FVT region).

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**Figure 2.** Percentage of responses to question 4: “What is your understanding of a tropical cyclone?”. Absolute numbers of responses are noted.

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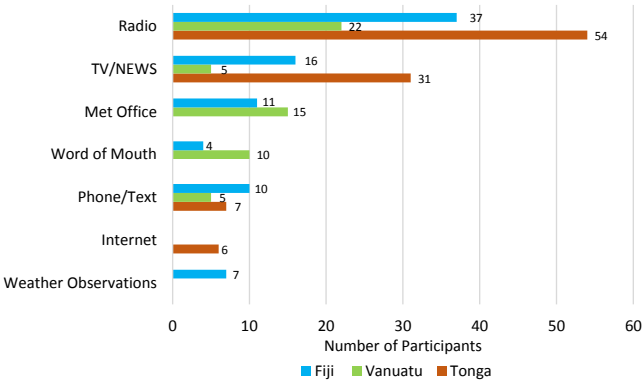
**Figure 3.** Word cloud summarising 40 most frequently used words in response to question 5: “How do tropical cyclones impact you and your community?”, for Fiji (a), Vanuatu (b) and Tonga (c).

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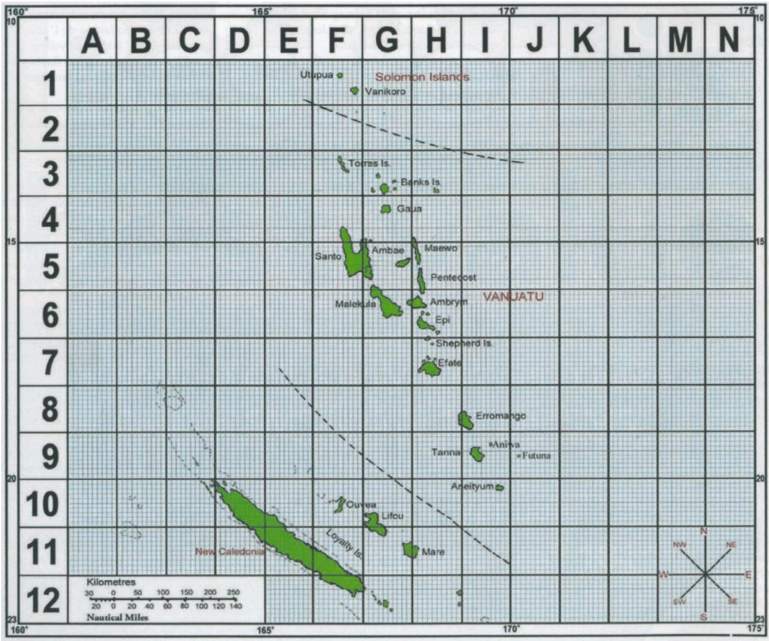
**Figure 4.** A typical outhouse in Mele Matt Village, Efate, Vanuatu. An example of climate adaptation in practice. Photo taken: 10 October 2013 by Andrew Magee.

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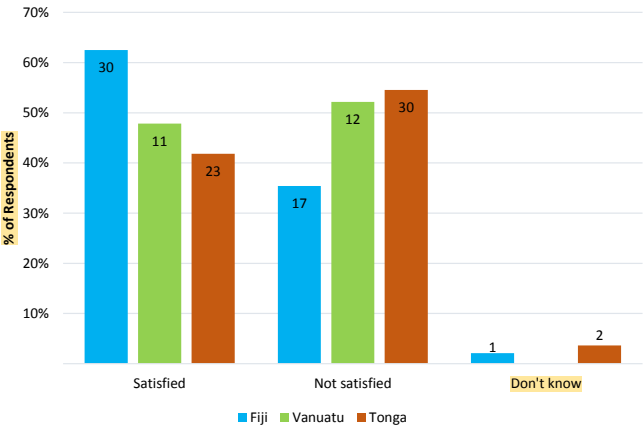
**Figure 5.** Proportion of responses to question 6: “How do you get your information when a TC is about to hit?” Absolute numbers of responses are noted.

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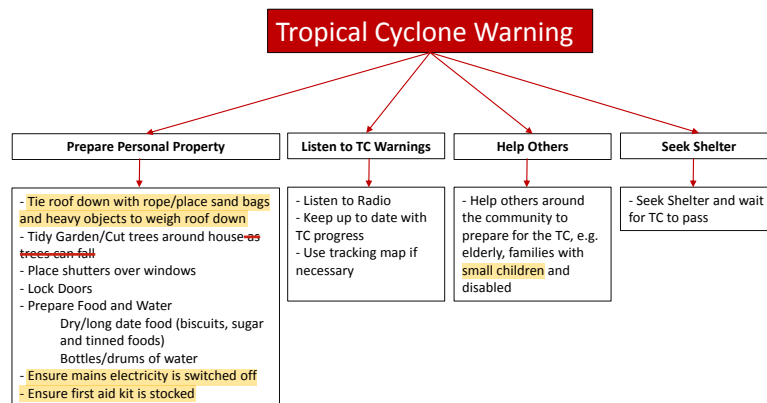
**Figure 6.** Cyclone tracking map of Vanuatu, New Caledonia and Solomon Islands. Courtesy of the Vanuatu Meteorological Service (VMS).

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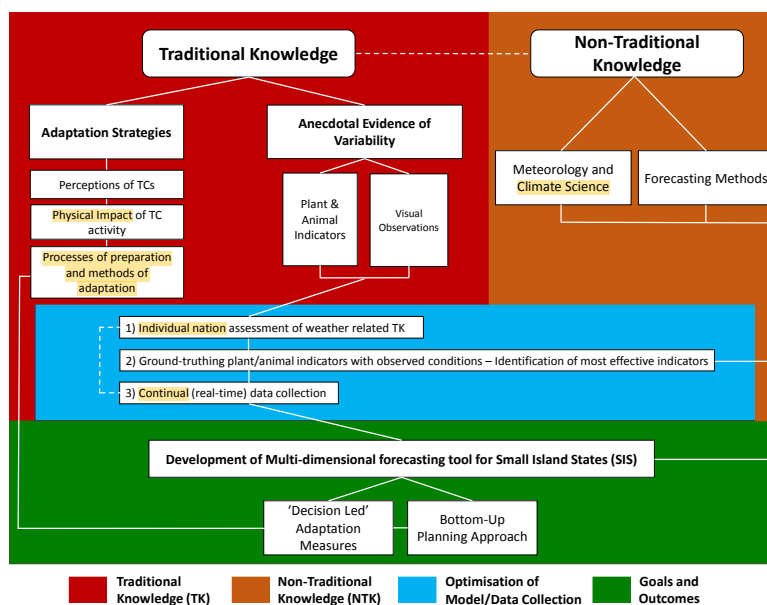


**Figure 7.** Percentage of responses to question 7: “Is there any other information you need to be better prepared for a TC?” Absolute numbers of responses are noted.

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**Figure 8.** Schematic summarising methods of preparation after a tropical cyclone warning has been issued.



**Figure 9.** Proposed conceptual framework to integrate traditional knowledge (TK) with non-traditional knowledge (NTK) to develop a multi-dimensional forecasting tool for small island states (SIS).