https://doi.org/10.5194/nhess-2022-4
Preprint. Discussion started: 14 March 2022

Natural Hazards and Earth System Sciences
Discussions

Assessing the impacts of tropical cyclones on rice production in Bangladesh, Myanmar, Philippines, and Vietnam

Kai Wan Yuen[1], Adam D. Switzer[1], Paul P. S. Teng[2], Janice Ser Huay Lee[1]

[1]Earth Observatory of Singapore, Asian School of the Environment, Nanyang Technological University, Singapore 637459, Singapore

[2]S. Rajaratnam School of International Studies, Nanyang Technological University, Singapore 639798, Singapore

Correspondence to: Janice Ser Huay Lee (janicelee@ntu.edu.sg)

Abstract.

Information on agriculture-related damage and losses in Asia is under-reported in major multi-peril disaster databases. National disaster databases in some countries may have information on agricultural losses, but this information is not always available. We address this knowledge gap by creating a database of cyclone-induced rice damage from 1970-2018 for four major rice producing countries in Asia which experience frequent and intense tropical cyclones as a result of their geographical location (Philippines, Vietnam, Bangladesh, and Myanmar). We collated information using online news sources on rice damage locations, rice area damaged, loss in rice production, and loss in rice value from 1970-2018. Of the 1,046 cyclone events recorded, 138 events were associated with rice damage and loss, and majority of these events (93%) happened in the Philippines and Vietnam. The average area of rice damaged per cyclone event ranged from 42,407 ha in Vietnam to 423,075 ha in Myanmar. The average rice production loss per cyclone event ranged from 460,667 metric tonnes in Bangladesh to 2,943,088 metric tonnes in the Philippines. Losses in rice production value from 1970-2018 were only reported in the Philippines and amounted to an average of US$42 million per cyclone event. Although Category 4 events tend to cause the most damage, tropical storms and Category 1 events were more frequent, especially in Vietnam. While our study is limited by the availability and quality of online news sources, we provide an assessment of rice agricultural damage from tropical cyclones in major rice producing countries in Asia.

Key words.
Agricultural damage, Food security, Natural hazards, Rice agricultural systems

1 Introduction

Information on disaster-related damage and losses is highly sought after by researchers, government agencies, aid organizations to inform aid and relief efforts, as well as insurance companies for financial payouts. In the long term, such data is needed for risk assessment and for disaster preparation. Meanwhile, insurance and financial companies use damage

https://doi.org/10.5194/nhess-2022-4
Preprint. Discussion started: 14 March 2022

and loss data for risk analyses, to develop risk transfer products, and to determine compensation payouts (Wirtz et al., 2014). Commonly reported damage and loss data in newspaper articles and reports released by various agencies include fatalities, the number of people injured, homeless and affected, as well as the amount of material damage to housing, infrastructure, and agriculture. Information related to disaster damage and loss reported immediately after a disaster is often unreliable and estimates tend to be exaggerated in the hope that emergency aid will be mobilized quickly (Kron et al., 2012; Wirtz et al., 2014).

Apart from biased reporting by interest groups seeking to obtain more aid, damage and loss figures may be deliberately revised downwards to cover up inadequate disaster preparedness and response. In addition, faulty translations and errors in conversions of currencies and units are another source of error (Kron et al., 2012). In the chaos of a disaster, double counting and false reporting is also possible (Kron et al., 2012). For Typhoon Ketsana in 2009, a comparison of central government data with provincial level data for Quang Nam province in Vietnam showed a large difference in the quantity of paddy inundated. The Central government reported 3,930 ha of paddy were inundated while provincial data records showed 22,523 ha, suggesting that potential errors were introduced in the process of data collection (Hughey et al., 2011). Meanwhile, descriptive terms used for the classification of damage may be ambiguous. The lack of standardized definitions may be one of the reasons why the province of Quang Tri reported 231,026 ‘people affected’ by Typhoon Ketsana while the central government had no data for the same variable (Hughey et al., 2011). Similarly, when flood damage data from the United States National Weather Service, a national-level agency, was compared against data collected by five state-level emergency management agencies, large errors in damage estimates for individual counties were found especially for small-scale events. Specifically, for damages between US$5 and 50 million, 55% of state-level estimates differed from national-level estimates by a factor of two or more. For damages between US$50 and 500 million, 30% of state estimates differed by a factor of two or more. State- and national-level estimates differed by a factor of less than two for major flood events with >US$500 million of damages. While collection of data for larger events was more likely to be systematic and complete, for small events, data collection tend to be haphazard (Downton and Pielke, 2005).

In 2015, 187 countries at the United Nations World Conference on Disaster Risk Reduction adopted the Sendai Framework for Disaster Risk Reduction (SFDRR) as a guide for risk reduction action from 2015-2030. The SFDRR was preceded by the Hyogo Framework for Action (HFA) which sought to develop indicators for assessing disaster risk and vulnerability at the national and sub-national scales. These indicators are useful for assessing the social, economic, and environmental impacts of disasters (Guha-Sapir and Vos, 2011; Ito et al., 2016). Building on the HFA, seven global targets were adopted in the SFDRR that included reduced disaster mortality, reduced number of affected people, reduced direct economic losses, reduced damage to critical infrastructure and disruption of basic societal services, increased number of countries with risk reduction strategies, enhanced international cooperation with developing countries, and increased availability and access to multi hazard early warning systems (Johansson, 2017; UNISDR, 2015). To implement the SFDRR and assess progress in reducing disaster losses, standardized and comparable disaster data is needed (Conforti et al., 2020).

To address the challenge of obtaining authoritative and standardized disaster data, there are several disaster databases that compile damage and loss disaster data at the international, regional, and local scale. DesInventar Sendai, Emergency Events Database (EM-DAT), NatCatSERVICE, and Sigma are four major international databases which provide damage data related to biological, geophysical, hydrological, meteorological and climatological disasters (Below et al., 2009) (Table 1). The Asian Disaster Reduction Centre (ADRC) provides disaster information in Asia since 1998. Data in this regional database is obtained from United Nations agencies, international news agencies and non-governmental organizations. However, the inclusion criterion is not made public. Reported losses include the number of dead, missing, affected or displaced, as well as the amount of material damages (Asian Disaster Reduction Center, 2021; Tschoegl et al., 2006). In Southeast Asia, some countries have specific organizations that compile disaster data. The National Disaster Risk Reduction and Management Council (NDRRMC) in the Philippines and the Philippines Disaster Response Management Bureau (DRMB) publish information on natural disasters (Table 2, Table S1). In Indonesia, disaster information is collated on the *Data Dan Informasi Bencana Indonesia* (DIBI) or Disaster Data and Information database and spatially mapped under the *Geoportal Data Bencana Indonesia* or Indonesia Disaster Data Geoportal (Table 2, Table S2). Likewise, Malaysia and Vietnam also have a publicly available national-level disaster database published in their official languages (Table 2, Table S3-4). The General Statistics Office of Vietnam also has a natural disaster damage database published in English.

While international databases such as DesInventar Sendai, EM-DAT, NatCat, Sigma, and the ADRC regional databases provide information related to human impacts, infrastructure damage and economic loss, only the DesInventar, Sendai, and ADRC regional databases have information on agricultural related damage. However agricultural losses are not always available. For example, in the DesInventar Database, Vietnam was amongst the 82 countries that supposedly had data. A search for information pertaining to cyclone induced crop damage from the year 2000-2018 did not yield any results. In other international databases, it is possible for agriculture specific losses to be aggregated and included in “total property losses” and “insured property losses”. A lack of information on how these loss values were derived makes it impossible to independently estimate the quantity of agricultural related losses. While local databases may include agricultural losses, the information was sometimes incomplete as only certain indicators of loss were reported. Among the national databases, only four databases reported agricultural losses - NDRRMC for the Philippines, DIDB for Indonesia and the two Vietnamese databases. The NDRRMC database reported economic losses in pesos while DIDB and the two Vietnamese databases reported areal losses in hectares. Hence, we attempt to fill the knowledge gap by compiling information on rice related damage from hazards, specifically cyclone hazards, from published online news sources to create a database of cyclone-induced rice damage from 1970-2018.

https://doi.org/10.5194/nhess-2022-4
Preprint. Discussion started: 14 March 2022

We focused on the impacts of tropical cyclones on rice agriculture in Asia as tropical cyclones which include tropical storms, typhoons or hurricanes are one of the most destructive multi-hazard events. Cyclones have severe impacts on agriculture, of which rice is a major staple crop in Asia (Hattori et al., 2010; Masutomi et al., 2012; Rana et al., 2018; Vink and Ahsan, 2018). Strong winds from tropical cyclones cause lodging, striping and induced water stress in rice fields (Blanc and Strobl, 2016). In addition, flooding caused by high rainfall and storm surges may decrease photosynthesis and respiration in rice plants and destroy them. Documenting the damage of tropical cyclones on rice production area, production losses and value at which locations would allow researchers and policymakers to determine the spatial distribution of cyclone-induced rice damage. Here, we aim to construct a database of tropical cyclone induced rice damage in four countries in Asia (Philippines, Vietnam, Bangladesh, and Myanmar) from 1970 to 2018 using online news sources. These countries represent top rice producers in the world and have been affected by frequent and intense tropical cyclones based on their geographical locations. We standardized values reported for rice area damaged, rice production lost, and rice value lost from tropical cyclones in these four countries.

