Climate Resilient WaSH in the Pacific

Developing Bayesian Belief Network models for water and sanitation

METHODS BRIEF

Research statement

Understanding interactions between the many factors that affect water and sanitation is a complex challenge, particularly in Pacific Islands Countries (PICs) where there is uncertainty surrounding future climate projections and impacts on water and sanitation, and where data on these systems is sparse. A computer modelling approach called a Bayesian Belief Network (BBN) can be used to contribute new knowledge and assist decision-makers in situations of high uncertainty and when available data is limited. This brief describes the development of BBN models for floodplain and atoll communities in the Solomon Islands and Republic of the Marshall Islands, and how such models can improve our understanding of water and sanitation outcomes under different scenarios.

Findings

1. Using a BBN model simplifies and assists in understanding complex WaSH systems. A variety of methods can be used to better understand a system, and a BBN approach allows incorporation of diverse sources of information, including participatory stakeholder methods, expert opinion and survey data.

2. A BBN model can be used to compare the likely outcomes of different scenarios, to support decision-making for WaSH interventions, management and policy development.

Background

Climate change poses a serious threat to PICs and their freshwater resources. Sea level rise, saltwater intrusion, increasing evaporation rates and changing rainfall patterns will all affect the water cycle and, potentially, the availability of water for human use. This poses significant adaptation challenges for development and human health in PICs. The research team has worked closely with local stakeholders to examine household and community-level water use and management practices, and to develop sophisticated tools and processes to assist local people and agencies with their adaptation planning.

Models are simplifications of complex systems that help us understand how they work. A BBN is essentially a diagram that shows what we understand about the primary cause-and-effect relationships between different variables in a particular system. It also includes probabilistic information on how much, and in what way each of the variables affects the others. In this study, BBNs were developed representing two extreme ends of the environmental spectrum in PICs: floodplain and atoll environments.

Methods

Research described in this brief was conducted as part of thePacific Adaptation to Climate Change for WaSH (PACCWASH) Project. This research was funded by the Australian Government Department of Foreign Affairs and Trade, and managed by the International WaterCentre. The research partners were the Water Institute at the University of North Carolina, Griffith University, Monash University, University of Alabama, and the University of the South Pacific.

A short description of the rationale and the methods for BBN modelling is provided below. A BBN developed for floodplain communities in the Solomon Islands has been used to illustrate the application of BBNs to inform decision-making for climate resilient WaSH.

Who is this brief intended for?

This brief is intended for local and international water, sanitation and hygiene program managers and policymakers, and is particularly relevant for the Solomon Islands and the Republic of the Marshall Islands.

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Finding 1: Understanding complex systems through quantitative modelling and the development of BBNs

Participatory processes and guided discussions were conducted with men and women of different age groups in floodplain and atoll communities in the Solomon Islands and the Marshall Islands in 2014 and 2015. These discussions took place with individuals and in small, gender-separated groups, to learn about local priorities for WaSH management and other factors, or "variables", affecting local water and sanitation systems, including hazards or threats in the community and wider catchment.

The primary concern of all communities involved in the study was whether or not they would have enough drinking water of adequate quality, and this was used as the focus, or "endpoint", for both the floodplain and atoll BBNs. Conceptual mapping exercises were further used to draw out the cause-and-effect relationships between key variables (see Figure 1).

