

Manual for Operationalizing Impact-based Forecasting and Warning Services (IBFWS)



Contents

Acknowledgements	3
Overview	4
Manual Introduction	4
Learning Outcomes	5
Module 1: Introduction to impact-based forecasting	6
Introduction	6
What is impact-based forecasting?	7
Methodological approach	8
Collaboration with users and practitioners	9
Current practices	9
Opportunities	17
Challenges	18
Impact-based forecasting conceptual framework of the manual	19
Module 2: Impact-based forecasting for typhoons	22
Introduction to data layers	23
Preparing hazard layers	23
Assessing population exposure to typhoons	27
Assessing the vulnerability of the population exposed to typhoons	31
Assessing agricultural exposure to typhoons	32
Assessing energy powerplants exposure to typhoons	35
Assessing critical infrastructure exposure to typhoons	39
Assessing economic stock exposure to typhoons	41
Assessing possible convergence with COVID-19 and potential impacts on the health system	43
Module 3: Impact outlooks using seasonal forecasts	46
Preparing the seasonal forecast data layer	46
Assessing population exposure to potential drought risk	51
Assessing agricultural exposure to potential drought risk	54
Assessing possible convergence with the COVID-19 and waterborne diseases	58
Annex I: Types and scales of data used	64
Annex II: List of potential exposure and vulnerability indicators	66
Annex III: QGIS User Guide Calculating Population Exposed to Typhoon Molave	68

Acknowledgements

This training manual is prepared to support the Viet Nam Meteorological and Hydrological Administration (VNMHA) in building capacity to provide impact-based forecasting and warning services, with generous financial support from WMO (Climate Risk Early Warning Systems-Canada Fund).

Members of the core authors team consisted of Sanjay Srivastava, SungEun Kim, Lam Hoang, Jin Rui Yap, Jaehee Hwang, and Maria Bernadet Dewi. Valuable advice, reviews and inputs were received from following experts: Ananda Kumar Das (India Meteorological Department); Mamoru Miyamoto (International Centre for Water Hazard and Risk Management); Le Ha (Viet Nam Meteorological and Hydrological Administration); Samuel Muchemi; Taoyong Peng; Anne-Claire Fontan; Jun Yu (WMO); Anshul Agarwal (Regional Integrated Multi-Hazard Early Warning System for Africa and Asia); Yuichi Ono (Tohoku University); and Bui Minh Tuan (Vietnam National University).

The graphic design and layout were created by Jeff Williams. Natacha Pitaksereekul provided administrative assistance to the authors team.

Manual for Operationalizing Impact-based Forecasting and Warning Services (IBFWS)

Overview

In line with the WMO Guidelines on Multi-hazard Impact-based Forecast and Warning Services, many National Meteorological and Hydrological Services (NMHS) agencies have begun exploring impact-based forecasting and warnings as a means to communicate risks and impacts to the public and sector end-users. Impact-based forecasting is a structured approach for combining hazard, exposure, and vulnerability data to identify risk and support decision-making, with the ultimate objective of encouraging early action that reduces damages and loss of life from natural hazards.

Traditionally, governments have employed hazard-focused warnings to communicate impending extreme weather conditions. However, while providing scientifically accurate information is important, it is critical to communicate what people need to know to effectively respond to hazard risks. This indicates a need to communicate specific and relevant potential consequences with respect to local contexts, not just for public end-users, but as well for different sectors and agencies. The development of this communication entails synthesizing weather information with quasi-static information on exposure and vulnerability profiles to identify the range of risks in an area. The identification of different levels of risks and impacts enables the issuance of different warnings to encourage adequate responses by relevant users to reduce damage and losses.

Manual Introduction

This manual was developed under the project “Operationalizing Impact-based Forecasting and Warning Services (IBFWS)”, to support the capacity of the Viet Nam Meteorological and Hydrological Administration (VNMHA) to provide impact-based forecasting and early warning services. The objective is to introduce impact-based forecasting and the substantive steps for producing an impact-based forecast, with a focus on the local context of Viet Nam. This will be covered over 3 modules in the training manual.

- **Module 1** discusses what impact-based forecasting is, why it is used, and provides examples of successful implementation and use of impact-based forecasting by governments across the world.
- **Module 2** introduces the steps required for producing an impact-based forecast for typhoons.
- **Module 3** guides steps to develop impact outlooks based on anomalies in seasonal forecasts (e.g., lower-than-usual rainfall) which may contribute to the exacerbation of slow-onset disasters such as droughts.

This manual is prepared based on data collected from various sources for demonstration purposes. An explanation of the various data types, the data sets used, and potential other data sets that can be used are available in Annexes I and II of this manual. This manual is intended to demonstrate the concepts of impact-based forecasting using example data. However, higher resolution data and additional indicators can be used as appropriate.

Learning Outcomes

By completing the training contained in this manual, users are expected to understand the following:

- **Benefits** of impact-based forecasting
- **A methodological framework** of impact-based forecasting
- **How to produce and interpret** impact-based forecasting using GIS software
- **Information and data** required, and their potential sources

The software used to produce the examples in Modules 2 and 3 is QGIS. However, as the objective of this manual is to guide the substantive steps required to produce an impact-based forecast, it is expected that the user can adapt the steps in this manual in accordance with other GIS software such that the same impact-based forecasting steps and outcomes can be achieved.

MODULE 1

INTRODUCTION TO

IMPACT-BASED FORECASTING

Objective: To understand what impact-based forecasting is.

Module 1 introduces the concept of impact-based forecasting and provides an overview of the methods and approaches to generate impact-based forecasts.

Contents

- Introduction
- What is impact-based forecasting?
- Methodological approach
- Collaboration with users and practitioners
- Current practices
- Opportunities
- Challenges
- Impact-based forecasting conceptual framework of the manual

Introduction

Viet Nam has a tropical monsoon climate, which produces large amounts of rain in short time periods, associated with typhoons and thunderstorms. The country recorded a total of 237 disaster events between 1970 and 2020 in the EM-DAT project database, which resulted in over 18,000 loss of lives and close to 97 million people affected. Extreme climate events (storms, floods, and droughts) were responsible for almost 95 percent of fatalities and 99.9 percent of people affected during this period (Figure 1).¹

Such disaster events cause high fatalities and wreak havoc on lives and livelihoods. The country is expected to face an average of 4-6 typhoons every year.² With an estimated 70 percent of the population living in coastal areas and low-lying deltas, Viet Nam faces high exposure to the risk of flooding.³ In addition, slow-onset disasters also cause substantial economic and social impacts. According to the Asia-Pacific Disaster Report 2019, more than half of Viet Nam's average annual loss can be attributed to recurrent droughts.

