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# Indigenous Knowledge for Environmental Prediction in the Pacific Island Countries

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ABSTRACT

Indigenous people in Pacific Island countries (PICs) often use their knowledge of the environment, acquired through generations of holistic observational practices and experimental learning, to make meteorological forecasts. Such knowledge systems are now recognized by several institutions, including the Intergovernmental Panel on Climate Change, as an important participatory forecast approach for decision making, particularly at a farm level. In this article, the authors show that indigenous knowledge of weather and seasonal climate forecasting is a crucial component of a potential strategy for making farming-related decisions and reducing vulnerability to environmental hazards.

## 1. Introduction

Weather forecasting has been practiced by humans for millennia and is an aid to decision making under conditions of uncertainty. Early forecast decisions were made entirely with knowledge accumulated over generations of local observations. Even today, one does not have to be a trained meteorologist to be a forecaster. Indigenous farmers, for example, whose livelihoods directly depend on weather and climate, often monitor and predict weather and seasonal climate events through locally observed variables such as the behavior of plants and animals, meteorological fields (e.g., strength and directions of winds), and astronomical indicators (e.g., sun and stars) in order to make farming-related decisions (e.g., Green et al. 2010; Lefale 2010; Sanni et al. 2012). Orlove et al. (2000) have clearly demonstrated the compatibility of lay and scientific methods of weather forecasting in a particular context, that of farmers in drought-prone regions of Andean South America. However, the utility of lay and indigenous forecasting methods in the Pacific Island countries (PICs) remains largely unexamined.

In this article we argue that indigenous knowledge of seasonal climate forecasts can form an important participatory strategy for improved decision making, risk management, and disaster prevention in PICs when used together with model-based seasonal forecasts. As such, this article contributes to the growing body of literature that emphasizes the importance of indigenous knowledge systems for decision making (e.g., Cronin et al. 2004; Mercer et al. 2007; Agrawal 2009; Maclean and Cullen 2009; Berkes 2009; Green et al. 2010; Prober et al. 2011). We start by discussing scientific forecast systems

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currently used by National Meteorological Services (NMSs) in the Pacific and their limitations (section 2). This is followed by a discussion of the importance of modern scientific and indigenous knowledge systems for seasonal forecast applications (section 3). A synopsis of our proposed methodological framework for forecast integration is given in section 4. Using Vanuatu as a case study, we illustrate community reliance on indigenous methods for forecasting seasonal climate, and work under way to reduce community risk through integration of indigenous and modern scientific forecasting methodology (section 5). Finally, a summary is given in section 6.

## 2. Overview of weather and climate forecasting in the PICs

Weather and climate have major implications for vital infrastructure, facilities, agriculture, and food security in PIC communities (e.g., Mimura et al. 2007; Mercer et al. 2007). For example, timely and accurate forecasts of weather can have considerable societal and economic benefits in terms of making more effective and coordinated disaster-management decisions. More importantly, tailoring forecasts to local needs can help rural farmers, for example, by adopting appropriate agricultural practices such as adjusting harvesting and planting schedules to avoid periods of heavy rainfall or moving livestock to safety when major flooding is forecast. Often in PICs, a bad harvest in one year due to a poor forecast decision can put farmers in debt for many years, potentially contributing to generations of poverty (e.g., Lal et al. 2009).

Advances in meteorological and computational sciences in the past decades have enabled the development of state-of-the-art forecast models that are capable of making region-specific forecasts up to months in advance (e.g., Webster 2013). However, such models are expensive to build and maintain, and are only run by a few national or multinational government organizations, including the European Centre for Medium-Range Weather Forecasts (ECMWF), the National Centers for Environmental Prediction (NCEP), and the Met Office. Small island developing countries in the Pacific are often unable to run these complex models for a number of reasons, including budget constraints and limited resources. Even when high-resolution, country-specific forecasts are freely available from international agencies such as NCEP (Saha et al. 2010), accessing them may be hampered in PICs due to slow Internet connections. In addition, for PICs where seasonal forecasts are issued, for example, by the Australian Bureau of Meteorology's Predictive Ocean–Atmosphere Model (POAMA; e.g., Cottrill et al. 2013), the spatial resolutions of such models are often too coarse to resolve small-scale phenomena. A lack of complete in situ data records, particularly for Southern Hemisphere regions, that are needed for model initialization, calibration, and evaluation may also contribute to forecast uncertainties (e.g., Webster 2013).

