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Household Risk Indices for the Atoll Islands of Tuvalu

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Abstract

Small atoll islands often inherit unique natural beauty, but on the flip-side to this are disaster risks associated with its economic characteristics and physical factors of the environmental (geographical and topographical). To this, we examined the importance of having risk indices for the islands and villages of Tuvalu by employing a principal component analysis to construct an overall risk index for households to determine "at risk" households that is broadly represented by villages and islands in Tuvalu. The risk index serves as a metric for measuring the potential risk that is expected to surface in relation to household vulnerability to natural disasters. Such risk classifications are imperative for policy and decision making.

JEL Codes: C38, Q54, Q56

Keywords: Disasters, Risk Indices, Hazard, Vulnerability, Exposure, Tuvalu

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1 Introduction

Natural disasters have many forms that distress populations around the world. The Asia-Pacific region is highly prone to disasters with the uppermost number of affected populations in the world (UNESCAP and UNISDR 2012). Tuvalu is one of the smallest island nations in the world located in the central Pacific, with scattered low-lying atolls that have less capacity to face and respond to the impacts of climatic disasters, the changing climate and sea-level rise. Tropical cyclones and even strong winds of lesser magnitude with storm surges are serious threats to these low-lying islands. Noy & Edmonds (2018) shows that Tuvalu is highly vulnerable to disasters if compared to other Pacific Island Countries (PICs).

Recently, disaster risk has been increasing in the Pacific region. Disaster risk itself is well defined by UNISDR (2009) as potential future disaster losses and damages to the people. It is also conventionally perceived as a function of hazard, exposure, and vulnerability (GFDRR 2016; Wisner, Gaillard, and Kelman 2012). Hallegate (2017) extended the disaster risk function to capture socioeconomic resilience. Others argued that resilience and responsiveness are other important components of disaster risk (Noy et al. 2018; Taupo and Noy 2017).

The impact of disasters on households and communities vary, depending on the circumstances of the hazard, exposure, vulnerability and resilience. Yonson et al. (2018) argued that the hazard itself poses less influence on disaster impact than socioeconomic vulnerability and exposure. Taupo & Noy (2017) quantified the impact of Tropical Cyclone Pam (TC Pam) on small atoll islands like Tuvalu, showing the high degree of vulnerability for these islands to distant cyclones that does not even make landfall. It is not just the strong winds and heavy rains, but the associated storm surges that affects these low-lying atoll islands. These unaccounted factors relating to the impact of climatic disasters often lead to underestimations of expected annual average losses (Taupo 2017), and even commonly used database for disasters (e.g. EM-DAT) significantly underestimates the burden of disasters in the Pacific (Noy 2016b).

Much of the recent literature assesses and estimate disaster risk using various methods of measurements (Cavallo and Noy 2011; Hallegatte et al. 2015, 2017; Noy 2016a; Noy et al. 2018; Schumacher and Strobl 2011; Strobl 2012; Taupo, Cuffe, and Noy 2018; Taupo and Noy 2017). However, most of the work focusing on the Pacific region uses macro-level data rather than micro-level data due to the limited and restricted access to these datasets. For this paper we aim to produce risk indices for both islands and villages of Tuvalu using household level data. These risk indices were constructed in association with risk factors influencing the resulting impacts of disasters on people, assets and the economy.

2 Estimation Method

We employed a principal component analysis (PCA) method from variables in datasets. PCA is a data reduction technique utilized to calculate weights to be used in developing our risk indices. From a set of correlated variables, PCA extracts a set of uncorrelated 'principal components' where each is a weighted linear combination of the original variables, i.e. if we have n correlated variables $X_1 - X_n$ where each principal component is the sum of each variable multiplied by its weight (the weight for each variable is different in each principal component), hence represented by $PC_i = a_1X_1 + a_2X_2 + .. + a_nX_n$. The number of variables in PCA is the same as the numbers of 'principal components'. The components are ordered so that the first principal component (PC_1) explains the largest amount of variation in the data. We did not include binary and categorical variables as they can lead to counter-intuitive weights. The number of components is equal to the total number of variables. All components explain the full variation in the data (i.e., 1.00). The Kaiser rule implies that you should retain the ones that have the eigenvalue of above 1 (Braeken and van Assen 2017; Kaiser 1960). The principle components will be normalized to a [0, 1] scale as our risk index.