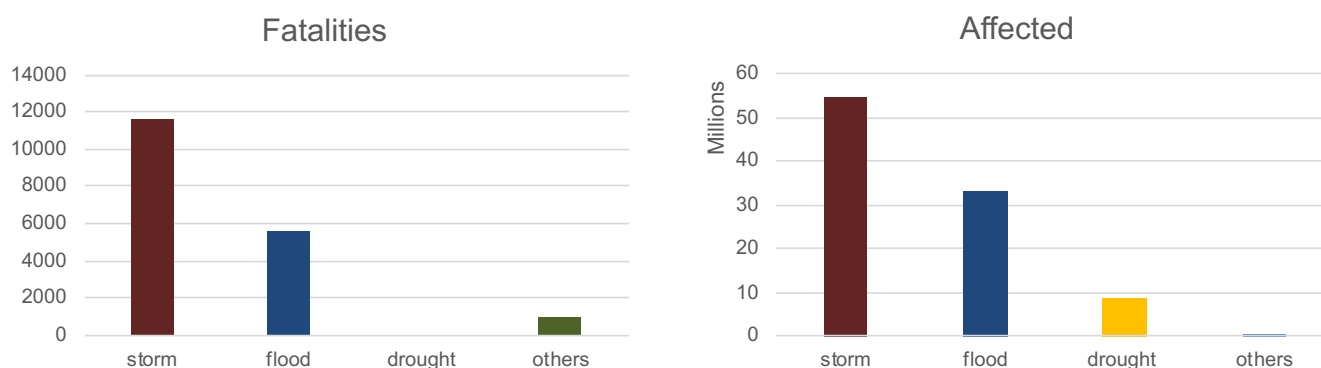
1. Data source: EM-DAT, <https://www.emdat.be/> (Accessed on 31 January 2021)

2. Source: <https://www.vietnam-briefing.com/news/typhoon-season-vietnam-how-to-prepare-your-business.html/>

3. Source: Country Profile for Vietnam, GFDRR, <https://www.gfdr.org/en/publication/country-profile-vietnam>

The Sendai Framework for Disaster Risk Reduction 2015-2030 calls for *substantially increasing the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030*. To better address the impacts of natural hazards, it is essential to improve multi-hazard early warning systems and to understand their potential impacts in advance. Oftentimes, multiple hazards may coincide, such as when typhoons trigger floods, which further cause landslides.

Figure 1: Fatalities and the number of affected by disaster type in Viet Nam (1970 – 2020)



Data Source: EM-DAT (Accessed on 31 January 2021)

What is impact-based forecasting, and why is it important?

Impact-based forecasting is a structured approach for combining hazard, exposure, and vulnerability data to identify risk and support decision-making, with the ultimate objective of encouraging early action that reduces damages and loss of life from natural hazards. Traditionally, governments have employed hazard-focused warnings to communicate impending extreme weather conditions. However, while providing scientifically accurate information is important, it is critical to communicate what people need to know to effectively respond to hazard risks.⁴ This indicates a need to communicate specific and relevant potential consequences with respect to local contexts, not just for public end-users, but as well for different sectors and agencies.

Moving from broadcasting what the **weather will be** to what the **weather will do** entails synthesizing weather information (such as weather forecasts) with quasi-static information on exposure and vulnerability profiles (such as geodemographic and essential facility maps) to identify the range of risks faced over an area (Figure 2). It is critical that the exposure and vulnerability profiles are up to date, as this directly influences the insights gained from the impact-based forecasting process. The identification of different levels of risks and impacts enables the issuance of different warnings to encourage adequate responses by relevant users to reduce damage and losses. This approach is rooted in the understanding that clear communication of hazard impacts can effectively influence the risk perception of a user to facilitate the acceptance and personalization of warning messages.

4. Weigold, (2001)

Figure 2: Moving from traditional forecasting to impact-based forecasting⁵



Impact-based forecasters consider a range of contextual factors and uncertainties when generating forecasts. The randomness of weather events creates the need for forecasters to manage the uncertainty such as by implementing scenario-based approaches. For example, by accounting for the impacts that may occur given most likely scenarios as well as reasonable worst-case scenarios, forecasters can develop robust impact-based warnings that may effectively mitigate damages and losses under a broad range of outcomes. Uncertainty is also often accounted for in risk matrices that combine the likelihoods (unlikely to very likely) and estimated impacts (minor to severe) of hazard occurrence. These risk matrices are then used to communicate the level of risk experienced by users in different sectors over a geographic area.

Contextual factors include whether a location has been struck by recent extreme weather conditions, as this can influence the ability of local users to recover from yet another extreme weather event. Other contextual factors include consideration of the type of location where extreme weather is expected to occur (e.g., farmlands, densely populated areas, informal settlements) as well as whether significant events are expected to take place concurrently (e.g., elections, sporting events). These factors come together to influence the number of people as well as the magnitude and types of impact that is expected to occur. Such considerations are critical given the variation in vulnerabilities across an area. This variation in vulnerabilities means that weather conditions that can cause severe impacts in some areas may result in limited and minor impacts elsewhere. An example of this is when heavy rainfall may cause flooding and severe damage to infrastructure in informal settlements with inadequate drainage infrastructure, as compared to formal settlements with well-planned and constructed drainage facilities.

Methodological approach

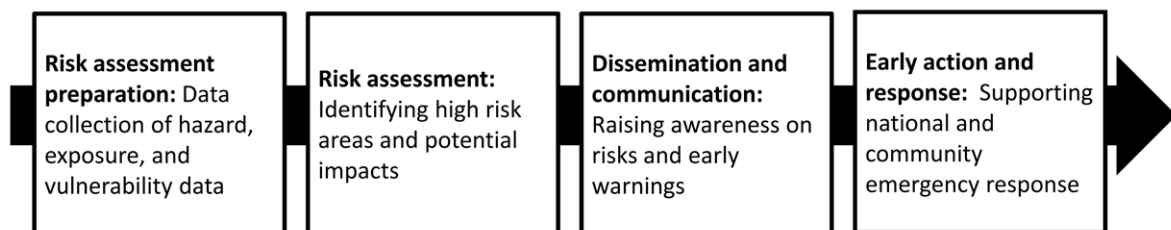
In line with the WMO Guidelines on Multi-hazard Impact-based Forecast and Warning Services, many National Meteorological and Hydrological Services (NMHS) agencies have begun exploring impact-based forecasting and warnings. The approach as outlined in the WMO guidelines starts with first generating weather forecasts. Subsequently, thresholds for significant events (e.g., flooding) should be identified, alongside thresholds for significant impacts as agreed upon with users and practitioners. The weather

5. Powerpoint presentation (Introduction to Impact-based Severe Weather Warning System) by the South African Weather Service under the Viet Nam WMO CREWS-Canada Sub-Project Training Workshop on Impact-based Forecast and Warning Services, on 30 November 2020

forecasts and thresholds will be considered in conjunction with contextual factors and socio-economic exposure and vulnerabilities to generate impact forecasts.

This process of determining potential impacts may incorporate the use of quantitative hazard impact models (e.g., the Surface Water Flooding Model and Vehicle Overturning Model by the United Kingdom Meteorological Office) to identify impacts. However, such models require quantification of the processes that come together and cause the final impact, which can be challenging. An alternative approach may be to determine impacts based on heuristics and past experiences of emergency management stakeholders on the ground. After identifying potential impacts, forecasts and warnings are to be provided to communicate the impending risks and estimated impacts to users of early warning information.

Figure 3: Step-by-step development of effective impact-based forecasting systems



Collaboration with user sectors

WMO guidelines highlight that the process of forecasting actual impacts requires strong collaboration with partner agencies. Given that severe impacts are often triggered by extreme hydrometeorological events, NMHS agencies play a unique role in facilitating or supporting impact-based forecasting, particularly through a partnership with other user sectors and agencies. Collaborations enable NMHS agencies to leverage the experience and expertise of other non-weather-related agencies (e.g., agriculture, disaster risk management, energy, health, and water management) in defining impact thresholds, exposure, and vulnerabilities. Collaborative actions should include data collection and sharing, consultation involving the selection of indicators and impact thresholds, and interpretation of results. This directly supports the development of meaningful targeted warnings that assist those organizations in decision-making and management of their activities.

Current practices

This section includes multiple examples of how impact-based forecasting systems are implemented in various countries in the region and the world. Each example is included to highlight a key feature of the implemented system.

