Appraising New Damage Assessment Techniques in Disaster-Prone Fiji

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ADVANCES IN POST-DISASTER DAMAGE ASSESSMENT

Recent technological advances in remote sensing have led to significant increases in temporal, spatial, and spectral resolutions of these images. Improvements have also been made in data availability and accessibility, as well as advances in the processing methods required to effectively interpret these large amounts of data. These developments have led to an increase in the opportunities for the use of satellite imagery for more effective disaster risk management.

One such application that has advanced because of these improvements is post-disaster damage assessment. Traditionally, in a post-disaster scenario, a team of experts is sent to the impact area to conduct a ground survey and assess damages (often connected to a Post-Disaster Needs Assessment report), which the Asian Development Bank (ADB) typically undertakes jointly with impacted country governments and other relevant agencies. While extremely useful, this process is time-consuming, costly, and problematic because often access to the affected area is difficult, dangerous, or restricted. Alternatively, governments, and especially public and private insurance companies, use risk models to quantify the damages. Risk models, however, can be inaccurate and are generally unable to account for compounding or cascading events, which are much more difficult to quantitatively model. Similarly, the standard approach to nowcast disaster impacts, which relies on risk models, does not typically account for the compounding impact of various hazard phenomena, such as wind and rainfall associated with tropical cyclones.

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Satellite imagery may provide an easily available and accurate data source to gauge a disaster’s specific impacts and can account for a disaster’s compounding effects. While it can serve as a strong complement, if accurate enough, satellite imagery may potentially replace some components of the ground surveys. An approach that has been calibrated with remote-sensing imagery can also be used as a component in a nowcasting tool to assess the impact of a specific disaster, for example, a tropical cyclone, based only on its known trajectory, and even before post-event satellite imagery is available. We discuss such an approach in this brief.

ASSESSING IMPACT OF TROPICAL CYCLONES ON FIJI’S AGRICULTURE

A knowledge and technical assistance is currently underway to investigate the feasibility of using innovative data, such as satellite imagery for nowcasting and post-disaster damage assessment.1 Noy et al. (2022) examine the possibility of combining remote-sensing data with socioeconomic sources of information (household surveys and the census) to nowcast the damage from tropical cyclones on agriculture. In doing so, it goes beyond the now-routine procedure of linking hazard indicators (such as strong winds) with remote-sensing data, to the next step of assessing economic impacts.

In this study, data on vegetation cover derived from satellite images before and after tropical cyclones in Fiji are linked with available household surveys and the agricultural census data to obtain an improved assessment of tropical cyclone impacts. Tropical cyclones are the main disaster-inducing hazard in Fiji and in many Pacific island countries (PICs). Damages are assessed around four destructive tropical cyclones (TCs) that occurred in Fiji between 2016 and 2020. They are

- TC Winston (15 February 2016),
- TCs Josie (2 April 2018) and Keni (10 April 2018), and
- TC Harold (7–8 April 2020).

As measured by windspeed, TC Winston (a Category 5 cyclone) was one of the strongest tropical storms in recorded history and the strongest cyclone ever to make landfall in the Southern Hemisphere, with estimated wind speeds of up to 230 kilometers (km) per hour. After making landfall in Fiji in February 2016, TC Winston caused massive destruction, damaged 32,000 houses, and left approximately 350,000 Fijians in need of humanitarian aid. The total economic losses were estimated at $1.38 billion,2 approximately one-third of Fiji’s gross domestic product (Reliefweb 2016a; Reliefweb 2016b; NOAA 2016; WFP 2017; UNICEF n.d.).

In April 2018, Category 1 TC Josie affected the central and western parts of Fiji and caused heavy flooding, mainly on the main island of Viti Levu; whereas, Category 3 TC Keni passed close to Viti Levu just 1 week later, causing repeated flooding. The two cyclones affected approximately 78,000 Fijians, with 12,000 people seeking emergency shelter at evacuation centers. The economic losses caused by these two events were estimated at $3 million (Reliefweb 2018; RNZ 2018).

In April 2020, Category 5 TC Harold caused destruction in the Pacific island nations of Vanuatu, Fiji, Tonga, and Solomon Islands. It impacted the southern part of Fiji as a Category 4 storm and affected more than 180,000 people, displaced around 10,000 people, and destroyed or damaged almost 4,000 homes. The economic losses associated with the event were estimated to exceed $40 million (DFAT n.d.; Reliefweb 2020). There are no publicly available estimates of losses in agriculture from these four TCs, which is a focus of Noy et al. (2022).