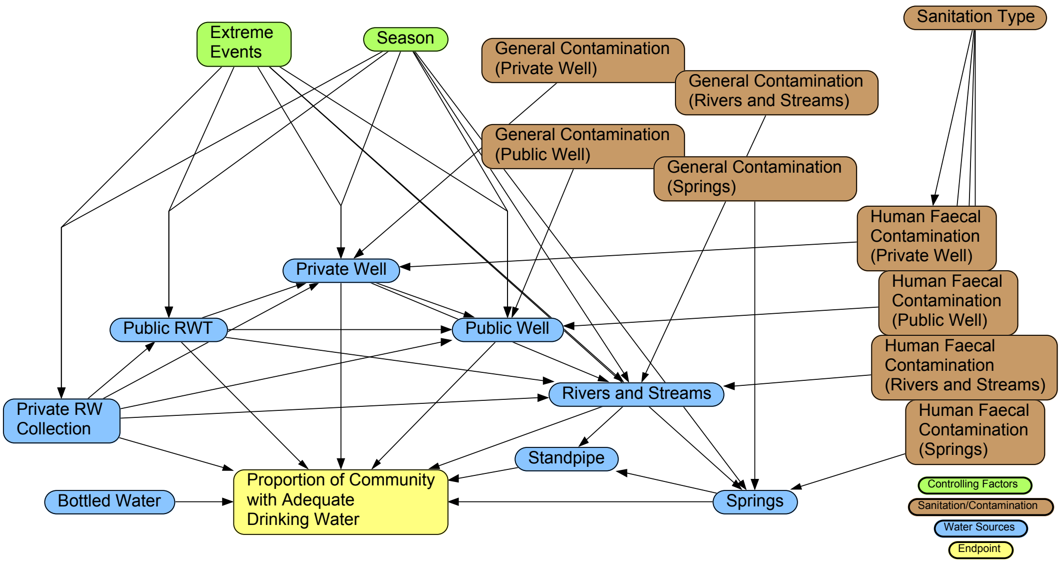
Stakeholder participation and input improved analysis of the local WaSH system, and ensured that local concerns were addressed in the BBN models. The community outputs were then compiled by the research team to produce a conceptual diagram describing the key factors that affect drinking water in the two environments studied: floodplains and atolls.

As an example, Figure 2 shows the conceptual diagram for the Solomon Islands (floodplain) case.

Figure 1: Men's community stakeholder group participating in conceptual mapping exercises.

Photo credit: Terence Chan, 2015

Figure 2: Conceptual diagram for drinking water in floodplain communities, including multiple water sources and impacts from sanitation
Note: The figure excludes location variables (community and region) for simplicity



Quantitative BBNs were then developed using modelling software, and based on these conceptual diagrams. Individual households were surveyed on water sources, uses and sanitation under a variety of seasonal and extreme weather conditions, including droughts, floods and cyclones. In the drought-prone atoll country of the Marshall Islands, we carried out 299 household interviews across eight communities. In the Solomon Islands, we conducted 106 household interviews across five flood-prone communities. This data was used to define how relationships between different variables in local WaSH system change, using Bayes' probabilistic theorem, that incorporates whatever quantitative information is available to calculate the likelihood of a certain variable behaving in a certain way, given how the other variables linked to it are behaving. The more evidence there is on how a system has behaved in the past, the more certain the BBN will be that it will behave in a similar way in the future. This explicit accounting for uncertainty is useful given the complexity of systems in the natural world, and the difficulty of making precise predictions about the effects that different management actions might have.

Finding 2: Using BBN models to inform decision-making for climate resilience WaSH

Decision-makers, including program managers and policymakers, need to balance the desirability of a certain outcome against the chance that a particular management action may not lead to the outcome they expected. BBNs can be used to examine and compare different scenarios to inform decision-making.

The baseline BBN for the Solomon Islands is shown in Figure 3.

Figure 3: Model with survey data incorporated to define quantitative relationships