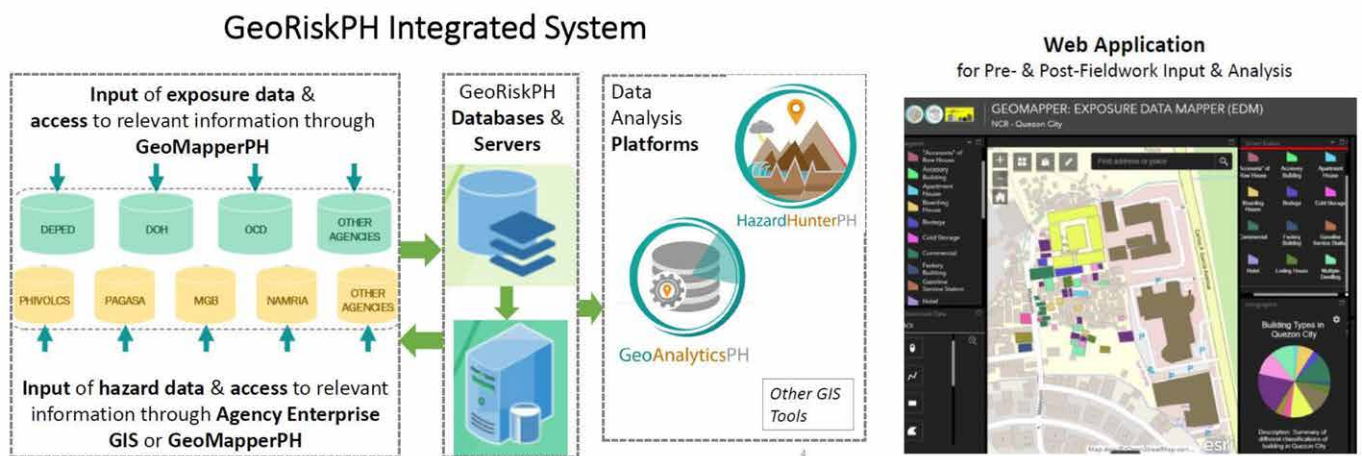
PAGASA in the Philippines: A comprehensive data management system

As part of the endeavor of the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) to advance impact-based forecasting and early warning services, the agency has developed an integrated system called GeoRiskPH, which combines database management with analytics for impact-based forecasting. Data is collected from PAGASA assets, such as field stations and weather radars that generate weather or hazard forecasts, and channeled into the GeoRiskPH database.

Beyond data collection, PAGASA also works on developing hazard maps for floods, typhoons, and storm surges. Such hazard data can be analyzed within the integrated system alongside data on exposure and vulnerabilities to estimate risks. The various data layers are processed into warnings that are tailored towards the needs of specific agencies. The insights gathered are then disseminated to the public to stimulate early action.

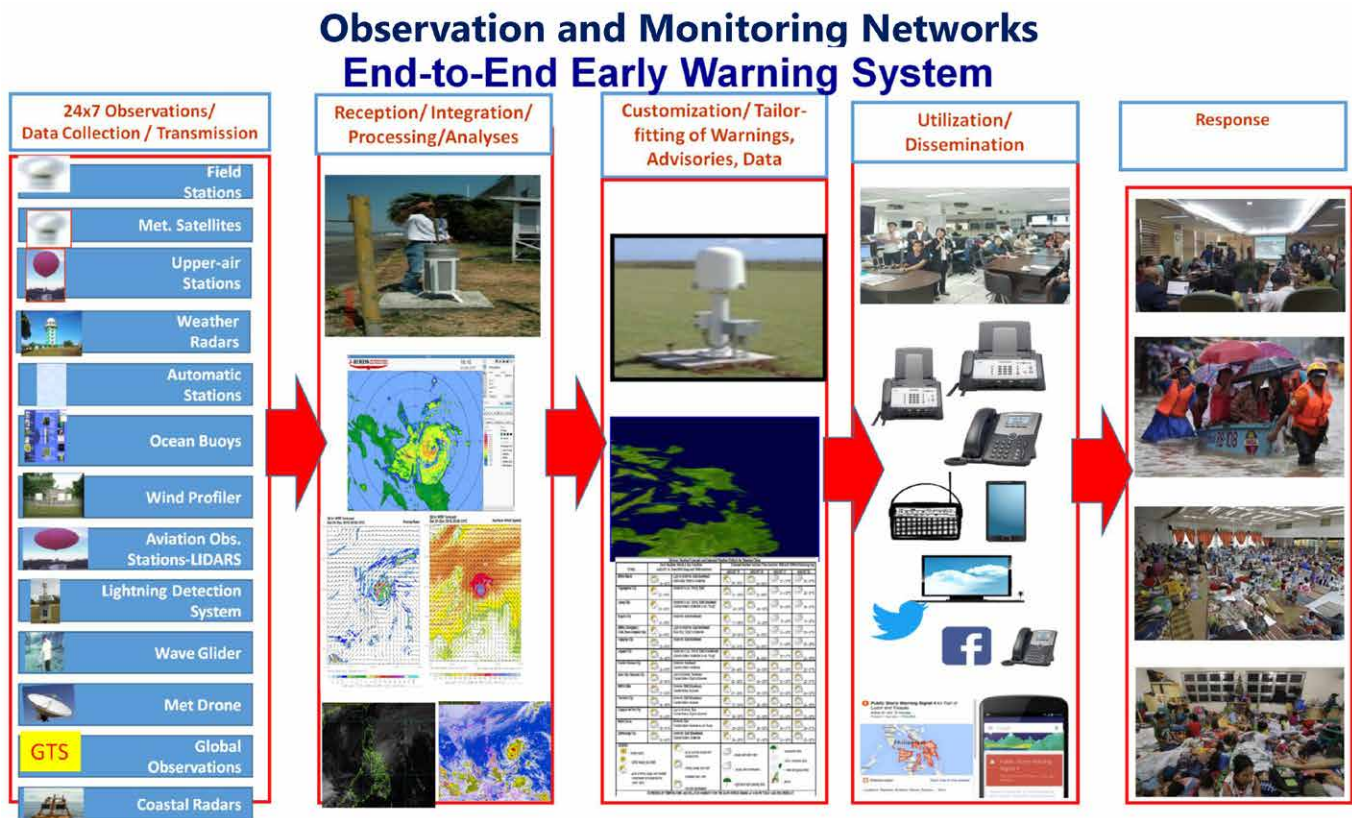
Furthermore, the Philippines has enacted a Disaster Reduction and Management Act which mandates the formation of a multi-sectoral National Disaster Risk Reduction and Management Council (NDRRMC), in coordination with subnational-level committees. NDRRMC includes representatives from relevant agencies responsible for coordinating early action within their respective sectors. PAGASA works with the NDRRMC and subnational committees to increase disaster preparedness among local communities and sectoral stakeholders.