The agriculture sector is important to Fiji’s economy as a key source of food and livelihood, and repeated occurrences of natural hazards pose a serious risk to food security, income, and employment. The sector contributed about 8.1% of Fiji’s gross domestic product in 2021 and is the main source of work and income for more than 80% of rural households (ITA 2022). Besides sugar, the island grows and exports kava, spices, fruits, and vegetables including root crops. The government is actively supporting the expansion and development of the agriculture sector.

COMBINING DATASETS FOR IMPACT ASSESSMENT

The study shows that combining remote-sensing measurement with socioeconomic, demographic, and agronomic data is useful for nowcasting damage to agriculture during a cyclone and directly thereafter. Satellite data can be selected in terms of their spectral, temporal, and spatial resolutions to obtain detailed, granular information. Further, these data can be matched with traditional socioeconomic information (e.g., census) to better gauge the determinants of impacts and to improve our ability to nowcast them. The study extracts the change in the Enhanced Vegetation Index (EVI) around four tropical cyclones. Data on the EVI is aggregated to the district level and matched with data from Fiji’s household income and expenditure survey (HIES) and its agriculture census. The main datasets used are the EVI, administrative data, and distance from the cyclone.

Enhanced Vegetation Index

Satellite imagery is obtained from two sources—Sentinel-2 and Moderate Resolution Imaging Spectroradiometer (MODIS)—with different characteristics and resolutions. Good quality images with less cloud coverage are extracted. A commonly used change-detection method is vegetation index differencing, which is applied to estimate vegetation and crop damage induced by tropical storms. This method has the advantages of being straightforward and of reducing the impact of topographic effects and illumination. The vegetation index

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2 Unless otherwise specified, “$” refers to United States dollars.
most used with the index differencing technique to estimate the impact of tropical storms is the normalized difference vegetation index. The EVI is a modified version of the normalized difference vegetation index and has more sensitivity over high-biomass regions, such as forests, and less sensitivity to atmospheric noise. Thus, the EVI is more representative of the dense vegetation of Fiji compared with other vegetation indexes.

The impact of a tropical cyclone is estimated by measuring the EVI before and after an event, to assess the vegetation cover damage. As cloud contamination can hinder the acquisition of images, the closest available images to landfall are selected within 2 months before and after each tropical cyclone that is investigated. For example, Figure 1 shows the EVI before (left) and after (right) TC Winston in Viti Levu, the largest island in Fiji. Healthy vegetation (i.e., those with high EVI values) are represented by green areas on the map, while nonvegetation surfaces or damaged vegetation (i.e., those with low EVI values) are shown in yellowish to reddish areas. Comparing the pair of images, there was a noticeable transition from green to yellow and red across Viti Levu Island after TC Winston had passed.

**Administrative Data**

Socioeconomic and demographic data were obtained from two sources: Fiji’s 2013–2014 Household Income and Expenditure Survey and the 2020 Fiji Agriculture Census (FAC). The HIES data from over 6,000 households were used to derive average household income per district (tikina covata). The FAC is organized at the subdistrict level (tikina vou) and captures detailed economic and demographic information for over 71,000 households relating to the agriculture sector in rural and peri-urban areas, including the crop composition of the district. Information in the FAC is grouped up to the district level to match the resolution available in the HIES. In the absence of annual district-level agricultural income, the annual agricultural income of Fiji from the Reserve Bank of Fiji (2021) is used for country-level analysis. Since we are combining satellite data of high frequency and survey data that is available once every few years, the accuracy of estimates will improve by using the latest surveys as they become available.

**Figure 1: Enhanced Vegetation Index Values in Fiji’s Viti Levu Island, Before and After Tropical Cyclone Winston**

Note: Left panel shows the enhanced vegetation index before Tropical Cyclone Winston (2016) and the right panel shows the enhanced vegetation index after the tropical cyclone.

Sources: Authors’ calculations using data from the Moderate Resolution Imaging Spectroradiometer and district boundary data from the Database of Global Administrative Areas (both accessed 31 January 2022).
To account for the effect of cyclone proximity on vegetation damage, the distance of a district from the cyclone is measured using cyclone trajectory maps from the International Best Track Archive for Climate Stewardship (NOAA, IBTrACS) and from Reliefweb (2016a). The value of the distance variable ranges from 1 (closest to the cyclone path) to 4 (furthest from the cyclone path) based on four zones, with borders at 50 km, 100 km, and 200 km from the cyclone path (as shown in an example in Figure 2).