2 Method

We limit our search to four major rice producing countries frequently impacted by tropical cyclones – Philippines, Vietnam, Bangladesh, and Myanmar. Over a ten-year period from 2010 to 2019, these countries were ranked as one of the top ten rice producers worldwide (Table 3). Over the same period, a yearly average of 4 and 6 tropical cyclones made landfall in the Philippines and Vietnam respectively (Table 4). These cyclones spawn in either the Pacific Ocean or South China Sea (Cinco et al., 2016; Nguyen-Thi et al., 2012). Conversely, cyclones from the Bay of Bengal often track north towards Bangladesh and Myanmar (Alam and Dominey-Howes, 2015). Although the average number of tropical cyclones that made landfall in Bangladesh and Myanmar over the same ten-year period was 1 and 0.4/year respectively, we focused on these countries because Bangladesh has a history of being devastated by natural disasters (Alam and Collins, 2010) and there is limited research on Myanmar because the authorities had limited the reporting of natural disasters (Grundy-Warr and Sidaway, 2006).

To obtain a list of cyclones that caused rice damage, tropical cyclones that passed through or passed close to each country (within 500 km from the coastline) from 1970 to 2018 were first identified from three tropical cyclone databases including Digital Typhoon, the Joint Typhoon Warning Centre (JTWC), and the International Best Track Archive for Climate Stewardship (IBTrACS). A 500 km buffer was chosen because rain within 500 km from the center of a cyclone can be considered cyclone rain (Hattori et al., 2010). The cyclones that affected Philippines and Vietnam were collated from the Digital Typhoon (2021) database while those for Bangladesh and Myanmar were from the Joint Typhoon Warning Centre (JTWC, 2021) and the International Best Track Archive for Climate Stewardship (IBTraCS, 2021). We grouped the tropical cyclones into six categories based on their landfall intensity to reflect each cyclones' potential to cause damage. Cyclones that did not make landfall were also included as a separate category as rice crops in coastal areas can be damaged by strong winds and heavy rain from a passing cyclone. The six categories are: No landfall (LF), tropical storm (TS), Typhoon Categories 1, 2, 3 and 4. Except for the LF category, classification for the rest was based on the Saffir-Simpson Hurricane Wind Scale (Taylor et al., 2010).

Next, information on damage locations and damage were compiled from newspaper reports, humanitarian relief reports and other published online sources for each typhoon event. Non-English publications were translated with the help of Google Translate and the information was included, if relevant. These sources were obtained from a Google search with various permutations of the following keywords: “cyclone/typhoons”, “rice”, “damage” and the country name. Individual cyclone name(s) and the year of occurrence were also used. Information was also obtained by searching in the regional ADHRC database, the national level NDRRMC database for the Philippines and ReliefWeb, a website for humanitarian information. To reflect the diversity of information reported, rice damage was classified according to (i) the size of rice areas damaged, (ii) the quantity of rice production lost, and (iii) the value of rice lost. Units were standardized to hectares (ha) for areal damages, metric tonnes for production losses, and United States dollar (US$) for monetary losses. As the monetary value of rice lost may be reported in the domestic currency, we used the prevailing yearly US$ exchange rate at the time of the report to convert all values to US$ to facilitate comparison. The currency exchange rates used are reported in the Supplementary Data accompanying this paper.

3 Results

A total of 1,046 cyclone events made landfall or passed within 500 km of the Philippines, Vietnam, Bangladesh, and Myanmar from 1970-2018 (Table 5). However, only 138 events (13%) were associated with reports of rice damage from our online news search (Table 5). The number of online news sources for rice damage associated with tropical cyclones were expectedly higher in 2010-2018, likely a result of the widespread use of the internet and increase in online news sources as compared to previous decades (Table 5).

3.1 Cyclone frequency and landfall intensity

During 1970-2018, a total of 526 cyclones made landfall or passed within 500 km of Philippines. Of these, 60 cyclone events (11%) had reports of rice damage. Majority of these cyclone events (97%) originated in the Pacific Ocean. Of the 60 cyclone events, 70% or 42 events reported rice damage from 2010-2018. In the preceding ten years, 2000-2009, there were only 9 cyclones with rice damage reported. There was no data from 1970-1979 (Table 5). Of the 60 cyclones that damaged rice in the Philippines, 28% were tropical storms while 25% were Category 1 cyclones. Stronger Category 2 and 3 cyclones each made up 13% and 17% of cyclone-induced rice damage reports. There was one category 4 event, Typhoon Megi in 2010. 9 cyclones out of 60 cyclones did not make landfall but the accompanying rains and strong winds damaged rice.

For Vietnam, 303 cyclones occurred from 1970-2018, with 68 cyclones (22%) associated with reports of rice damage. 27 out of these 68 cyclones (40%) occurred from 2010–2018. The next highest number of cyclone-induced rice damage reports was from 1980 – 1989 (17 cyclones). There was no agricultural loss data reported from cyclones from 1970-1979 (Table 5). For these 68 cyclones, the location of cyclone genesis was evenly split between the Pacific Ocean (52%) and the South China Sea (43%). 69% of cyclones affecting rice crops in Vietnam was a tropical storm with the remaining 21% classified as a stronger Category 1 cyclone. There were no stronger cyclones that damaged rice. Six cyclones caused rice damage without making landfall.

A total of 96 and 121 cyclones were recorded for Bangladesh and Myanmar respectively. Statistics on rice damage in Bangladesh were found for eight out of the 96 cyclones (8%). The most data was from 2010-2018 and 1980-1989 (3 cyclones each). Meanwhile the corresponding number for Myanmar was only two Category 4 cyclones (2%), Cyclone Nargis in 2008 and Cyclone Giri in 2010 (Table 5; "landfall category" in Supplementary Data). Like Vietnam, most of the cyclones that damaged rice crops in Bangladesh were classified as a tropical storm (five cyclones). The remaining three cyclones consisted of two Category 1 cyclones (1970 Bhola cyclone and Cyclone Mora in 2017) and one Category 4 cyclone (Cyclone Sidr in 2007). The two cyclones that damaged rice in Myanmar spawned in the Bay of Bengal while the Bay of Bengal and the Andaman Sea were the genesis locations for 56% and 33% of the Bangladesh cyclones (Supplementary Data).

3.2 Spatial frequency of cyclone-induced rice damage

In the Philippines, during 1970-2018, cyclone induced rice damage was most frequently experienced in Cagayan, Tarlac (both 16 times) and Nueva Ecija (15) – Figure 1. The provinces of Albay, Aurora, Bulacan, Isabela, Pangasinan, Zambales, Camarines Sur, Ifugao and Pamapanga were affected 13 to 14 times (Figure 1). Provinces in Cagayan Valley and Central Luzon in northern Philippines and Bicol Region in the east were highly exposed to cyclone-induced rice damage. In Vietnam, Nghe An (17 times), Khanh Hoa, Phu Yen, Quang Nam, Quang Tri and Thanh Hoa (all 13 times) had the most reports of cyclone-induced rice damage (Figure 2). At a regional level, these provinces are evenly split between the North Central Coast (Nghe An, Quang Nam and Quang Tri) and the South Central Coast (Khanh Hoa, Phu Yen and Quang Nam). While rice crops in the central coastal regions were most prone to cyclone damage, the hubs of rice production in Vietnam are in the Red River Delta in the north and the Mekong Delta in the South (Nelson and Gumma, 2015).

In Bangladesh, Chittagong district had the highest frequency of rice damage (8 times). Patuakhali, Noakhali (both 6) and Bhola (5) districts were equally vulnerable. Chittagong and Noakhali are in Chittagong Division while Bhola and Patuakhali are in Barisal Division – all skewed towards southeast Bangladesh. (Figure 3). The dataset from Myanmar showed that Sittwe district in Rakhine State had the highest frequency of cyclone induced rice damage (2 times). Bassein, Kyaunkpyu

https://doi.org/10.5194/nhess-2022-4
Preprint. Discussion started: 14 March 2022

Maungtaw, Myoungmya, Pyapon, and South Yangon all had rice fields that were damaged once (Figure 4). Except South Yangon which is in Yangon Region, the rest were either in Ayeyarwady Region or Rakhine State.

3.3 Cyclone-induced rice area damaged, rice production loss and rice value loss

The average area of rice damaged per cyclone event from 1970-2018 was highest for Myanmar, followed by Bangladesh, Philippines, and Vietnam. Vietnam had the most data on areal loss (66 data points), followed by the Philippines (26), Bangladesh (8), and Myanmar (2) (Table 6). Cyclones that did not make landfall caused little damage compared to those that did make landfall. Overall, Myanmar had the highest area of rice damage as the values were skewed by two Category 4 cyclones – Cyclone Nargis (2008) (range: 15,126 – 1,600,000 ha) (MOAI, 2015; USDA, 2008) and Cyclone Giri (2010) (38,587 ha) (MOAI, 2015). The high value for Bangladesh was due to Cyclone Sidr in 2007, another Category 4 cyclone (range: 94,200 – 1,261,337 ha) (Ahmed, 2007; ReliefWeb, 2008). Philippines also had a single Category 4 cyclone - Cyclone Megi which damaged 425,134 ha of rice in 2010 (NDRRMC, 2010). Vietnam had the lowest rice area damaged as all the cyclones that made landfall were either tropical storms or Category 1 cyclones.

Even though Category 4 events were the most powerful, actual losses of rice did not necessarily have a direct relationship with cyclone intensity. In Vietnam, the average area of rice damaged by a cyclone with the intensity of a tropical storm (52,687 ha) was higher than the areal damage reported by a stronger Category 1 cyclone (18,758 ha). Similarly, tropical storms also damaged greater extents of rice in Bangladesh than a Category 1 storm (394,918 ha vs 211,746 ha). The same phenomenon applied for Category 2 cyclones in the Philippines which caused less damage compared to cyclones of lower intensity (Figure 5a; Table 6). The lower values may be due to the stronger cyclones missing the vulnerable growing and harvesting periods of rice production or major rice growing regions.