Figure 4: PAGASA's system for impact-based forecasting⁶



6. Powerpoint presentation by DOST-PAGASA for the Joint Workshop on Strengthening Multi-Hazard Early Warning Systems and Early Actions in Southeast Asia in Bangkok, Thailand on 18-20 February 2020

Figure 5: PAGASA's end-to-end approach to impact-based forecasting⁷



Disaster preparedness in Indonesia: The importance of collaboration and communication

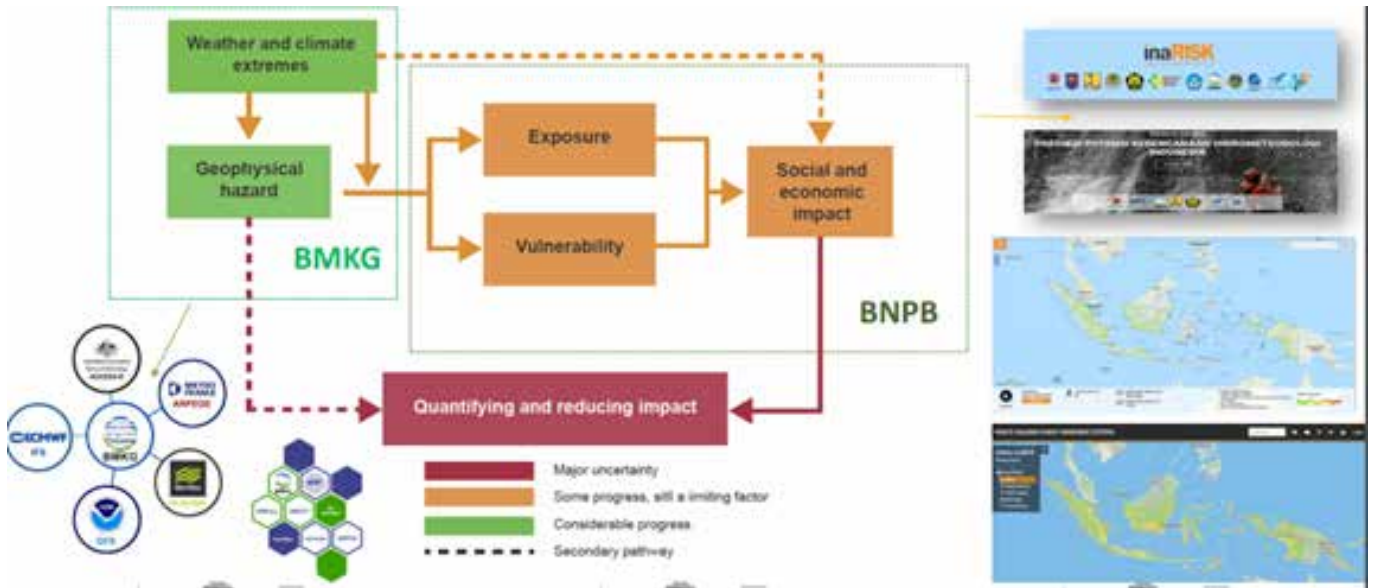
In Indonesia, the BNPB (Indonesian National Board for Disaster Management) and the BMKG (Meteorology, Climatology, and Geophysical Agency) work together to produce hazard and response matrices. The BMKG provides hydrometeorological forecasts with different levels of hazard likelihood, while the BNPB provides geospatial economic and population data and estimates the different levels of impact. Together, these agencies align strategies to communicate potential hazards and risks to the public.

In a push to focus on early education for disaster preparedness in local communities, the government also introduced a strong public outreach and awareness program in schools and local communities. One example of this is the Tagana network, comprised of “Disaster Prepared Cadets” that facilitate programs such as the Tagana Goes to School Program or the Village’s Disaster Preparedness Program. Another example is MOSAIC, a program to strengthen Indonesian communities’ understanding of climate and weather. The MOSAIC program seeks inputs and facilitates workshops for various groups in disaster management as well as specific sector agencies (e.g., agriculture, health, and forestry).

The agencies also provide various avenues for conveying information on disaster risk to the public, such as through dedicated cell phone applications, newspapers, radio broadcasting services, and so on. However, the government also draws on the potential for the public to act as a source for information. For example, www.petabencana.id enables crowdsourcing of information on disasters from the public. Other avenues for the public to contribute critical information to strengthen the government’s disaster preparedness include social media outlets as well as volunteer networks such as the Tagana network.

7. Ibid.

Figure 6: Nature of the BMKG and BNPB collaboration⁸



The UK Meteorological Office: Quantifying impacts via model-based methods

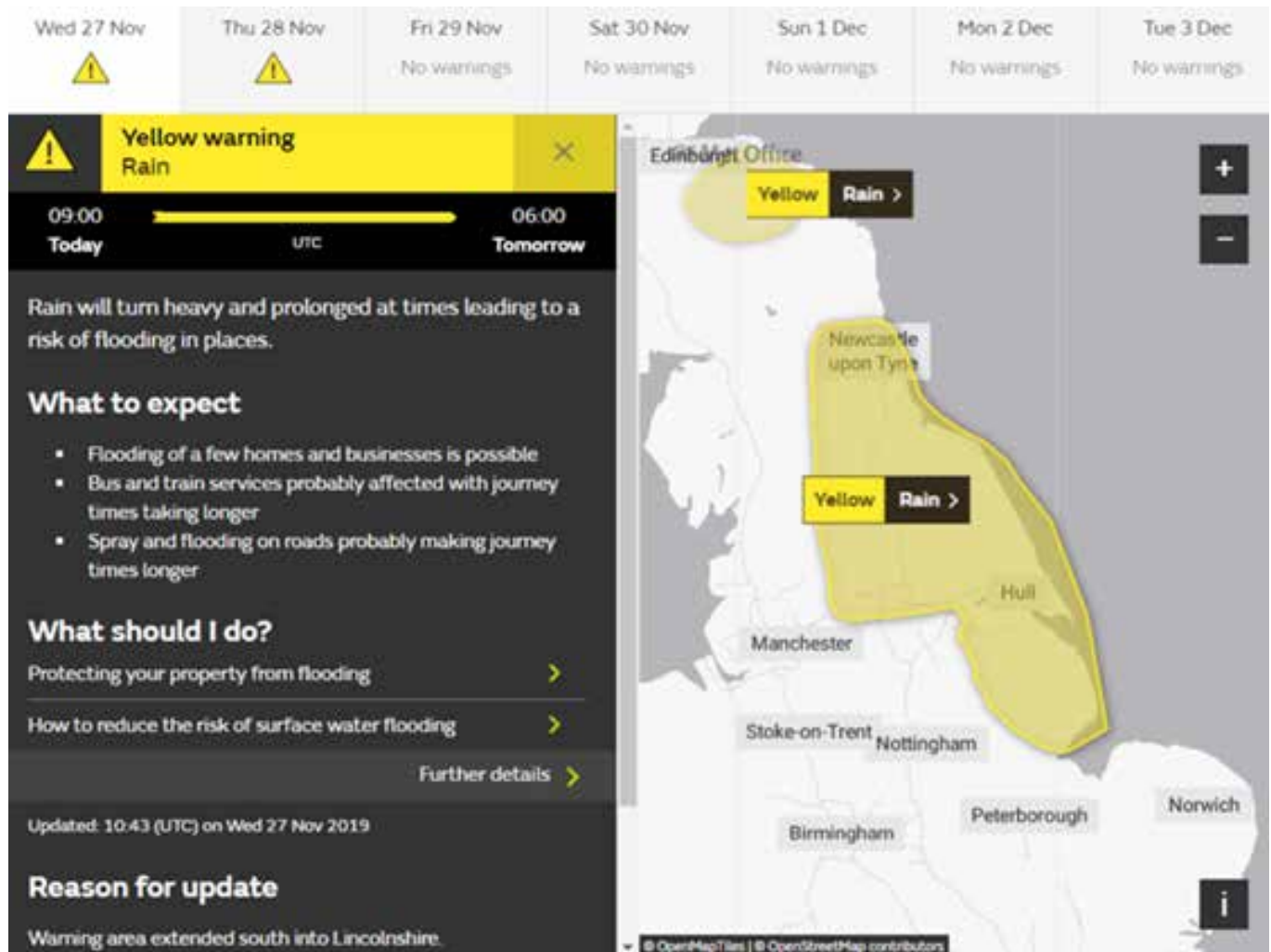
The UK Meteorological Office (UKMO) has issued impact-based warnings since 2011, which are based on a combination of the severity of potential impacts and the likelihood of those impacts occurring, as determined using a risk matrix. This provides a qualitative indication of the types of impacts expected for each weather type and impact level.⁹

(a) Vehicle OverTurning (VOT) model

The UKMO implements a model-based approach for identifying impacts, using the Vehicle OverTurning (VOT) model (Figures 7 and 8). The VOT model was developed to test the hypothesis that risk models can be run in real-time for short-term weather-related hazards. The UKMO collaborated with the Transport Research Group at Birmingham University to use a mechanical model to calculate accident gust speeds for different vehicle types. The objective was to provide a consistent assessment of potential risk to road users in Great Britain during high-wind events by highlighting areas of the road network that are at risk of disruption due to vehicle overturning.