Numerous analytical techniques have been proposed and explored in the past to characterize model forecast uncertainty, minimize forecast errors, and provide probabilistic guidance on the future state of weather and climate for decision making (see Wilks 2006). One such tool routinely used in PICs to produce site-specific seasonal forecasts is Seasonal Climate Outlooks in Pacific Island Countries (SCOPIC; additional information is available at its website http://www.bom.gov.au/cosppac/comp/scopic/). SCOPIC is an analytical decision-support system that uses historical PIC weather station data (e.g., rainfall) and large-scale climate indices (such as sea surface temperature patterns and the Southern Oscillation index) in the preceding months to generate probabilistic climate forecasts (e.g., seasonal rainfall) for the upcoming season. This has no doubt greatly advanced the prospects and understanding of seasonal forecasts in the Pacific. However, limitations remain when using analytical techniques (including SCOPIC) for weather and climate forecasting for farming-related decision making, including the following:

1) The sparse distribution of weather stations in PICs and a lack of complete long-term records limit the number of site-specific forecasts that can be issued by techniques such as SCOPIC.
2) NMS forecasts are often delivered in forms that are difficult to understand for citizens who have not had formal training in meteorological or mathematical sciences.
3) These NMS forecasts rarely provide information on the onset and distribution of rainfall needed for farming-related decisions.
4) Modern forecasters may lack the experience necessary to make decisions to aid local communities, particularly if the spatial scale required by the communities is smaller than that resolvable by the analytical forecasts (e.g., Doswell 2004).

Given these limitations, analytical forecast outlooks are often not very well received by local communities in the Pacific (e.g., Cronin et al. 2004; Green et al. 2010; Lefale 2010) and elsewhere (e.g., Sanni et al. 2012), particularly by indigenous farmers, who have adopted their own method of weather forecasting through generations of holistic traditional utilization of lands, natural resources, and the environment. One way to recognize these differences and to increase the likelihood of NMS forecasts being used by local communities, potentially increasing community resilience to extreme weather and climate events, is to identify the benefits of indigenous and modern scientific forecasts for decision-making purposes.

## 3. Indigenous knowledge application

Indigenous knowledge is built upon experimental learning and on accumulated knowledge passed orally from generation to generation; it is rarely recorded in a written format. As such, this knowledge does not always conform to "standard" westernized scientific formats, thus making scientific analysis difficult (e.g., Mackinson 2001). Regardless, indigenous knowledge continues to play a significant role in the modern world. Recently there has been a resurgence of interest in indigenous knowledge in areas such as disaster risk reduction and planning (e.g., Mercer et al. 2007; Cutter et al. 2012), and it is now recognized as an important knowledge system for decision making, particularly at a farm level.

Indigenous knowledge for weather and seasonal climate forecasting is commonly practiced in many regions of the world (e.g., Raj 2006; King et al. 2008; Green et al. 2010; Lefale 2010; Chang'a et al. 2010; Acharya 2011; Chinlampianga 2011; Mogotsi et al. 2011; Shoko 2012; Risiro et al. 2012). However, there are growing concerns that changes in climatic conditions due to anthropogenic influences may be reducing the effectiveness of some local biological indicators routinely used for weather and seasonal climate forecasts (e.g., King et al. 2008; Chinlampianga 2011). This highlights the need to assess the desirable properties of indigenous knowledge indicators (e.g., reliability, robustness, and relevance) through monitoring and verification with observations.

This need has been recognized in the Pacific. The Australian Bureau of Meteorology, through the Climate and Oceans Support Program in the Pacific [COSPPac; funded by the Australian Department of Foreign Affairs and Trade (DFAT)], has implemented a project to integrate seasonal forecasts presently generated by NMSs in the Pacific with indigenous knowledge. The primary goal of the project is to work with local communities in the Pacific to document their indigenous knowledge of weather and seasonal climate forecasts, examine the reliability of that knowledge, incorporate it with conventional scientific methods, and develop mechanisms to disseminate the integrated product back to the community. We believe for the reasons evident in subsequent sections that this process can potentially harness the benefits of both indigenous and scientific knowledge forecast systems for decision-making processes.