From 1970-2018, average rice production lost per cyclone event was highest in the Philippines, followed by Myanmar, Vietnam, and Bangladesh. Philippines had 21 data points, Vietnam had 4, while Bangladesh and Myanmar had two data points each (Table 6). The highest production loss was caused by Typhoon Rosita, a Category 1 cyclone that affected Philippines in 2018. Likewise, the relationship between rice production and cyclone intensity was not correlated for Vietnam. The average production loss from tropical storms that affected Vietnam (718,600 metric tonnes) was 900 times higher than the damage incurred from Category 1 events (800 metric tonnes) (Table 6). For Bangladesh, though there was a direct relationship between cyclone intensity and loss, this could be an outcome of the data available – production loss was contributed by one cyclone each from three categories (Figure 5b). The production losses reported for Myanmar were from the same two Category 4 cyclones, Nargis and Giri. Cyclone Nargis destroyed 707,500 metric tonnes of stored paddy and milled rice (FAO, 2009) while Cyclone Giri caused 1.7 million metric tonnes of rice loss (MOAI, 2015) .

Monetary value of rice lost was largely limited to the Philippines (50 data points). The sole data point from outside Philippines was from Cyclone Sidr in Bangladesh (Table 6; Figure 5c). There was only one Category 4 cyclone in the Philippines for comparison - Cyclone Megi. Reports of the value of rice lost due to Cyclone Sidr ranged from US$270 million to 290 million (ReliefWeb, 2007, 2008). The only report for Cyclone Megi had US$198 million of loss (NDRRMC, 2010). With data from the six categories of cyclones available for the Philippines, the value of rice lost from 1970-2018 was the highest under Category 4 cyclones, followed by Category 2, Category 3, Category 1 cyclones, tropical storms, and cyclones that made no landfall (Figure 5c). From 1970-2018, the Philippines suffered an average rice production loss of US$42 million per cyclone event (Table 6).

4 Discussion

Our database on cyclone induced rice damage from 1970-2018 for four major rice producing countries provides baseline knowledge on the impacts of tropical cyclones on rice production as the impacts of natural disasters on agriculture are seldom quantified. We showed that around 13% of the cyclone events from 1970-2018 were associated with reports of rice damage through online news sources, and that the availability of this information was higher in more recent decades. We spatialized where cyclone-induced rice damage was more frequent at the provincial level for each of our four countries. While Category 4 level tropical cyclones were associated with highest reports of rice area damaged, the relationships between rice area damaged, rice production loss, and rice value loss were weakly correlated with the strength of the tropical cyclones.

Rice damage data from the 1970s was limited to a 1970 cyclone in Bangladesh, a powerful cyclone that claimed more than 300,000 lives and destroyed 400,000 metric tonnes of rice (Agency for International Development, 1971; Islam and Peterson, 2009). More information was available from year 2000 onwards when the internet became more ubiquitous. While information was previously scarce, the proliferation of online reports by different publishers resulted in numerous data sources to select from. For example, in 2018, we found a total of 19 different reports of agricultural damage for Typhoon Rosita in Philippines and 13 different reports for Typhoon Son-Tinh in Vietnam (Supplementary Data).

The information reported for each country also varied significantly. The unusually low number of cyclones that damaged rice in the Philippines relative to the total number of cyclones that passed through or came close to the country (526) reflects the way disaster data was reported in the Philippines - rice related loss tends to be aggregated with other crops instead of being reported separately. On the other hand, it is likely that the limited information for Bangladesh and Myanmar was due to a lack of reporting and not a lack of damage as Bangladesh and Myanmar are both agrarian countries with a substantial rice output (GRSP, 2013; Grundy-Warr and Sidaway, 2006) (Table 6). Rice is grown throughout Bangladesh including the cyclone-prone coastal regions of Barisal, Chittagong and Khulna (Haque and Jahan, 2016; Shelley et al., 2016). Likewise, major rice producing regions in Myanmar include Ayeyarwady, Yangon and Bago which border the sea (Naing et al., 2008). Tropical cyclones affect both countries from April to May and October to November every year. The former coincides with the harvesting of the boro rice crop in Bangladesh and the dry season crop in Myanmar while the latter coincides with the harvesting of the aman rice crop in Bangladesh and the main rice crop in Myanmar (Alamgir et al., 2017; Torbick et al., 2017). The lack of rice damage information for Bangladesh may be due to the authorities' focus on saving lives during environmental disasters (Ahmed et al., 2019) while Myanmar's economic and political isolation has limited the availability of information (Webb et al., 2014). For Myanmar, the two cyclones that damaged rice were Category 4 events which suggest that cyclone damage was only reported if the cyclone was a powerful one that warranted international attention. Cyclone Nargis was the worst natural disaster in Myanmar's recorded history (Fritz et al., 2009) while Cyclone Giri caused extensive damage in Rakhine State, one of the poorest regions in Myanmar (The Guardian, 2010).

4.1 Data limitations and uncertainty

A lack of methodological standardization complicates analysis and has been repeatedly highlighted by reviewers of disaster data (Gall et al., 2009; Guha-Sapir and Below, 2002; Tschoegl et al., 2006). Likewise in our approach, we found that damage locations were reported at a range of spatial scales ranging from region/division level (largest scale) to province/district level to municipalities/districts/sub-districts/townships (smallest scale). Some sources provided detailed locations of rice damage while others provided non-specific geographical information like "Northern Vietnam" (ReliefWeb, 2005) or "South of Hai Phong" (ReliefWeb, 1989). There were also spelling errors, different spellings for a similar place, and changes to the names of locations which increased the error for data collation.

Secondly, non-standardization also meant that several indicators of rice damage were used. Some sources provided areal damages; others published production losses. For our database, units were standardized to hectares for areal damages, metric tonnes for production losses and US$ for monetary losses. The definition of "damage" also varied across news sources. Some news sources used the term "damage" to describe the impact to rice crops. Other news sources used terms such as "affected", "ruined", "destroyed" and "submerged." The terms "affected" and "submerged" could indicate that the crop was affected by the cyclone but not damaged. As a conservative measure, we considered all values as the amount of rice damaged by the cyclone.

In addition, damage values were sometimes amalgamated while location specific figures were available in some sources. Notably, from 2007 onwards, provincial level breakdowns were available for many of the major cyclones that affected

Philippines. This information was published by two agencies, ReliefWeb and the Philippines National Disaster Risk Reduction and Management Council (NDRRMC). The availability of such location specific values was less consistent for the other three countries which highlight disparities in data collection capabilities. Ideally, a spatial analysis of rice damage should be done to have a better overview of geographical vulnerability. However, this was not possible as damage data from various locations were often amalgamated to give a single loss value.

Lastly, online news sources do not always provide information on how their data was collected. In our analysis, for each cyclone, we shortlisted data based on the minimum and maximum values reported and derived a midpoint as we found it challenging to evaluate which source had the "most accurate" rice damage value. While the most recent source may be published when the event has concluded and there was arguably more time to collect and verify information, without any detailed methodological information, attempting to a make a value judgement was difficult.

4.2 Towards better data

The Food and Agricultural Organization (FAO) has partnered the United Nations Office for Disaster Risk Reduction (UNDRR) to develop a standardized methodology for Damage and Loss Assessment in Agriculture (Conforti et al., 2020). This methodology has been adopted by the two main 2015 international agendas – the Sustainable development goals (SDG) and the Sendai Framework for Disaster Risk Reduction (SFDRR). The methodology consists of five components that are aggregated to quantify the total effect of disasters on agriculture:

$$\text{Impact to agriculture} = DL\ (C) + DL\ (L) + DL\ (FO) + DL\ (AQ) + DL\ (FI)$$

Where DL (C) is direct damage and loss to crops, DL (L) is direct damage and loss to livestock, DL (FO) is direct damage and loss to forestry, DL (AQ) is direct damage and loss to aquaculture and DL (FI) is direct damage and loss to fisheries. This methodology distinguishes between damage (ie. total or partial destruction of physical assets such as machinery, seeds and crops) and loss (ie. declines in the value of agricultural production resulting from the disaster). Each subsector is also further divided into two main components: production and assets. For crop loss, DL (C) = Annual crop production damage + Perennial crop production damage + annual crop production loss + perennial crop production loss + crop assets damage (complete and partial) (cf. Conforti et al., 2020).

Through the use of the FAO Damage and Loss methodology, a standardized approach for collecting, analysing, reporting and disseminating agriculture related impacts can be achieved. One caveat of this methodology is that information such as the number of hectares of crops damaged and/or destroyed (disaggregated by crop type), expected yield reduction of each crop in partially affected plot areas (t/ha), and baseline information on the original area of each type of crops cultivated (ha) are needed (Conforti et al., 2020).

https://doi.org/10.5194/nhess-2022-4
Preprint. Discussion started: 14 March 2022

Arguably, data collection in the immediate aftermath of a disaster is challenging and under emergency conditions, first responders have other priorities than attempting to collect and disseminate detailed loss statistics. To facilitate data collection, prior to a disaster, good baseline information on communities, infrastructure and properties, including crop growing areas should be collected. In addition, place names, definitions, codes, categories and units of measurement should be clearly defined and standardized. An appropriate geographical unit should be specified to ensure data is collected at an appropriate scale. For this, a template for data collection can be created.