8. Powerpoint Presentation by Indonesia Agency for Meteorology Climatology and Geophysics for the Joint Workshop on Strengthening Multi-Hazard Early Warning Systems and Early Actions in Southeast Asia in Bangkok, Thailand on 18-20 February 2020
9. UK Met Office, 2017

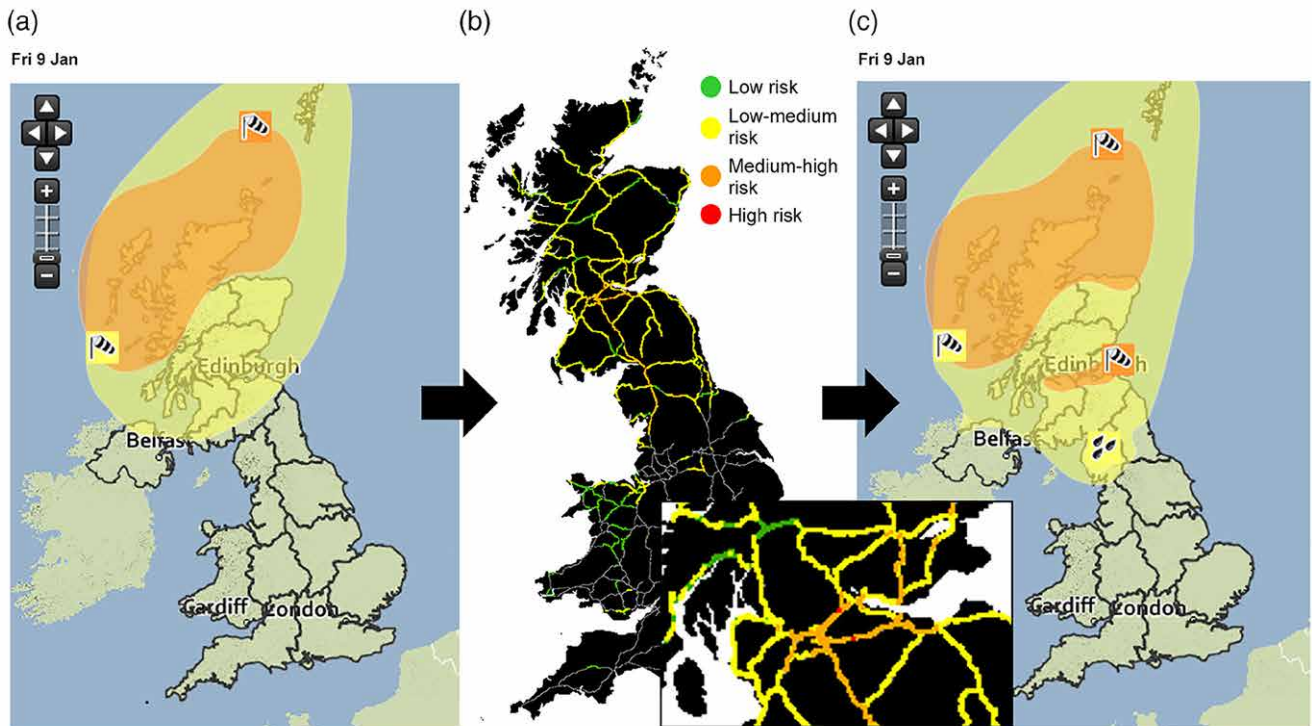
Figure 7: Weather warnings provided by the National Severe Weather Warning Service¹⁰



- The approach starts with a definition of the hazard. The WMO Guidelines define a hazard as a hydrometeorological-based, geophysical or human-induced element that poses a level of threat to life, property, or the environment.
- Subsequently, vulnerability is quantified. Defined as the susceptibility of exposed elements in the WMO Guidelines, the *vulnerability* of a location is defined in terms of factors such as the number of lanes, road orientation, and altitude of the road section.
- The next step is to quantify exposure, which refers to who and what may be affected in an area in which hazardous events may occur. In this case, the exposure may be quantified as the total volume of traffic traversing a particular location.
- Finally, the risk of a vehicle overturning is calculated by multiplying all three equally weighted components of hazard, vulnerability, and exposure together.

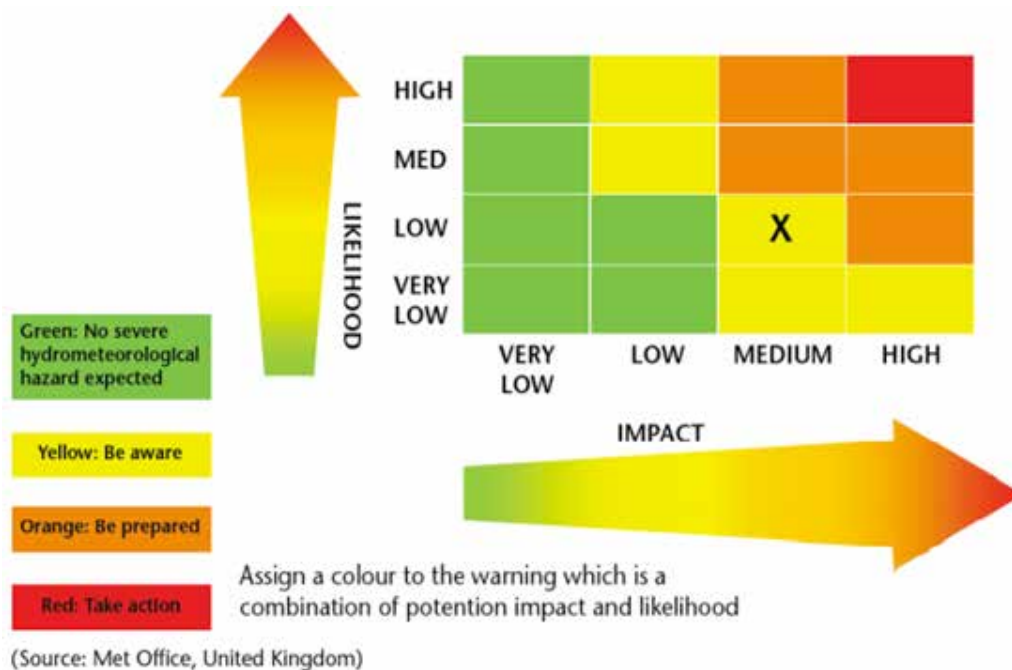
10. <https://www.metoffice.gov.uk/weather/guides/warnings/>

Figure 8: Visualization of impact forecasts from the VOT model¹¹



This approach is an example of combining probabilistic hazard information (i.e., on wind gust and direction) with vulnerability and exposure data to produce impact forecasts, thereby facilitating the identification of parts of the network that are likely to experience vehicle-overturning incidents (Figure 9).