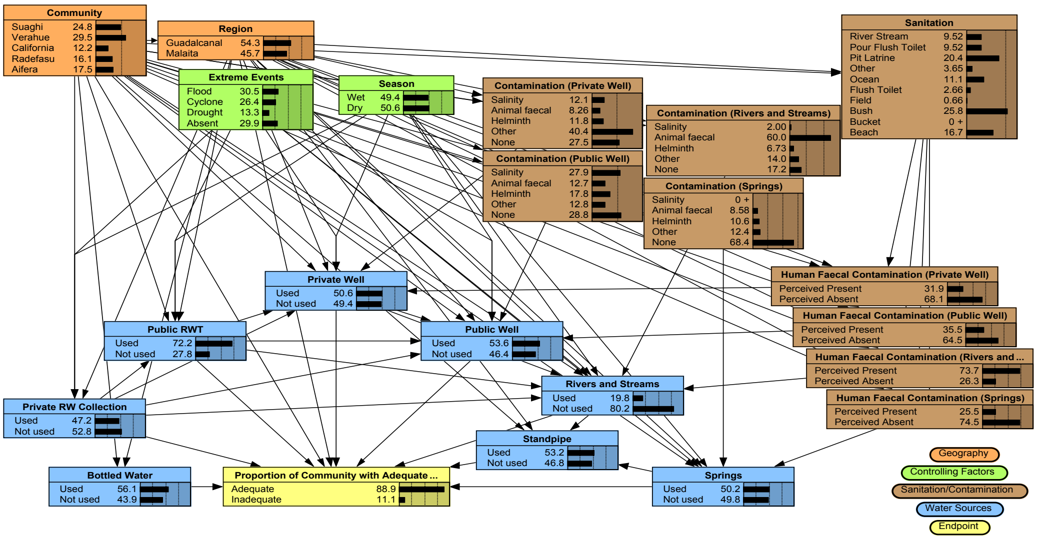
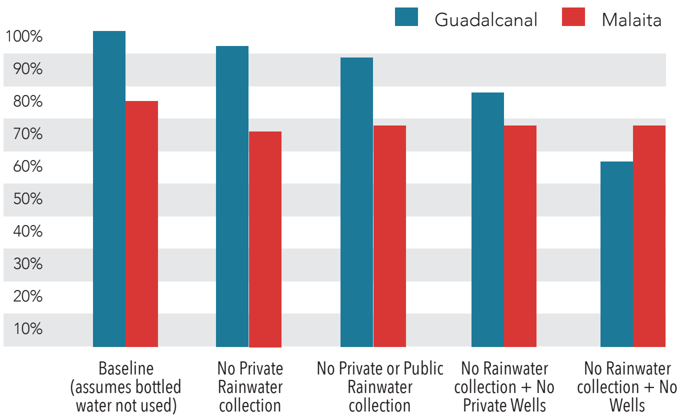


Figure 4: Proportion of community with adequate drinking water in different regions of Solomon Islands



As an example, five different scenarios are illustrated in Figure 4 for two different provinces in the Solomon Islands.

This information can be used to analyse and compare how the availability of different drinking water sources changes with different collection methods on a regional scale.

In general terms, BBNs can aid decision-makers through scenario testing. The BBNs visualise the impacts of different climate events on WaSH and, in turn, evaluate the likely impact and efficacy of different adaptation options. At the same time, BBNs provide numerical outputs which allow for direct comparisons to see which scenarios maximize benefits and to allocate resources efficiently. These BBNs have been built from household level data which means that they can be used to evaluate and compare intervention and adaptation options for a) individual communities, and b) groups of communities (eg. regions or provinces). BBNs explicitly consider the uncertainty that will always exist in a complex system, allowing for informed decisions even when data is incomplete.

Want to know more?

This brief describes findings from the Pacific Adaptation to Climate Change for Water, Sanitation and Hygiene (PACCWASH) Project. For more information, please contact Principal Investigator, Dr Wade Hadwen, at w.hadwen@griffith.edu.au, or visit www.watercentre.org/portfolio/wash-and-climate-change-adaptation-in-the-pacific.

For more information on Bayesian networks, these sources may be useful:

General/popular articles:

- Leonhardt (2001) Adding art to the rigor of statistical science, New York Times, April 28 2001 www.nytimes.com/2001/04/28/arts/28BAYE.html
- Black (2001) The ghost machine, Business Week, July 31 2001, www.businessweek.com/bwdaily/dnflash/jul2001/nf20010731_509.htm

More detailed articles:

- Murphy (1998) A brief introduction to graphical models and Bayesian networks, www.cs.ubc.ca/~murphyk/Bayes/bayes.html
- Niedermayer (n.d) An Introduction to Bayesian Networks and their Contemporary Applications, www.niedermayer.ca/papers/bayesian/index.html

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