While collecting and consolidating baseline data, creating templates for data collection and training end-users is time consuming and resource intensive, these challenges are more easily overcome outside the context of an emergency. If resources are limited, collecting baseline data for hazard prone areas should be prioritized. Finally, to facilitate the reporting and updating of information, a system that allows end-users to input data directly via cellular or satellite network could be created (Amin et al., 2008; Soto, 2015). When reporting information, the time of recording, the source of information and uncertainties as well as information on the assessment methodology should be furnished to inform quality assessment (European Commission, 2015). Recognizing these challenges, the FAO has also created a National-level Damage and Loss Information Systems for agriculture, a tool kit that consist of sample survey forms, data collection tools and database templates and guidance documents. This was created to assist governments in assessing damage and loss and provide standard operating procedures for quantifying agricultural losses (Conforti et al., 2020).

5 Conclusion

Natural disasters have always threatened human security and will continue to do so. The recent UN Climate Change Summit (COP26) has also predicted that the frequency of climate-related disasters is likely to increase in the coming decade. However, with proper preparation, future damage can be minimized. To inform preparation efforts, accurate disaster data is needed to have a better understanding of the frequency and impacts of previous disasters. In the aftermath of a disaster, accurate information on damage locations and the extent of damage are critical for relief efforts. However, the immediate aftermath of a disaster is chaotic and data collection in these situations is likely incomplete. With a lack of standardized collection methodologies and definitions, damage figures reported are fraught with uncertainties (Guha-Sapir et al., 2004; Tschoegl et al., 2006). Multi-peril disaster database providing loss data at the international, regional, and local levels have become go to places for disaster data. A review of these database found that information on agricultural related damage was lacking. While national databases may have more complete information, not all national databases have agricultural data. Thus, we attempt to fill the gap in information by compiling information on rice related damage from published sources to create a historical database of cyclone-induced rice damage from 1970-2018.

We acknowledge that our database has accounting, geographic and systemic bias as the primary sources we draw upon have similar ambiguities (Gall et al., 2009). Besides a lack of data in the first 30 years, we encountered problems related to a lack of disaggregated crop and locational data. To address uncertainties and provide high quality data for researchers, policymakers and other users, clear guidelines and standard procedures should be developed. Thereafter, these protocols should be implemented across the various agencies and stakeholders involved in collecting disaster data (Gall et al., 2009). The FAO Damage and Loss methodology is one recent standardized approach for recording agriculture related impacts under precise impact categories. Even though the FAO Damage and Loss methodology is an attempt to establish standardized protocols, (Wirtz et al., 2014) it is unclear what is the level of uptake of this approach from government and non-governmental organizations and aid agencies. End-users of disaster data must be cognizant of the errors and uncertainties inherent in the impact values reported and acknowledge these limitations in their analyses.

Author contributions

KW and JSH came up with the idea for this project. KW wrote the manuscript with discussions and improvements from all co-authors. JSH, AD and PT provided feedback on the analysis of data and helped in the revisions. JSH provided financial support for this work.

Competing interests

The authors declare that they have no conflict of interest.

Acknowledgements

We thank Skye Lee, Nai Ze Ming and Maye Woo for help with compiling the rice damage data.

Financial support

This research has been supported by the Earth Observatory of Singapore (grant no. M4430263.B50.706022) via its funding from the National Research Foundation Singapore and the Singapore Ministry of Education under the Research Centres of Excellence initiative. This work comprises EOS contribution number 360.

References

Asian Disaster Reduction Center: https://www.adrc.asia/latest/, last access: 28 May 2021, 2019.

Agency for International Development: 11th Report. Foreign disaster emergency relief. Fiscal year 1971: https://reliefweb.int/sites/reliefweb.int/files/resources/4CACB65FF4524CE38525777D006DD685-USAID_AR1971.pdf, last access: 28 May 2021, 1971.

Ahmed, H. S.: A trail of death: http://archive.thedailystar.net/magazine/2007/11/04/cover.htm, last access: 2 June 2020, 2007.

Ahmed, I., Ayeb-Karlsson, S., van der Geest, K., Huq, S., and Jordan, J. C.: Climate change, environmental stress and loss of livelihoods can push people towards illegal activities: a case study from coastal Bangladesh, Climate and Development, 11, 907-917, 10.1080/17565529.2019.1586638, 2019.

Alam, E. and Collins, A. E.: Cyclone disaster vulnerability and response experiences in coastal Bangladesh, 34, 931–954, https://doi.org/10.1111/j.1467-7717.2010.01176.x, 2010.

Alam, E. and Dominey-Howes, D.: A new catalogue of tropical cyclones of the northern Bay of Bengal and the distribution and effects of selected landfalling events in Bangladesh, 35, 801–835, https://doi.org/10.1002/joc.4035, 2015.

Alamgir, M. S., Furuya, J., and Kobayashi, S.: Determinants of early cropping of rice in Bangladesh: An assessment as a strategy of avoiding cyclone risk, Japanese Journal of Agricultural Economics, 19, 27-30, 10.18480/jjae.19.0_27, 2017.

Amin, S., Cox, M., and Goldstein, M.: Using data against disasters: Overview and synthesis of lessons learned, Data against natural disasters : establishing effective systems for relief, recovery, and reconstruction, edited by: Amin, S., World Bank, Washington DC, 1-22 pp., 2008.

Below, R., Wirtz, A., and Guha-Sapir, D.: Disaster category classification and peril terminology for operational purposes, 2009.

Blanc, E. and Strobl, E.: Assessing the Impact of Typhoons on Rice Production in the Philippines, 55, 993–1007, https://doi.org/10.1175/JAMC-D-15-0214.1, 2016.

Cinco, T. A., de Guzman, R. G., Ortiz, A. M. D., Delfino, R. J. P., Lasco, R. D., Hilario, F. D., Juanillo, E. L., Barba, R., and Ares, E. D.: Observed trends and impacts of tropical cyclones in the Philippines, 36, 4638–4650, https://doi.org/10.1002/joc.4659, 2016.

Conforti, P., Markova, M., and Tochkov, D.: FAO's methodology for damage and loss assessment in agriculture. FAO Statistics Working Paper 19-17, Rome, https://doi.org/10.4060/ca6990en, 2020.

Digital Typhoon: Typhoon images and information: http://agora.ex.nii.ac.jp/digital-typhoon/index.html.en, access: 29 May 2021, 2021.

Downton, M. W. and Pielke, R. A.: How accurate are disaster loss data? The case of U.S. flood damage, 35, 211–228, https://doi.org/10.1007/s11069-004-4808-4, 2005.

FAO: FAO post-Nargis recovery and rehabiliation program: http://www.fao.org/fileadmin/user_upload/emergencies/docs/MYANMAR_-_FAO_Post-Nargis_Recovery_and_Rehabilitation_Programme_Strategy_Ag_Clust_requirements_-_27_04_09_VS.pdf, access: 2 June 2019, 2009.

Fritz, H. M., Blount, C. D., Thwin, S., Thu, M. K., and Chan, N.: Cyclone Nargis storm surge in Myanmar, Nature Geoscience, 2, 448-449, 10.1038/ngeo558, 2009.

Gall, M., Borden, K. A., and Cutter, S. L.: When do losses count?: Six fallacies of natural hazards loss data, Bulletin of the American Meteorological Society, 90, 799-810, 10.1175/2008bams2721.1, 2009.

GRSP (Global Rice Science Partnership): Rice almanac, 4th edition, International Rice Research Institute, Los Baños, 2013.

Grundy-Warr, C. and Sidaway, J. D.: Politcal geographies of silence and erasure, 25, 479–481, https://doi.org/10.1016/j.polgeo.2006.06.001, 2006.

Guha-Sapir, D., and Below, R.: The quality and accuracy of disaster data: A comparative analyse of three global data sets, WHO Centre for Research on the Epidemiology of Diasasters, University of Louvain School of Medicine, Brussels, Belgium, 2002.

Guha-Sapir, D., Hargitt, D., and Hoyois, P.: Thirty years of natural disasters 1974-2003: The numbers, Presses univ. de Louvain, 2004.

Guha-Sapir, D. and Vos, F.: Quantifying global environmental change impacts: Methods, criteria and definitions for compiling data on hydro-meteorological disasters, in: Coping with Global Environmental Change, Disasters and Security: Threats, Challenges, Vulnerabilities and Risks, edited by: Brauch, H. G., Oswald Spring, Ú., Mesjasz, C., Grin, J., Kameri-Mbote, P., Chourou, B., Dunay, P., and Birkmann, J., Springer Berlin Heidelberg, Berlin, Heidelberg, 693–717, https://doi.org/10.1007/978-3-642-17776-7_40, 2011.

Haque, A., and Jahan, S.: Regional impact of Cyclone Sidr in Bangladesh: A multi-sector analysis, International Journal of Disaster Risk Science, 7, 312-327, 10.1007/s13753-016-0100-y, 2016.

Hattori, M., Tsuboki, K., and Mori, S.: Contribution of tropical cyclones to the seasonal change patterns of precipitation in the Western North Pacific: Estimation based on JRA-25/JCDAS, 6, 101–104, https://doi.org/10.2151/sola.2010-026, 2010.

Hughey, E., Bell, H., and Chatman, M.: Who needs what? A case study of post-disaster damage and needs assessment (DANA) in Vietnam, 2, 1–24, https://doi.org/10.2202/1944-4079.1097, 2011.

IBTrACS (International Best Track Archive for Climate Stewardship): NOAA National Centers for Environmental Information: https://www.ncdc.noaa.gov/ibtracs/index.php?name=ib-v4-access, last access: 29 May 2021, 2021.