Figure 9: Color-coded risk matrix used to convey the severity of warnings

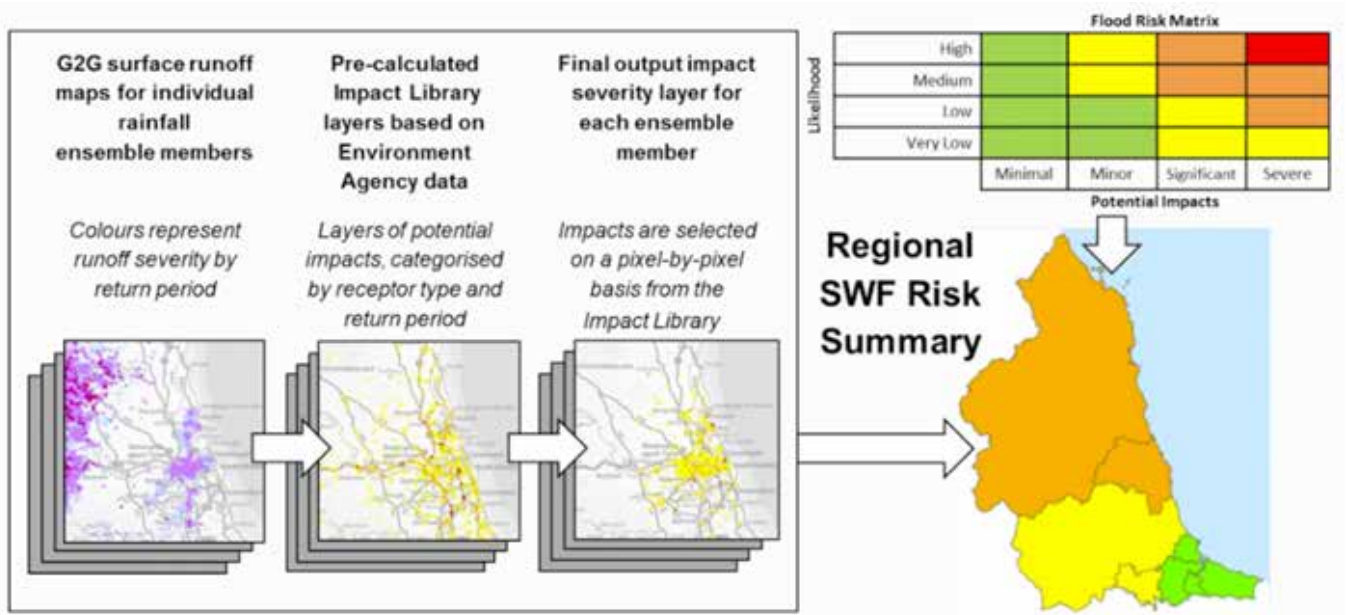


11. Hemingway & Robbins, 2020

(b) Surface Water Flooding model

A similar approach that is being developed by the UKMO is the Surface Water Flooding model, which builds forecasts based on UKMO predictions of likely rainfall. These probabilistic rainfall forecasts are converted into surface water runoff using a Grid-to-Grid model by the Centre of Ecology & Hydrology (Figure 10). Impact and vulnerability conditions are combined with the runoff model output to produce scenario maps of flood impact severity. These maps form the basis for country-wide risk scores linking potential impacts and likelihoods.

Figure 10: Overview of the Surface Water Flooding Hazard Impact model produced by the Flood Forecasting Centre in collaboration with the UK Meteorological Office¹²



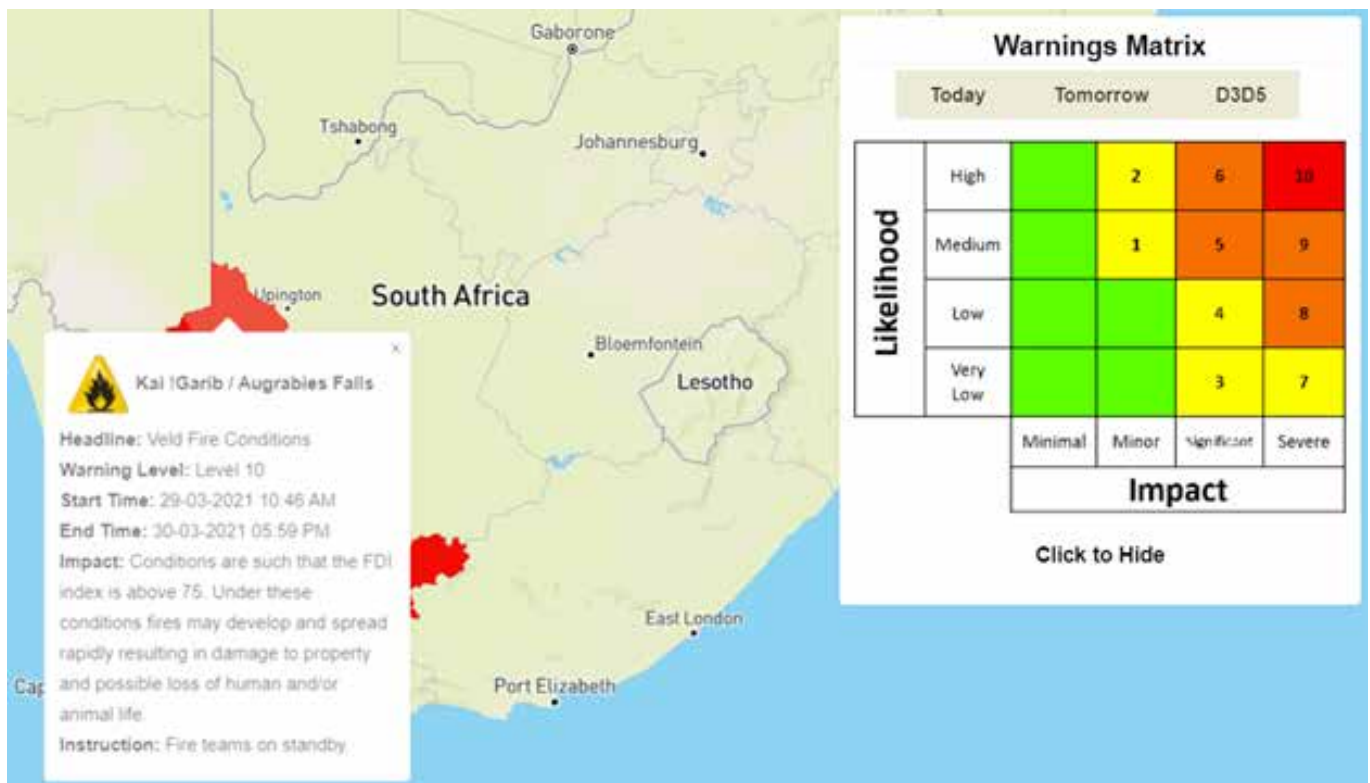
The South African Weather Service: Defining impact thresholds qualitatively

In 2020, the South African Weather Service (SAWS) introduced a new severe weather warning system that provided impact-based warnings rather than threshold-based warnings (Figure 11). In identifying hazard impacts, SAWS adopted a qualitative approach as opposed to a model-based approach whereby hazard forecasts are translated into qualitative and selected impacts by emergency managers on the ground. This approach means that emergency managers make the choices on which impacts deserve to be communicated, and which ones are left out.