## 4. Methodological framework

We propose a Participatory Rural Appraisal (PRA; e.g., Cronin et al. 2004) method in the development of a framework for integrating indigenous knowledge of weather and seasonal climate forecasts with modern scientific approaches. PRA is a research- and planning-based method in which a local community first identifies an issue of concern in their community, evaluates and prioritizes options, and develops action plans to address that concern. Cronin et al. (2004) showed the success of the PRA method for integrating indigenous and modern scientific knowledge systems for the case of improving responses to volcanic hazards in Vanuatu. We also consider this approach optimal for the development of weather and seasonal forecast applications as it involves direct participation of rural communities for collection, analysis, and presentation of locally used forecast indicators. This ensures active contribution by indigenous communities in appraising conditions and identifying solutions.

Difficulties may arise in this process if the participants lack formal education in modern scientific forecast methods, as is the case in a number of PICs. If participants fail to understand modern scientific forecasting, then they may be unable to effectively merge this knowledge with indigenous knowledge. In such cases, participants may benefit from a "consensus" forecast, based on both scientific and indigenous knowledge systems. Consensus forecast will be developed by the country's NMS through discussion with local indigenous communities, and with assistance from the Australian Bureau of Meteorology.

A four-step process framework is proposed to guide the integration of indigenous and scientific knowledge systems for weather and seasonal prediction applications. Here we summarize the main steps of the process. The first step is to identify priority communities whose livelihoods remain largely dependent on the use of indigenous knowledge for weather and seasonal forecasting, and building a relationship of respect and trust with those communities. The second step is to develop an infrastructure for collection, recording, and monitoring of locally observed weather and climate forecast indicators for participating communities. Indicators may consist of the behavior of plants and animals or meteorological and astronomical fields. The third step is to integrate indigenous and modern scientific forecasts for each locale area. The method of integration adopted will vary across PICs, depending on the preferred approach of the NMS and on historical data availability. This could range from consensus forecasts developed through discussions between the NMS and community members (as used by the Kenyan NMS, e.g., Ziervogel and Opere 2010) through to the development of formal statistical models using historical datasets of indigenous indicators. This third step also includes comparison of resultant consensus forecasts with observations. The final step is to disseminate consensus forecasts to user communities. User feedbacks on the success of the forecast are also obtained to help improve future forecasts.

In the next section we illustrate how this framework can be applied in practice, emphasizing the participatory nature of the approach, using a case study from Vanuatu.

## 5. Vanuatu case study

Many rural communities in Vanuatu have maintained their indigenous knowledge systems for weather and seasonal climate forecasting, especially those communities that have been least influenced by missionization and other outside interventions. Although rural farmers may listen to contemporary weather and seasonal forecasts via radio broadcasts, they may not use this advice for a number of reasons including a strong dependence on indigenous knowledge—continuance of tried and tested ways of doing things, historically rooted reasons for regarding outside knowledge with suspicion, or a lack of understanding of the forecast provided (Waiwai and Malsale 2013). This reluctance to use official forecasts and warnings is one of the main challenges of hazard and risk management in Vanuatu. It is anticipated that better uptake of official forecast products would be achieved through the integration of indigenous and modern scientific forecast knowledge within their risk reduction strategies, though the challenge remains how to best achieve this outcome.

To explore the role of indigenous knowledge in seasonal climate predictions, and possibilities using such knowledge systems together with modern scientific forecasts, a workshop was held on Pele Island, Vanuatu (15–19 April 2013; Waiwai and Malsale 2013), bringing together representatives from all six provinces. Coordinated by the Vanuatu Meteorology and Geo-Hazards Department (VMGD; the National Meteorological Service for Vanuatu), the Vanuatu Cultural Centre, and the Vanuatu Red Cross Society, with financial support from the Australian government, this workshop targeted the volunteer rainfall observer network with additional representatives from government agricultural and forestry departments. All participants (55 in total) acknowledged the existence of some form of weather and seasonal forecasts based on indigenous knowledge in their provinces. Village elders are the main custodians of such knowledge, which is mainly transferred to individuals within a province through storytelling. The participants comprised both village elders and more junior community members, with a good mix of genders. Participants were provided with free mobile phone access and encouraged to consult with elders back in their home village on indigenous indicators of weather and climate conditions and for permission to share this knowledge. Data collection took place in the form of small province-based groups and, importantly, included discussions (in local language) around what information could be shared and with whom. Only information considered to be "widely known" (i.e., had little or no cultural sensitivities or other restrictions associated with it) was shared with the wider group and included in the workshop report.