Islam, T., and Peterson, R. E.: Climatology of landfalling tropical cyclones in Bangladesh 1877–2003, Natural Hazards, 48, 115-135, 10.1007/s11069-008-9252-4, 2009.

Ito, J., Nishikori, M., Toyoshi, M., and Feuer, H. N.: The contribution of land exchange institutions and markets in countering farmland abandonment in Japan, 57, 582–593, https://doi.org/10.1016/j.landusepol.2016.06.020, 2016.

Johansson, M.: Experience of data collection in support of the assessment of global progress in the Sendai Framework for Disaster Risk Reduction 2015–2030 – A Swedish pilot study, 24, 144–150, https://doi.org/10.1016/j.ijdrr.2017.06.008, 2017.

JTWC (Joint Typhoon Warning Centre): Naval Oceanography Portal: https://www.metoc.navy.mil/jtwc/jtwc.html, last access: 29 May 2021, 2021.

Knoema: Rice, paddy production quantity: https://knoema.com/atlas/topics/Agriculture/Crops-Production-Quantity-tonnes/Rice-paddy-production, access: 29 May 2021, 2021.

Kron, W., Steuer, M., Löw, P., and Wirtz, A.: How to deal properly with a natural catastrophe database – analysis of flood losses, 12, 535–550, https://doi.org/10.5194/nhess-12-535-2012, 2012.

Masutomi, Y., Iizumi, T., Takahashi, K., and Yokozawa, M.: Estimation of the damage area due to tropical cyclones using fragility curves for paddy rice in Japan, 7, 14020–14020, 2012.

MOAI (Ministry of Agriculture and Irrigation, Myanmar): Myanmar climate-smart agriculture strategy: https://cgspace.cgiar.org/rest/bitstreams/63308/retrieve, last access: 2 June 2020, 2015.

Naing, T. A. A., Kingsbury, A., Buerkert, A., and Finckh, M. R.: A survey of Myanmar rice production and constraints, Journal of Agriculture and Rural Development in the Tropics and Subtropics 109, 151-168, 2008.

NDRRMC (National Disaster Risk Reduction and Management Council): NDRRMC Update. Semi-final report on the effects and response operations (Search and rescue, evacuation and relief) re: Typhoon "Juan" (Megi): https://reliefweb.int/sites/reliefweb.int/files/resources/793A890600498558492577CC002155D5-Full_Report.pdf, access: 2 June 2020, 2010.

Nelson, A. and Gumma, M. K.: A map of lowland rice extent in the major rice growing countries of Asia: http://irri.org/our-work/research/policy-and-markets/mapping, access: 19 November 2018, 2015.

Nguyen-Thi, H. A., Matsumoto, J., Ngo-Duc, T., and Endo, N.: A climatological study of tropical cyclone rainfall in Vietnam, 8, 41–44, https://doi.org/10.2151/sola.2012-011, 2012.

Rana, M. S., Al Azad, M. A. S., and Islam, M. J.: Vulnerability assessment of cyclonic hazards in coastal region of Bangladesh, 3, 34, https://doi.org/10.11648/j.urp.20180302.11, 2018.

ReliefWeb: Viet Nam Cyclone Cecil May 1989 UNDRO situation reports 1-3: https://reliefweb.int/report/viet-nam/viet-nam-cyclone-cecil-may-1989-undro-situation-reports-1-3, access: 2 June 2020, 1989.

ReliefWeb: Typhoon Damrey hits Vietnam, kills 16 in China: https://reliefweb.int/report/viet-nam/typhoon-damrey-hits-vietnam-kills-16-china, access: 2 June 2020, 2005.

ReliefWeb: Bangladesh: Rice crop hit by recent cyclone: https://reliefweb.int/report/bangladesh/bangladesh-rice-crop-hit-recent-cyclone, access: 2 June 2020, 2007.

ReliefWeb: Cyclone Sidr in Bangladesh: Damage, loss and needs assessment for disaster recovery and reconstruction: https://reliefweb.int/sites/reliefweb.int/files/resources/F2FDFF067EF49C8DC12574DC00455142-Full_Report.pdf, last access: 2 June 2020, 2008.

Shelley, I. J., Takahashi-Nosaka, M., Kano-Nakata, M., Haque, M. S., and Inukai, Y.: Rice cultivation in Bangladesh: present scenario, problems, and prospects, Journal of International Cooperation for Agricultural Development, 14, 20-29, 2016.

Soto, A.: Deriving information on disasters caused by natural hazards from limited data: a Guatemalan case study, Natural Hazards, 75, 71-94, 10.1007/s11069-014-1305-2, 2015.

Taylor, H. T., Ward, B., Willis, M., and Zaleski, W.: The Saffir-Simpson Hurricane wind scale, 2010.

The Guardian: Cyclone Firi leaves its mark on Burma: https://www.theguardian.com/global-development/gallery/2010/nov/15/burma-cyclone-giri, access: 29 May 2020, 2010.

Torbick, N., Chowdhury, D., Salas, W., and Qi, J.: Monitoring rice agriculture across Myanmar using time series Sentinel-1 assisted by Landsat-8 and PALSAR-2, Remote Sensing, 9, 119, https://doi.org/10.3390/rs9020119, 2017.

Tschoegl, L., Below, R., and Guha-Sapir, D.: An analytical review of selected data sets on natural disasters and impacts, UNDP/CRED Workshop on Improving Compilation of Reliable Data on Disaster Occurrence and Impact, Bangkok, Thailand, 2006.

UNISDR and Reduction., G. A. R. on D. R.: Making Development Sustainable: The Future of Disaster Risk Management., United Nations Office for Disaster Risk Reduction (UNISDR), Geneva, Switzerland, 2015.

USDA (US Department of Agriculture): Burma: Widespread cyclone damage in major rice production regions: https://ipad.fas.usda.gov/highlights/2008/05/burma_cyclone_nargis_rice_impact.htm, last access: 2 June 2020, 2008.

Vink, K. and Ahsan, M. N.: The benefits of cyclones: A valuation approach considering ecosystem services, 95, 260–269, https://doi.org/10.1016/j.ecolind.2018.07.035, 2018.

Webb, E. L., Jachowski, N. R. A., Phelps, J., Friess, D. A., Than, M. M., and Ziegler, A. D.: Deforestation in the Ayeyarwady Delta and the conservation implications of an internationally-engaged Myanmar, Global Environmental Change, 24, 321-333, https://doi.org/10.1016/j.gloenvcha.2013.10.007, 2014.

Wirtz, A., Kron, W., Löw, P., and Steuer, M.: The need for data: natural disasters and the challenges of database management, 70, 135–157, https://doi.org/10.1007/s11069-012-0312-4, 2014.

Table 1. Summary table of DesInventar Sendai, EM-DAT, NatCatSERVICE and Sigma databases (Below, 2009; Guha-Sapir and Below, 2002; Soto, 2015; Tschoegl et al., 2006).

Database	**DesInventar Sendai**	**Emergency Events Database (EM-DAT)**	**NatCatSERVICE**	**Sigma**
Organization	United Nations	Centre for Research on the Epidemiology of Disasters (CRED)	Munich Re	Swiss Re
Period covered	AD 1-present	1900-present	AD 79-present	1970-present
Disaster types	Accident; Alluvion; Boat capsize; Explosion; Extreme rain; Fire; Flood – urban flood; Leak/oil spill; Liquefaction; Panic; Pollution; Sedimentation; Soil erosion; Structural collapse.	**Disaster groups:** Biological; Geophysical; Hydrological; Meteorological; Climatological. **Disaster types:** Epidemic; Insect infestation; Animal stampede; Earthquake; Volcano; Mass movement (dry); Flood; Mass movement (wet); Storm; Extreme temperature; Drought; Wildfire	**Disaster groups:** Geophysical; hydrological; meteorological; climatological. **Disaster types:** Earthquake; Volcanic eruption; Storms; Flooding; Mass movement (wet); Extreme temperatures; Drought; Wildfire .	Cold, frost; Droughts, bush fires, heat; Earthquakes; Floods; Hail; Storms.
Inclusion criteria	Not specified	≥10 people reported killed and/or ≥100 people reported affected and/or declaration of a state of emergency and/or a call for international assistance.	Entry if any property damaged, any person sincerely affected (injured, dead). Only major events included before 1980.	>20 deaths and/or >50 injured and/or >2000 homeless and/or insured losses: >14 million US$ (marine), >28 million US$ (aviation), >35 million US$ (all other losses) and/or total losses >70 million US$.
Scale of reporting	Country, provincial and event level	Country level	Country and event level	Event level
Sources of data	Emergency management agencies, government institutions, archives of relief or aid organizations, findings by research institutions, media releases.	UN agencies, US government agencies, official government sources, International Federation of Red Cross and Red Crescent Societies (IFRC), research centres, Lloyd's Reinsurance sources, press statements, private sources.	Insurance reports, online databases, information from news agencies, governmental and non-governmental organizations, scientific and insurance contacts, technical literature, Munich Re clients and branch offices.	Newspaper articles, Lloyd's list, primary insurance and reinsurance periodicals, internal reports, online databases.
Damage data	No. of deaths; No. of injured; No. of missing; No. of houses destroyed; No. of houses damaged; No. indirectly affected; No. directly affected; No. relocated; No. evacuated; Losses (US$); Local losses (US$); No. of education centres damaged; No. of hospitals damaged; No. of lost cattle; Road damage (metres). Only database that reports on damaged crops (ha)	Total death; No. of injured; No. affected; No. homeless; Total affected; Reconstruction costs; Insured damage; Total damage.	No. of people killed/injured/affected, amount of economic losses.	No. of dead, missing, injured and homeless, amount of insured & uninsured losses, total losses.