- Like the approaches discussed in the previous examples, the SAWS approach first starts by generating a weather forecast.
- The forecasted impact levels are then determined based on impact tables generated in close collaboration with relevant stakeholders (including disaster managers from each district nationwide) through stakeholder workshops.
- Once the forecasted level of impact is determined, the district disaster managers are contacted prior to the issuance of the impact-based weather warnings.
- Lastly, the impacts are verified and evaluated in collaboration with local disaster managers as well as published media reports.

12. <http://www.naturalhazardpartnership.org.uk/science/hims/surface-water-flooding/>

Figure 11: Warnings on the South African Weather Service¹³



The Australian Bureau of Meteorology: Managing insufficient data availability

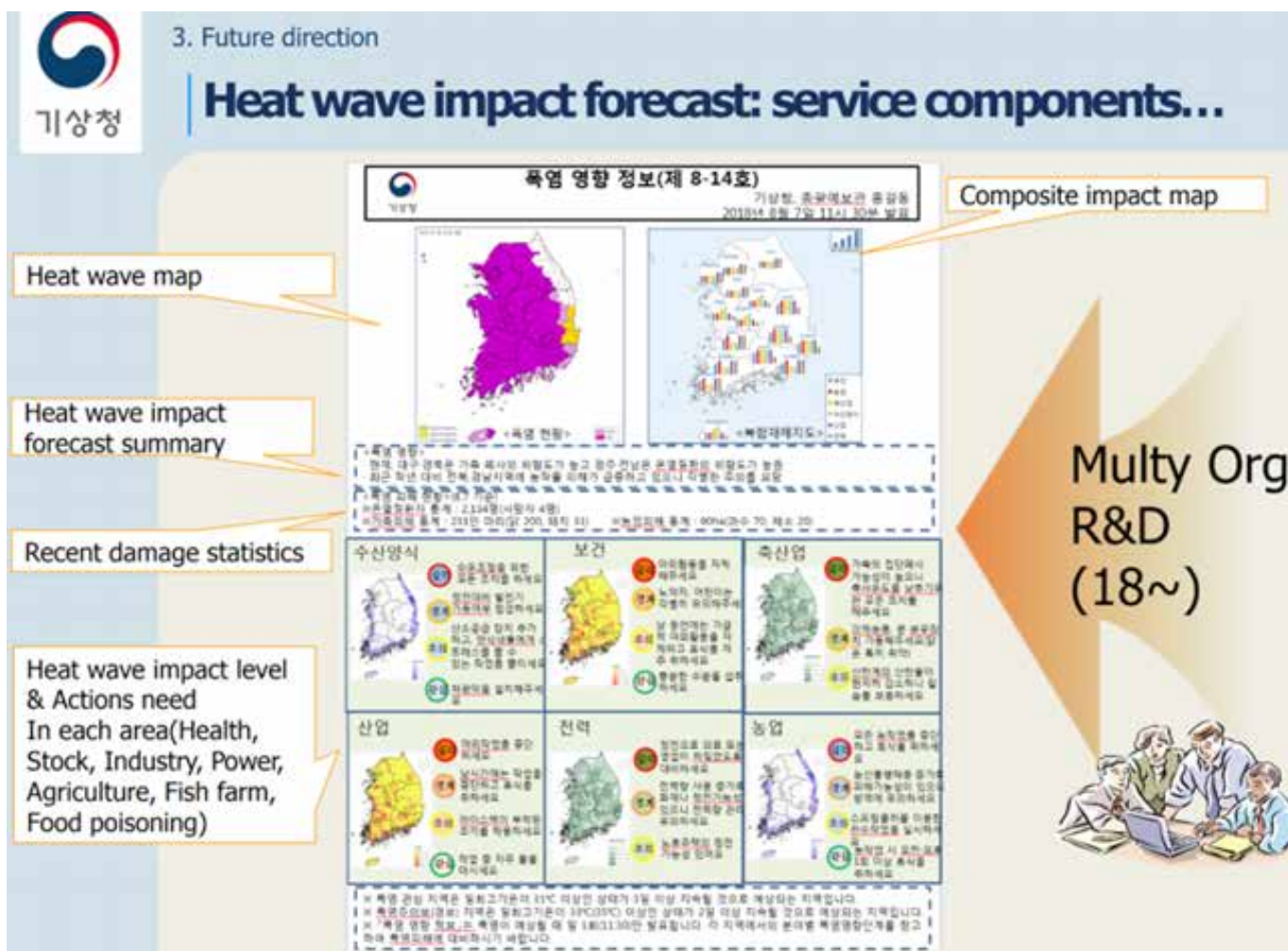
Impact-based Forecasting for the Coastal Zone: East-Coast Lows was a project focused on the wind impact on residential buildings. However, the Bureau of Meteorology (BOM) lacked data for determining the relationship between building damage and weather conditions, which can then be used to forecast levels of impact from a hazard. To address this, the BOM processed available records on past damage to residential properties caused by all kinds of hazards, retaining only those records related to the hazard of interest. These records were then analyzed in conjunction with relevant data on hydrometeorological conditions and events to identify damage curves and vulnerability relationships. The derived relationships were then used to forecast potential impacts on residential properties.

The Republic of Korea & Bangladesh: Targeted warnings for user sectors

The Republic of Korea (ROK) has pilot-tested a system for generating impact-based forecasts and warnings for heatwaves and cold waves. This is based on model-based probabilistic forecasts of thermal indices. The forecasts are converted from grid-point alerts to areal alerts for 165 regions, with risk maps updated twice a day for the following 3 days (Figure 12). The forecasts, warnings, and recommended actions provided by this system are broken down into specific sectors, such as public health, industry, and agriculture.

13. <https://www.weathersa.co.za/home/warnings>

Figure 12: Impact-based forecasting in the Republic of Korea¹⁴



Similarly, Bangladesh is initiating efforts to administer IBFWS via the Multi-Hazard Risk Vulnerability Assessment Mapping and Modelling (MRVA) program (Sai, Cumiskey, Weerts, Bhattacharya & Haque Khan, 2018). Rather than using quantitative approaches to define and forecast impacts, they used a community-based approach by directly soliciting inputs from stakeholders of interest. Impacts are delineated per sector in terms of crop damages, school closures, and disaster management warnings (e.g., households or roads inundated, power blackouts). This approach of targeting forecasts and warnings towards specific stakeholders yields the benefit of encouraging effective mitigation actions within targeted sectors.

Opportunities

Impact-based forecasting enables anticipatory actions and revolutionizes responses to weather and climate crises, providing national and local authorities the opportunity to anticipate and coordinate preemptive measures to mitigate the impacts resulting from climate-related events and hazards. The increasingly advanced and widespread use of data collection technologies and methods has led to an abundance of high-resolution data which will further strengthen the accuracy of impact-based forecasts.

14. Second KMA/WMO Workshop on Impact-based forecasts in Asia. Seoul, Republic of Korea, 19-21 November 2018

Where data is lacking, advanced tools in data analytics, including machine learning and artificial intelligence, may be used to fill in the gaps based on historical as well as existing and available data. An example is the Specialized Expert System for Agro-Meteorological Early Warning (SESAME) tool implemented by Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES) in Myanmar. SESAME integrates location-specific weather forecasts, historical climate data, and location-specific prioritized crop information to translate climate information of different timescales into agricultural plans and decisions. Such a system helps users to arrive at location- and crop-specific cost-effective strategies and measures to manage potential impacts from extreme weather and climate events. The SESAME system is also operational in Cambodia, Sri Lanka, and Papua New Guinea.

Decision-support systems offer opportunities for close collaboration between NMHS agencies and other stakeholders in a country. The SESAME system in Myanmar demonstrates this clearly, where the Department of Meteorology and Hydrology hosts the system but the Department of Agriculture uses it. By capitalizing on the expertise of NHMS in developing weather and hydrometeorological hazard forecasts, impact-based warnings can be generated and capitalized upon to inform measures that can strengthen the resilience of communities and reduce losses suffered by nations as a whole.