3 Data

We utilized two datasets, the 2010 Household Income and Expenditure Survey (HIES) and the 2015 Pam Survey. The 2010 HIES data was collected by the Central Statistics Division (CSD) of the Tuvalu Government for 2010 from 541 households representing around 33% of the population of Tuvalu where the sample selection was spread proportionally across all the islands with a selection process that listed each dwelling on the islands by their geographical position and systematically skipped through the list to achieve the 33% randomly selected sample. The 2015 Pam Survey is a detailed household survey that accounts for income, expenditure, and loss and damages conducted by Taupo & Noy (2017) for 321 households in the islands of Tuvalu that were heavily affected by the Tropical Cyclone Pam in March 2015. The survey followed analogous procedures used by the Tuvalu Central Statistics Division. Table 1 describes the variables from the 2010 HIES including geographical and topographical information made available from the available household geo-location coordinates.

Table 1: Description of variables for 2010 HIES

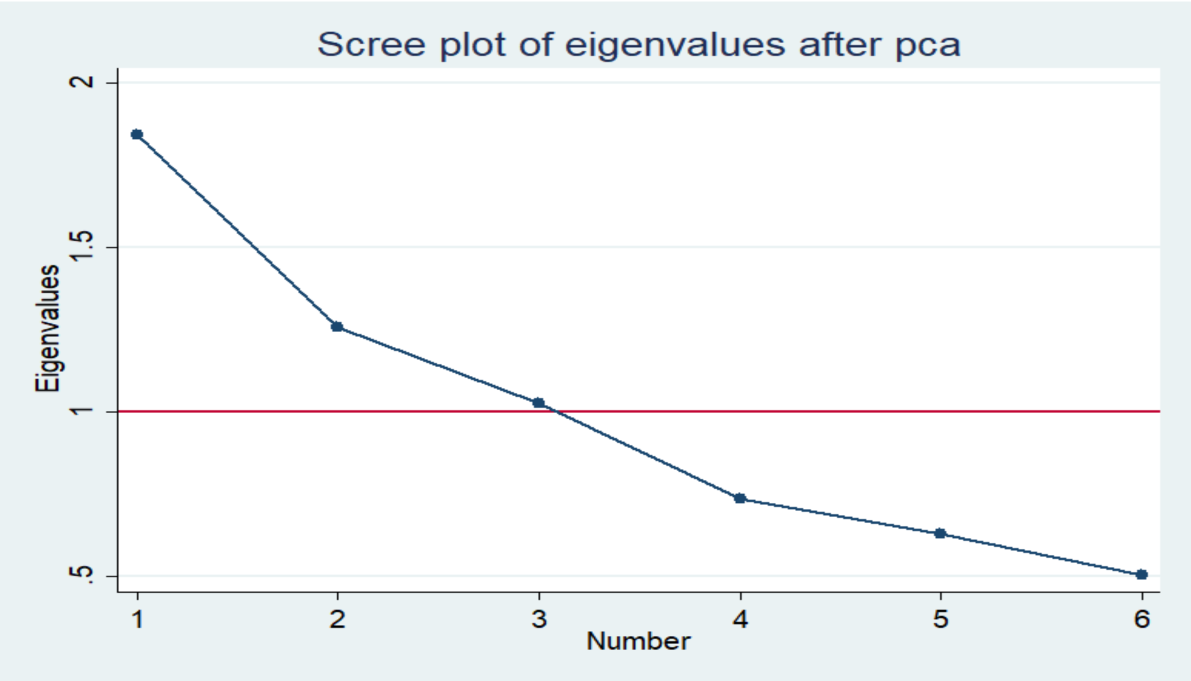
No.	Variable	Description	Obs	Mean	Std.Dev	Min	Max
1	lincpp	Log of income per person.	490	9.1329	0.7795	7.2605	11.9135
2	age	Years of age of the household head.	490	50.2551	12.4336	22	86
3	educ	Years of education of the household head.	490	8.7673	3.8783	0	18
4	dwide	Land width or distant from lagoon-coast to the sea-coast in kilometers (km).	490	1.5295	2.0121	0.0656	8.2440
5	dcoast	Distant to the nearest coastline in km.	490	0.1653	0.1426	0.0087	0.9016
6	elev	Elevation in meters.	490	9.2718	3.0608	1.8976	17.3287

Source: 2010 HIES data from the Tuvalu Central Statistics Division.