Access	Public	Public	Partial access for public	Partial access for public
Limitations	Data not available for all countries.	Smaller disasters not listed, difficult to disaggregate local and municipal level data.	Limited information publicly available.	Publicly available information displayed in graphs that are not downloadable.
Website	https://www.desinventar.net/	https://www.emdat.be/	https://www.munichre.com/en/solutions/for-industry-clients/natcatservice.html	https://www.sigma-explorer.com/

Table 2. Overview of national damage databases for the Philippines, Indonesia, Malaysia and Vietnam. There are two databases for Philippines, two for Indonesia, one for Malaysia and two for Vietnam.

	Philippines		Indonesia		Malaysia	Vietnam	
Name of database	-	Disaster Response Operations Monitoring and Information Centre (DROMIC)	Data Dan Informasi Bencana Indonsia (DIDB) – Indonesian Disaster Data and Information	Geoportal Data Bencana Indonesia – Indonesia's Disaster Data Geoportal	Portal Bencana Pusat Kawalan Bencana Negara – National Disaster Control Centre Disaster Portal	The Office of Central Steering Committee for Natural Disaster Prevention and Control	Natural disaster damage
Organization	National Disaster Risk Reduction and Management Council (NDRRMC)	Disaster Response Management Bureau (DRMB)	Badan Nasional Penanggulangan Bencana	Badan Nasional Penanggulangan Bencana	National Disaster Command Centre (NDCC)	Vietnam Disaster Management Authority	General Statistics Office of Vietnam
Period covered	2009-Present.	2014-Present.	1815-Present.	2008-Present.	2019-Present	2006-Present.	2011-Present.
Disaster types	Heavy rain; Severe weather; Gale; Tropical cyclone; Flood; Dam discharge; Earthquake; Tsunami; Volcano; Lahar.	Typhoon; Tropical depression; Severe Tropical Storm; Flood; Monsoon; Earthquake; Drought; Fire; Volcanic activity; Landslide; Whirlwind; Shooting incident; Bombing incident; Armed conflict.	Flood; Tornado; Landslide; Fire; Forest and land fire; Drought; Earthquake; Flood; Landslide; High tide/wave; Transportation accident; conflict/social disruption; Earthquake; Terrorism; Industrial accident; Tsunami; Agricultural pests; Climate change; Bridge collapse; Building collapse; Epidemic; Avalanche; Starvation; Wild animal attack; Broken embankment.	Flood; Landslide; Earthquake; Volcanic eruption; Tidal wave; Drought; Forest and land fires.	Flood; Haze; Landslide; Epidemic; Others.	Heavy rain, flooding; Drought, saltwater intrusion; Bank erosion; Cold temperature; Strong wind on the sea; Earthquake; Tornado, lightning; Flash floods; Landslide.	Not stated.
Geographic scale	National, regional, provincial, city/municipality /Barangay.	National, regional, provincial, city/municipality /Barangay.	Province, district, sub-district.	National, province, district.	National, state.	National	National
Access	Public	Public	Public	Public	Public	Public	Public
Website	https://ndrrmc.gov.ph/	https://dromic.dswd.gov.ph/ https://www.facebook.com/dswddromic/	http://dibi.bnpb.go.id/DesInventar/main.jsp?countrycode=id&lang=ID&datalng=LL	https://gis.bnpb.go.id/	https://portalbencana.nadma.gov.my/ms/ https://www.facebook.com/nadma.pmd/	http://phongchongthientai.mard.gov.vn/Pages/bang-thong-ke-thiet-hai-do-thien-tai-nam-2019.aspx	https://www.gso.gov.vn/en/px-web/?pxid=E1160&theme=Health%2C%20Culture%2C%20Sport%20and%20Living%20standard

Table 3. Total rice production in ten major rice producing countries every year from 2010-2019. Based on the average yearly production, Bangladesh was ranked 4th, Vietnam 5th, Myanmar 7th and Philippines 8th. The data was obtained from Knoema (2021).

Rice, paddy production (million metric tonnes)										
Year	**China**	**India**	**Indonesia**	**Bangladesh**	**Vietnam**	**Thailand**	**Myanmar**	**Philippines**	**Pakistan**	**Cambodia**
2010	197.2	144.0	59.3	50.1	40.0	35.7	32.1	15.8	7.2	8.2
2011	202.7	157.9	58.3	50.6	42.4	38.1	28.6	16.7	9.2	8.8
2012	205.9	157.8	59.7	50.5	43.7	38.1	26.2	18.0	8.3	9.3
2013	205.2	159.2	60.1	51.5	44.0	36.8	26.4	18.4	10.5	9.4
2014	208.2	157.2	59.1	51.8	45.0	32.6	26.4	19.0	10.5	9.3
2015	213.7	156.5	61.0	51.8	45.1	27.7	26.2	18.1	10.2	9.3
2016	212.7	163.7	59.4	50.5	43.1	31.9	25.7	17.6	10.3	10.0
2017	214.4	168.5	59.4	54.1	42.8	32.9	26.5	19.3	11.2	10.5
2018	214.1	174.7	59.2	54.4	44.0	32.3	27.6	19.1	10.8	10.9
2019	211.4	177.6	54.6	54.6	43.4	28.4	26.3	18.8	11.1	10.9
Mean	208.6	161.7	59.0	52.0	43.4	33.4	27.2	18.1	9.9	9.7

Table 4. Number of tropical cyclones that made landfall in the ten major rice producing countries from 2010-2019. In the North Pacific, an average of 6 and 4 tropical cyclones made landfall in Philippines and Vietnam every year. In the northern Indian Ocean, the corresponding number was 1 and 0.4 for Bangladesh and Myanmar. Typhoon track data for (eastern) China, Indonesia, Vietnam, Thailand, Philippines and Cambodia were from the Digital Typhoon (2021) Database. Data for (western) China, India, Bangladesh, Myanmar and Pakistan were from the Joint Typhoon Warning Centre (JTWC, 2021).

Year	China	India	Indonesia	Bangladesh	Vietnam	Thailand	Myanmar	Philippines	Pakistan	Cambodia
2010	6	3	0	0	2	0	1	3	1	0
2011	6	1	0	1	4	1	1	7	0	0
2012	5	4	0	0	5	0	0	4	0	2
2013	9	5	0	1	7	2	0	10	0	0
2014	5	1	0	0	3	0	0	7	0	0
2015	5	0	0	1	2	0	0	7	0	0
2016	8	2	0	1	3	1	0	4	0	0
2017	8	1	0	2	4	3	1	8	0	1
2018	10	4	0	1	4	1	1	4	0	1
2019	5	2	0	0	6	1	0	4	0	1
Mean	7	2	0	1	4	1	0.4	6	0.1	1

550 **Table 5. Total number of cyclone events that made landfall or passed within 500 km of Philippines, Vietnam, Bangladesh and Myanmar from 1970-2018. Numbers in parenthesis represent the number of cyclones with reports of rice damage associated with them.**

	Philippines	**Vietnam**	**Bangladesh**	**Myanmar**
Total cyclone events investigated (with rice damage)	526 (60)	303 (68)	96 (8)	121 (2)
Total no. of cyclones from 1970-1979 (with rice damage)	115 (0)	73 (0)	23 (1)	49 (0)
Total no. of cyclones from 1980-1989 (with rice damage)	111 (3)	68 (17)	18 (3)	19 (0)
Total no. of cyclones from 1990-1999 (with rice damage)	105 (6)	61 (11)	27 (0)	23 (0)
Total no. of cyclones from 2000-2009 (with rice damage)	100 (9)	48 (13)	19 (1)	19 (1)
Total no. of cyclones from 2010-2018 (with rice damage)	95 (42)	53 (27)	9 (3)	11 (1)

555

Table 6. Average rice area, rice production and rice value lost over the years from 1970-2018 according to landfall intensity. Cyclones came within 500 km of each country but did not make landfall was considered as cyclones with "no landfall." Cyclone intensity was classified according to the Saffir-Simpson Hurricane Wind Scale (Taylor et al., 2010). Numbers in parenthesis refer to the number of data points.