In terms of specific crops, land with a large proportion of banana and dalo crops in exposed areas show more damage, while land cultivating cassava crop suffers less damage. Looking at pre-event socioeconomic variables, districts with higher income and, in some cases, bigger households suffer less cyclone-induced vegetation damage; whereas, higher average levels of government transfer and remittances from abroad are associated with areas that suffer more damage to vegetation. There is some evidence that irrigated land and agricultural land under traditional ownership may be more sensitive to cyclone impacts, but these results need to be further investigated.

While preliminary, the analysis paves a possible approach for estimating the predicted change in agricultural income following a tropical cyclone. For example, consider three hypothetical cyclone tracks, as shown in Figure 3.
and the estimates from the analysis discussed, we can follow a few steps to nowcast possible damages to agriculture as follows:

1. For each cyclone track (this information is posted immediately after the event), derive a preliminary estimate of the district-level change in the EVI, based on relations estimated in the analysis for key variables: distance from the path of the cyclone, banana and cassava (as grown in each district), household income, and government transfers. For each simulated track, based on the change in the EVI, we identify five districts that face the highest possible crop damage, listed in the panels in Figure 4. As this information is not time-sensitive, it allows one to estimate damage to agricultural production based on the basic parameters of the event.

2. Once remote-sensing readings of the cyclone become available (specifically a vegetation index, preferably the EVI), affected districts can be more accurately identified and assistance can be redirected towards them. This, together with the information about general vulnerability (e.g., the share of banana plantations in the district), can assist in pre-disaster risk reduction planning.

**CHALLENGES AND NEXT STEPS**

The study stops short of estimating more detailed impact of the cyclone, such as district-level loss of agricultural output, households’ income, and aggregate income. More work is needed to substantiate the results including accessing detailed data, which will enable a closer examination of the reliability of the indicators the study has used thus far. For example,

(i) agriculture census data and maps at a subdistrict level and with geo-located information about crops can be combined with household survey data to provide more observations for analysis;

(ii) granular data on households such as at the subdistrict or village level, location, income from specific crops, and other features to assess direct impact on households; and

(iii) data over a longer time period, such as through several rounds of household surveys, for understanding changes in income over time.
In general, richer data will provide more accurate estimates and stronger insights, which are important for effective targeting of responses and support.

Satellite imagery can function as an easily and publicly available, timely, and accurate data source to gauge the damage severity, its likely spatial distribution, and the specific pattern of impacts caused by a disaster event. Indeed, one can also develop, with the assistance of remote-sensing data, nowcasting tools to predict the impact of the event when it is happening (or immediately thereafter). While these serve as effective complements to ground surveys, particularly for immediate assessment, if accurate enough, the satellite imagery can potentially replace some components of the ground survey efforts, particularly to obtain a quick grasp of the impacts. Moreover, the remote-sensing, high-spatial, and high-frequency imaging that is now available, when coupled with information from sociodemographic and economic data as well as local knowledge and experience, can support initiatives...
such as the Pacific Catastrophe Risk Assessment and Financing Initiative and other (micro) insurance efforts, such as the one being trialed for sugarcane.³

As stronger tropical cyclones become more prevalent and continue to affect the lives and livelihoods of people, efforts are ongoing to create action plans to reduce exposure to this hazard and minimize risks. In the meantime, disaster risk management agencies are also coping with assessment and resource allocation challenges in the aftermath of events. The type of nowcasting developed in this project holds significant promise for reducing vulnerabilities associated with tropical cyclone impacts in the South Pacific.

REFERENCES


³ The Pacific Catastrophe Risk Assessment and Financing Initiative is a joint initiative of the Pacific Islands Applied Geosciences Commission/Secretariat of the Pacific Community, World Bank, and ADB, with financial support of the Government of Japan; the Global Facility for Disaster Reduction and Recovery; and the African, Caribbean and Pacific Group of States–European Union Natural Disaster Risk Reduction Programme. The Pacific Catastrophe Risk Assessment and Financing Initiative aims to provide PICs with disaster risk modeling and assessment tools and to engage with the PICs on integrated financial solutions to reduce financial vulnerability to disasters and climate change.