4 Results

The first strand of risk indices, we used data with Global Positioning System (GPS) locations and ground elevation of households from the 2010 HIES, where we generated risk indices for households and then grouped by villages and islands.[1] We used six variables namely log of income per person (lincpp), age of the household head (age), education years of the household head (educ), ground elevation of household (elev), distant of the household to the coast (dcoast) and land width (dwide). Based on the Kaiser criterion and the scree plots (see Figure 1), we chose the first 3 components that explain 69% of variation in the data.[2]

Figure 1: Scree plot of Eigenvalues

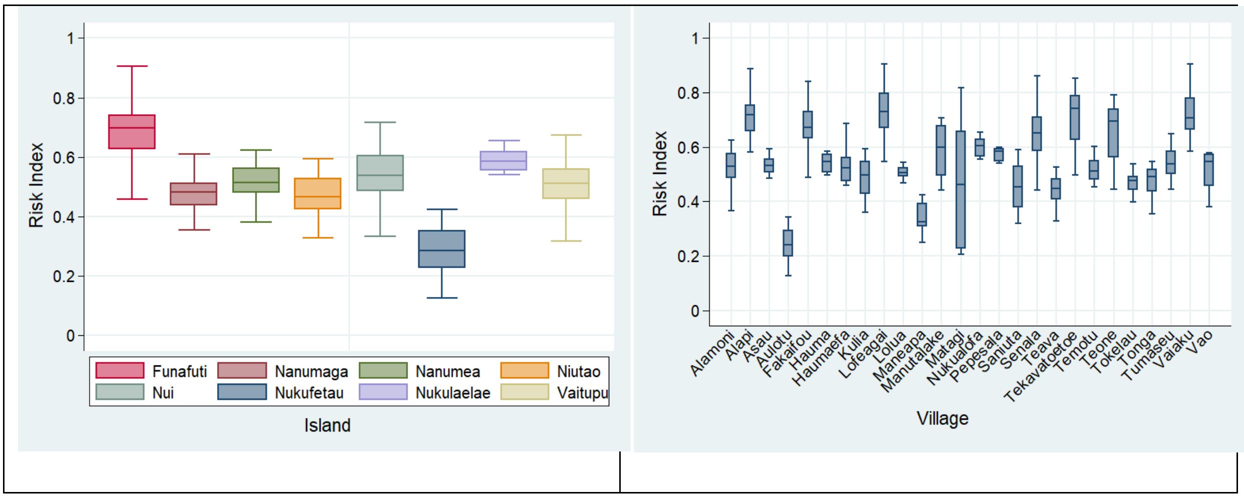


Source: Author's calculations.

[1] Out of the 541 households, 490 households have geographical (geo-location coordinates) and topographical information.
[2] The Kaiser rule states that you should retain the ones that have the eigenvalue of above 1.

We also estimate the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, resulting to 0.583, therefore indicating that the correlations among the variables is high enough and we are justified in using principal component analysis. Figure 2 shows risk indices after normalizing to a [0, 1] scale, thus enabling us to identify "at risk" households by village and island. The risk indices reflect on the vulnerability of households to natural disasters based on household vulnerability and exposure (Taupo, Cuffe & Noy, 2018).[3] These risk indices indicate that the capital island Funafuti has the highest risk indices in average terms while Nukufetau Island has the lowest. By village classification, the highest risk indices points to the villages of Funafuti (i.e. Lofeagai, Tekavatoetoe, and Teone).

Figure 2: Risk Indices by Island and Village.



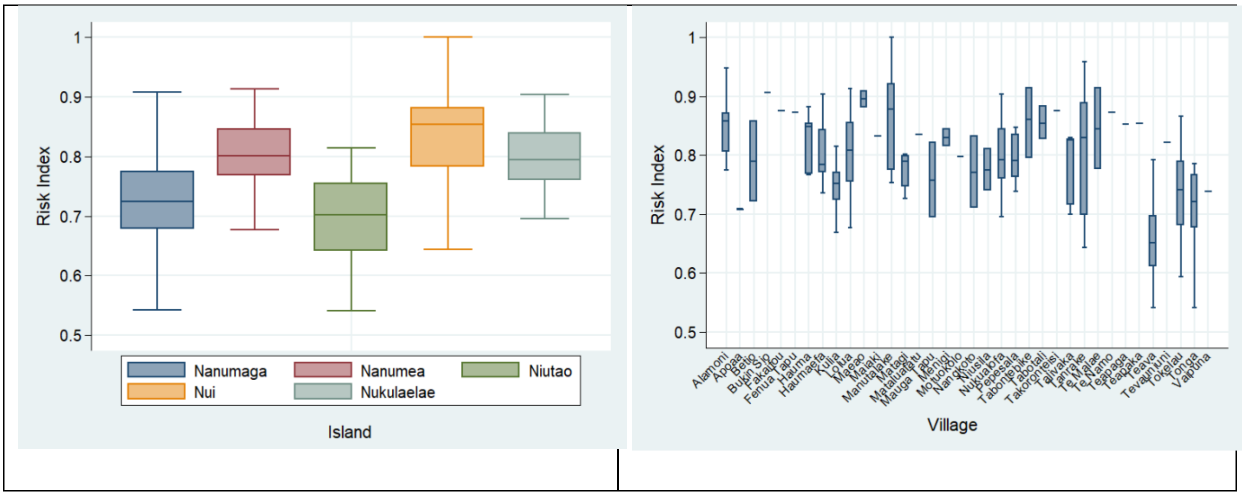
Source: Author's calculations from 2010 Household Income & Expenditure Survey (HIES) data.