	Philippines	**Vietnam**	**Bangladesh**	**Myanmar**
Average rice area lost (ha)				
No landfall	10,576 (5)	18,774 (6)	NA	NA
Tropical storm	64,839 (7)	52,687 (46)	394,918 (5)	NA
Category 1	91,999 (7)	18,758 (14)	211,746 (2)	NA
Category 2	13,032 (3)	NA	NA	NA
Category 3	185,953 (3)	NA	NA	NA
Category 4	425,134 (1)	NA	677,769 (1)	423,075 (2)
Overall	83,571 (26)	42,407 (66)	384,481 (8)	423,075 (2)
Average rice production lost (metric tonnes)				
No landfall	6,402 (1)	NA	NA	NA
Tropical storm	178,638 (6)	718,600 (3)	32,000 (1)	NA
Category 1	11,642,624 (5)	800 (1)	400,000 (1)	NA
Category 2	346,080 (4)	NA	NA	NA
Category 3	269,219 (4)	NA	NA	NA
Category 4	52,303 (1)	NA	950,000 (1)	1,203,750 (2)
Overall	2,943,088 (21)	539,150 (4)	460,667 (3)	1,203,750 (2)
Average rice value lost (US$)				
No landfall	8,689,695 (6)	NA	NA	NA
Tropical storm	21,629,199 (14)	NA	NA	NA
Category 1	38,852,791 (13)	NA	NA	NA
Category 2	75,951,909 (6)	NA	NA	NA
Category 3	60,474,973 (10)	NA	NA	NA
Category 4	198,221,629 (1)	NA	280,619,207 (1)	NA
Overall	42,374,321 (50)	NA	280,619,207 (1)	NA

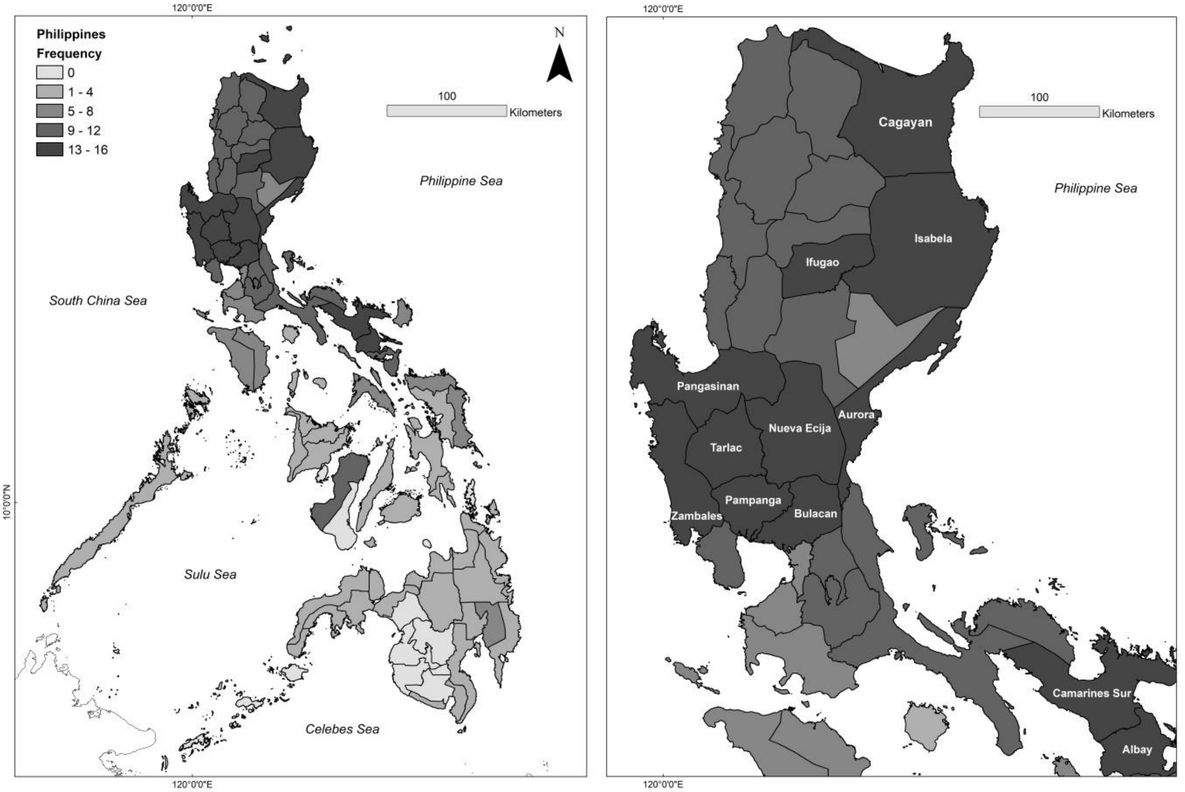

Figure 1: Spatial frequency of cyclone-induced rice damage in the Philippines from 1970-2018. Damage was most frequently experienced in in Cagayan, Tarlac (both 16 times) and Nueva Ecija (15). Albay, Aurora, Bulacan, Isabela, Pangasinan, Zambales, Camarines Sur, Ifugao and Pamapanga were affected between 13 to 14 times. Tarlac, Nueva Ecija, Aurora, Bulacan, Zambales and Pampanga are in Central Luzon; Cagayan and Isabela are in the Cagayan Valley of Northern Luzon; Albay and Camarines Sur are in the Bicol Region of Southern Luzon; Pangasinan belong to Ilocos Region; Ifugao is in Cordillera Administrative Region.

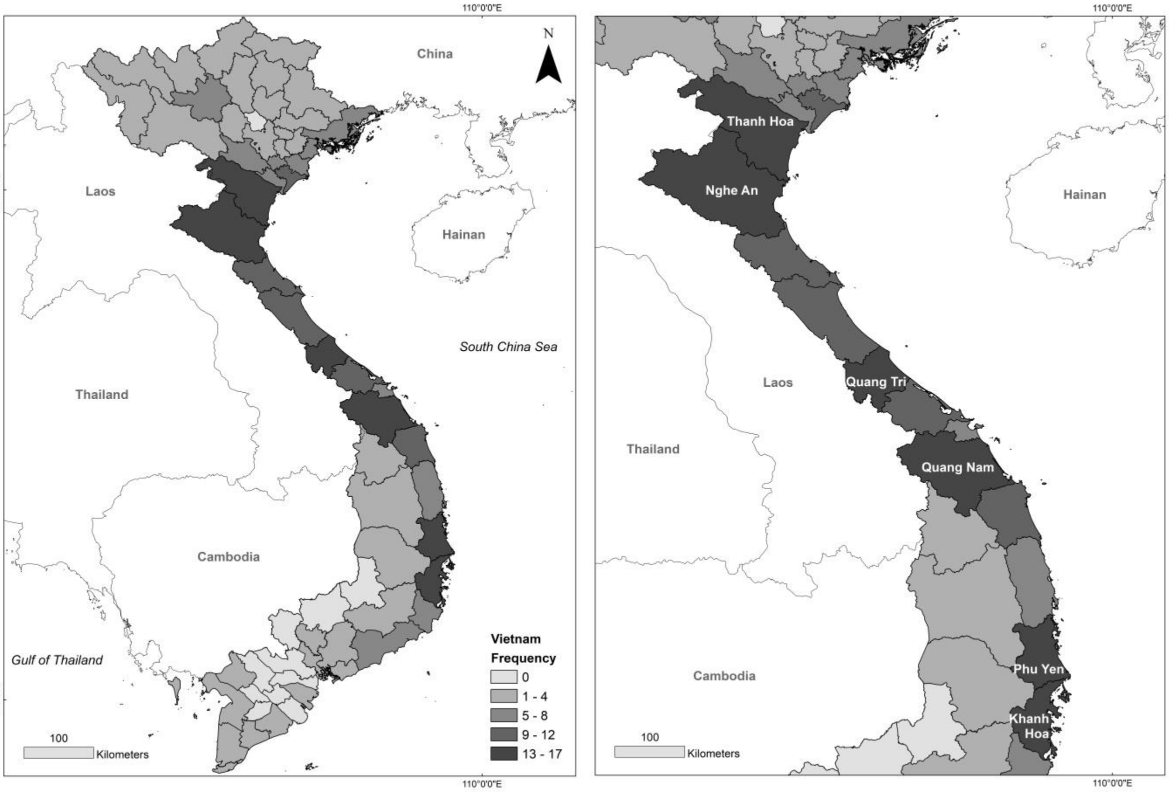

Figure 2: Spatial frequency of cyclone-induced rice damage in Vietnam from 1970-2018. Damage was most frequently experienced in Nghe An (17 times), Khanh Hoa, Phu Yen, Quang Nam, Quang Tri and Thanh Hoa (all 13 times). At a regional level, Nghe An, Quang Tri and Quang Tri are in the North Central Coast while Khanh Hoa, Phu Yen and Quang Nam are in the South Central Coast.