Indicators based on behaviors of plants and animals were common across most provinces in Vanuatu (Waiwai and Malsale 2013). For example, flowering density of plants such as mangoes (*Mangifera indica*), mangroves (*Rhizophora mangle*), and Nakavika (*Syzygium malaccense*), and the wilting of a local shrub known as *Diadia* are some indicators of the type of season to be expected. Changes in animal behavior, such as turtles laying eggs inland as opposed to near the shore, and hornets nesting at ground level are also indicative of the type of upcoming seasons. For example, wilting of *Diadia* in 1997–98 was interpreted as an indicator of upcoming drought, as turned out to be the case. Similarly, heavy flowering of *Nakavika* trees or early flowering of mango trees is an indicator of high tropical cyclone activity in the upcoming season. It also became evident in the workshop that turtles usually lay eggs farther inland in cases of a strong upcoming tropical cyclone season. At shorter time scales, the appearance of insects such as cockroaches and red ants appear to be good indicators of possible rain in a few days time. In addition, a new moon surrounded by a halo or covered by clouds are examples of short-term rainfall indicators commonly used by indigenous people in Vanuatu. A scientific reasoning for such instinctive behavioral changes in plants and animals can be attributed to changes in ocean and atmospheric fields such as barometric and hydrostatic pressure, humidity, and air temperature (e.g., Rice 1964; Tiwari and Tiwari 2011; Rosenzweig and Neofotis 2013) that may occur prior to events such as tropical cyclones and rainfall. Understanding how changes in these ocean and atmospheric conditions trigger behavioral response in plants and animals is beyond the scope of this paper.

To date, a lack of historical records associated with indigenous knowledge forecasts, such as flowering densities of mangoes, makes forecast verification difficult; hence, these indigenous forecast methods have received little attention in scientific discourse. The VMGD is currently working on addressing this issue by developing a system to monitor a selected number of indigenous weather and climate indicators in real time. Community members expressed their appreciation of VMGDs acknowledgment of the usefulness of indigenous knowledge forecasts and were keen to see these incorporated into the products produced by VMGD. Using local networks, such as the Volunteer Rainfall Observer Network, to record indigenous indicators will assist an ongoing dialogue between local communities (particularly those communities where network members reside) and VMGD. This will help with better utilization of the indigenous and model-based forecasts for decision-making purposes.

This case study from Vanuatu illustrates the first two steps in the process framework: identifying priority communities and building relationships and development of an infrastructure for community monitoring weather and climate forecast indicators. Presently, it is too early to determine what the final balance will be between the two knowledge systems in decision making by local provinces in Vanuatu (step 3). However, a process is now in place whereby the understanding of and confidence in scientific forecasts can be developed in local communities without undermining benefits provided by indigenous knowledge.

## 6. Summary

Indigenous people in the Pacific island countries commonly use local knowledge of their environment to generate weather and seasonal forecasts. It is recognized here that incorporating such knowledge systems into existing official seasonal forecasts, such as those generated by National Meteorological Services, can play an important role in strengthening community participation in the forecast process leading to improved farming-related and disaster-management decisions.

A framework based on the Participatory Rural Appraisal method is proposed to guide the integration of indigenous and scientific knowledge systems for seasonal prediction applications in the Pacific island countries. This framework facilitates a collaborative effort within and between indigenous groups, National Meteorological Services, and their stakeholders to identify the benefits of indigenous and scientific weather forecasts for decision-making purposes.

The method was applied in practice using a case study from Vanuatu. Preliminary results from the study demonstrated how forecasts are visualized by local indigenous communities in Vanuatu. It also indicated that indigenous weather and climate knowledge is a crucial component of a potential strategy reducing vulnerability to environmental hazards. Future work is planned to determine the effectiveness of the framework in integrating indigenous and scientific knowledge systems together.

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