The second strand of risk indices, we utilize data with GPS locations and ground elevation of households from the 2015 Pam Survey to generate another set of risk

[3] Variables such as income, education level, and household exposure in terms of proximity to the coast, and ground elevation are important factors in assessing risk for small island states.

indices for households. Estimates from the loss and damage regressions from Taupo & Noy (2017) were used to assess and predict "at risk" households from the impact of a disaster (i.e. from the Tropical Cyclone Pam in 2015). Figure 3 shows the risk indices that identifies "at risk" households by island and village. Nui Island was recognized to have the highest risk index followed by the islands of Nanumea, Nukulaelae, Nanumaga, and Niutao.[4] From a risk index scale of 0 to 1, all the islands and villages are at high risk from disasters as risk indices of all islands and villages are well above 0.5.

Figure 3: Risk Indices by Island and Village.



Source: Author's calculations from 2015 Pam Survey data.

Comparing the results of the two risk indices from the different datasets, we confirm that the direction of the cyclone is very important in this case.[5] The analysed results from the 2010 HIES (covering all the 8 islands) listing the islands in ascending order of high risk as Funafuti, Nukulaelae, Nui, Nanumea, Vaitupu, Nanumaga, Niutao

[4] Our risk index was normalized to a [0, 1] scale.

[5] Although the household geographical and topographical variables are the same, there are limitations to the other variables which are not entirely the same.

and Nukufetau. The analysed results from the 2015 Pam Survey (covering the 5 most affected islands) revealed the highest risk for Nui followed by Nanumea, Nukulaelae, Nanumaga, and Niutao. The capital Funafuti was not extremely affected by the TC Pam as expected. Based on Taupo, Cuffe & Noy (2018) and Taupo & Noy (2017), the magnitude and direction of the cyclone, and the geographical setting of the islands are very important factors that will determine the physical impact of a cyclone. The islets protect the main island, thus acting as a shield during strong winds and storm surges. In this connection, islands without islets are more vulnerable and exposed to cyclones especially for households residing in the direction of the cyclone.

If the cyclone path was on the eastern side of the islands, it would have been a different result for the capital Funafuti where most of the infrastructure are located and over 60% of the overall population resides, and the fact that it is open to cyclones without any shields from islets and the lagoon as they have on the western side. These geographical settings with low elevation are determining factors of the levels of household, village, and island vulnerability and exposure to tropical cyclones (with associated storm surge).[6] Even though the strength of the cyclone and storm surges are important factors in determining the impacts (direct and indirect) inflicted on households, the direction of the cyclone and island geographical buffers (e.g. islets, land-width, lagoons, elevation, etc.) are other key risk factors for low-lying atoll islands.

[6] However, in terms of a potential tsunami, it is expected that no one is safe on these low-lying atolls.

5 Conclusion

It is crucial to fully understand risks of disasters and to be taken seriously by policy makers in the Pacific region. The high vulnerability and exposure of small and low-lying atolls should be well received and recognised by governments, regional organisations, and various stakeholders. The developed risk indices (both pre and post risk indices) show incomparable results for the five islands pointing to the fact that both the cyclone path and direction are very important, apart from the magnitude of the hazard itself. The other fact was that our expectations of household disaster risk (pre risk indices) were lower than the actual impact (post risk indices) of a disaster, indicating that households are more risky than expected. However, one certain result is that households, villages, and islands of Tuvalu are highly exposed and vulnerable to climatic disasters, hence the need to direct policies at strengthening disaster risk management, reducing disaster risks, and promoting resilience at all levels.

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