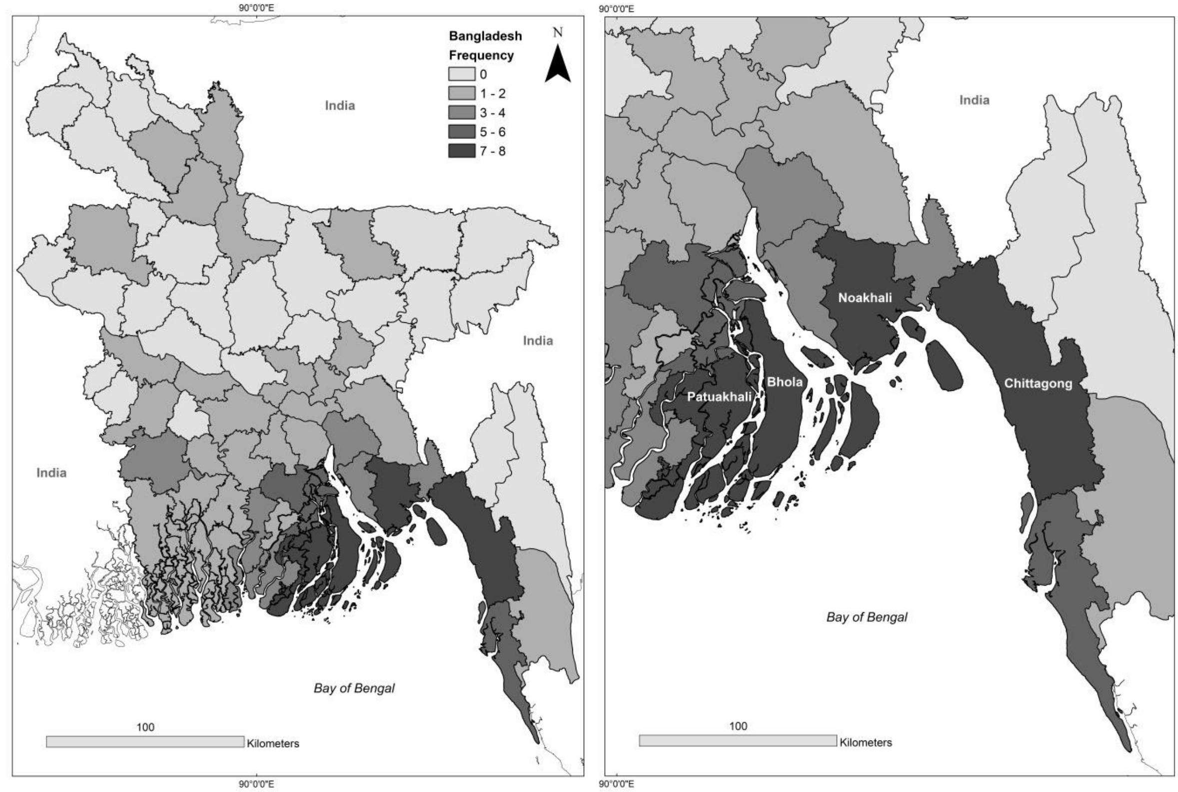

Figure 3: Spatial frequency of cyclone-induced rice damage in Bangladesh from 1970-2018. Chittagong district had the highest frequency of rice damage (8 times). Bhola, Noakhali and Patuakhali (all 7) districts were equally vulnerable. Chittagong and Noakhali are in Chittagong Division while Bhola and Patuakhali are in Barisal Division – all skewed towards southeast Bangladesh.

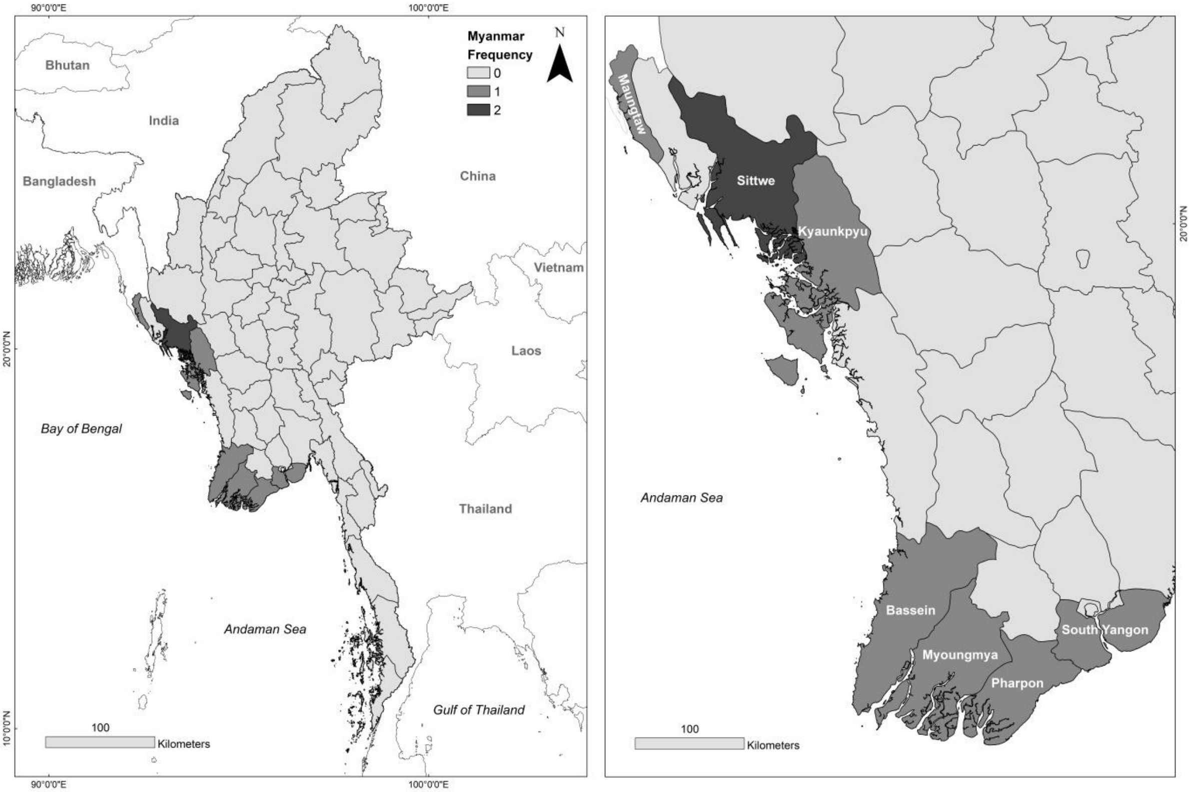

Figure 4: Spatial frequency of cyclone-induced rice damage in Myanmar from 1970-2018. Sittwe district had the highest frequency of cyclone induced rice damage (2 times). Bassein, Kyaunkpyu Maungtaw, Myoungmya, Pyapon, and South Yangon all had rice fields that were damaged once. Bassein and Pyapon are in Ayeyarwady Region; Kyaunkpyu, Maungdaw and Sittwe are in Rhakine State; South Yangon is in Yangon Region.

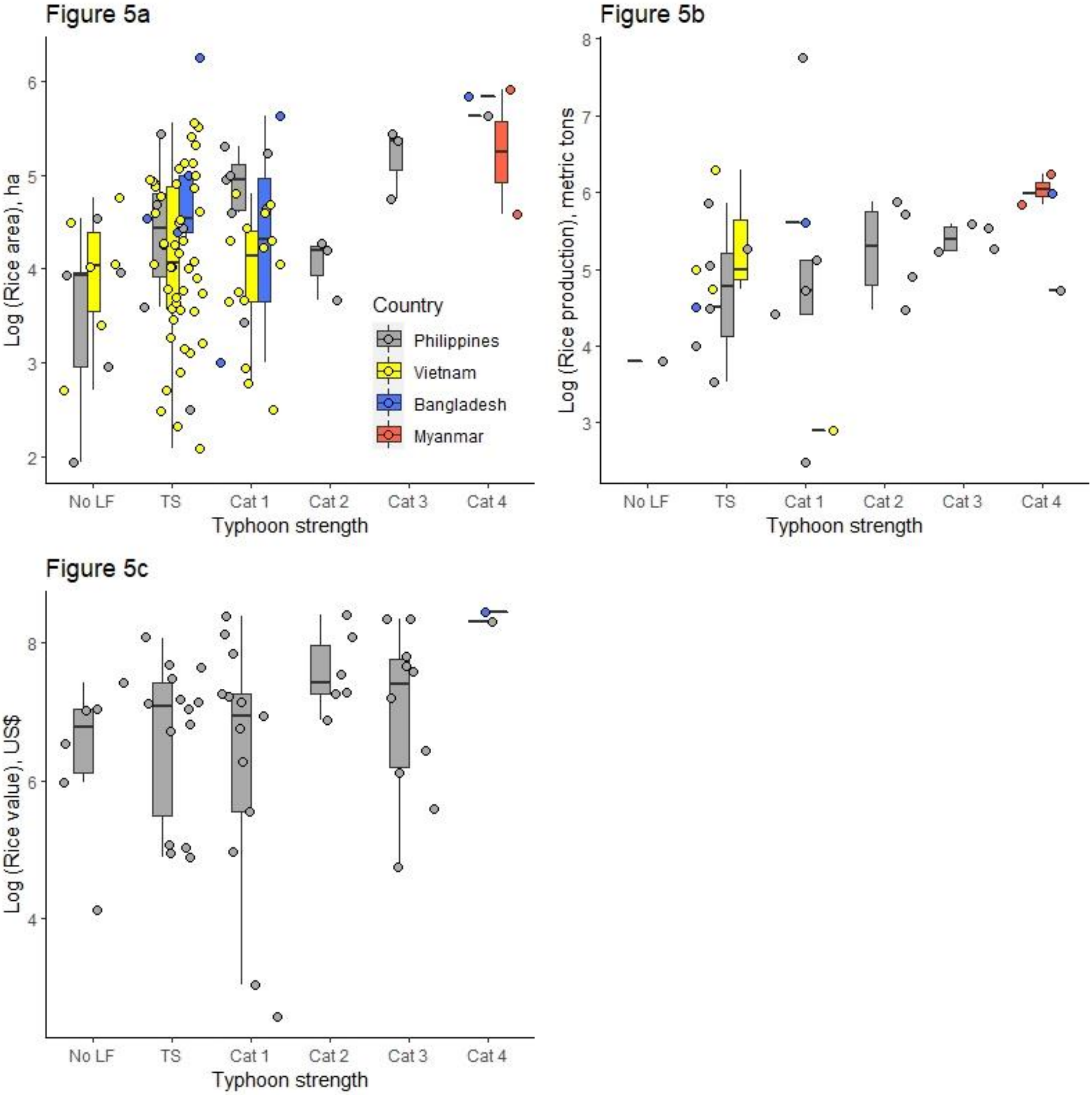

Figure 5: (a) Area of rice damaged (ha) based on cyclone intensity for Philippines, Vietnam, Bangladesh and Myanmar; (b) Rice production lost (metric tons) based on cyclone intensity; (c) Average rice value lost (US$) based on cyclone intensity. The six categories for cyclone intensity are: No landfall (No LF), tropical storm (TS), Category (Cat) 1, 2, 3 and 4. No LF refers to cyclones that came within 500 km from the coast of each country but no landfall was recorded. The other categories refer to the landfall intensity when the cyclone reached each country.