Challenges

There are multiple challenges involved in the production of effective and accurate impact-based forecasts. Primarily, the limitations are related to the limited availability of data with high resolution and coverage. The lack of directly relevant data was a notable challenge in the IBF project by the Australian Bureau of Meteorology, as described above. In that project, the lack of damage survey data made it challenging to identify the vulnerability-exposure relationship which was needed to identify communicable impacts from hazards. Ultimately, the project team implemented a sophisticated data filtering approach on existing data to obtain the relevant information required to facilitate impact-based forecasting.

Another challenge pertains to the quality and varying resolutions of input data on forecast outputs. For example, the UKMO used the 2km resolution of wind gust forecasts in conjunction with the VOT, which precluded the accurate modelling of local-level turbulence. As another example of how varying data inputs may change data outputs, the Australian Bureau of Meteorology found that the impact forecasts switched from none to moderate after switching from a 21-hour forecast to a 3-hour forecast. These challenges must be carefully considered when producing impact-based forecasts.

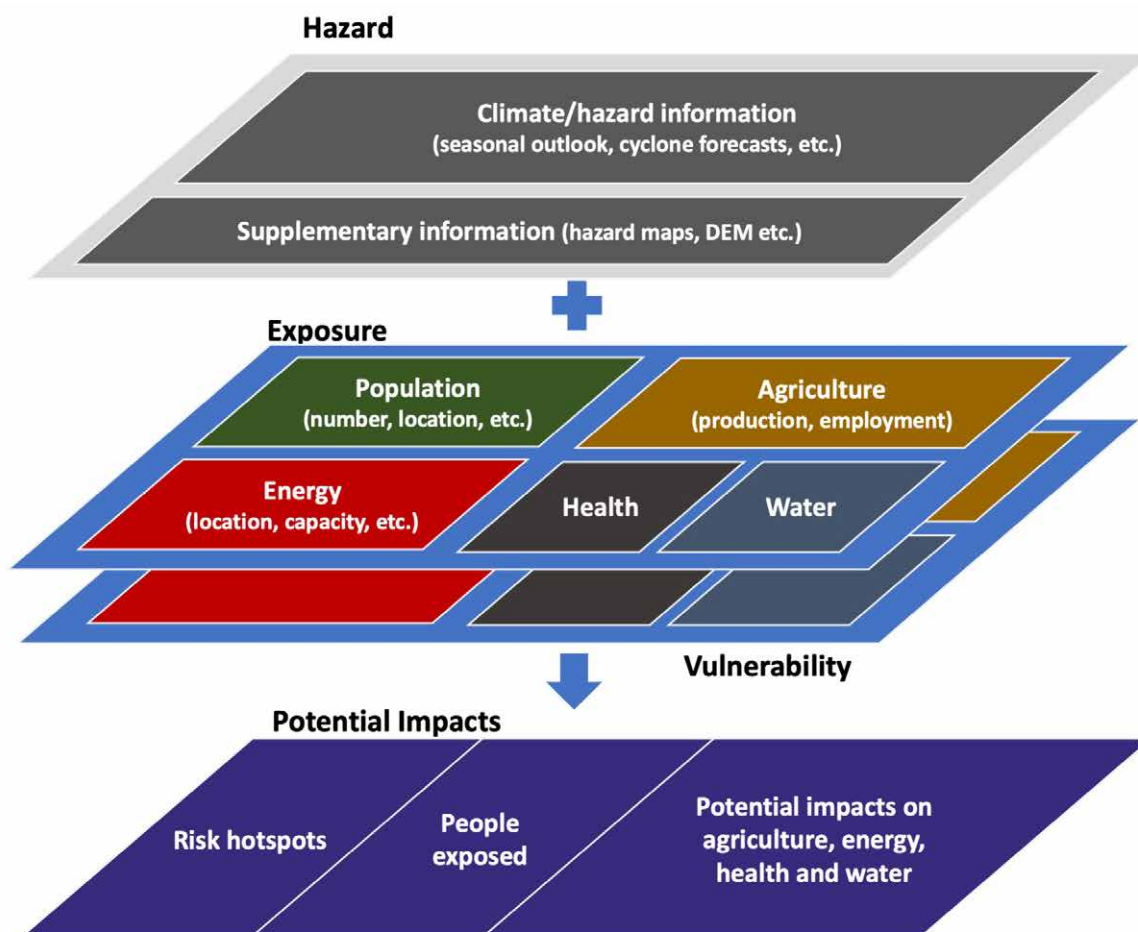
Additionally, up-to-date data on vulnerability and exposure profiles is required to strengthen the quality of impact forecasts and risk assessments. As demonstrated in this manual, this data is used to generate impact-based forecasts, which in turn directly informs the responses taken by the NMHS and other relevant agencies. Unfortunately, the necessary up-to-date information may not always be readily available.

Finally, the seasonal forecast data (for example, as discussed in Module 3) is probabilistic in nature. This necessitates careful interpretation of not just the potential impacts identified, but also the other information which are used for monitoring and assessment of potential risks. The communication of these impact outlooks to the user sectors must also ensure a strong understanding of the probabilistic nature of the results.

Impact-based forecasting conceptual framework of the manual

The examples included in this manual demonstrate the myriad ways in which IBFWS can be developed and implemented. Figure 13 provides a visualization of the impact-based forecasting concept that will be employed in the following modules of this manual.

Figure 13: Components of an impact-based approach to forecasting¹⁵



Input data layers encapsulating information on hazards, exposure, and vulnerability are gathered and combined. Each data layer should be in GIS format and typically consists of maps explicating the forecasted geographic extents of the hazard phenomena or the distribution of entities of interest (exposure) as well as information on the state of those entities (vulnerability). By overlaying these data layers and identifying the locations where hazards intersect with up-to-date locations of highly exposed and/or vulnerable entities, users can identify hazard hotspots which may then be targeted for monitoring and preventive measures that have the potential to greatly mitigate damage and losses.

This training manual aims to provide a step-by-step guideline for overlaying these layers and subsequently deriving the insights required for a risk assessment that forms the backbone of impact-based forecasts.

15. ESCAP (2021) Overview of the work of the secretariat and the United Nations system at the regional level. ESCAP/CDR/2021/INF/1

References

EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium.

ESCAP (2021) Overview of the work of the secretariat and the United Nations system at the regional level. ESCAP/CDR/2021/INF/1

Hemingway, R., & Robbins, J. (2020). Developing a hazard-impact model to support impact-based forecasts and warnings: The Vehicle OverTurning (VOT) Model. *Meteorological Applications*, 27(1), e1819.

Richter, H., Arthur, C., Wilke, D., Dunford, M., Ebert, B. & Wehner, M. (2020). impact-based forecasting for the coastal zone - East Coast Lows: annual report 2019-2020, Bushfire and Natural Hazards CRC, Melbourne.

Sai, F., Cumiskey, L., Weerts, A., Bhattacharya, B., & Haque Khan, R. (2018). Towards impact-based flood forecasting and warning in Bangladesh: a case study at the local level in Sirajganj district. *Natural Hazards and Earth System Sciences Discussions*, 1-20.

Weigold, M.F. (2001). Communicating science: A review of the literature. *Science communication*, 23(2), 164-193.

World Meteorological Organization (WMO) (2015). WMO Guidelines on Multi-hazard Impact-based Forecast and Warning Services. [online]. World Meteorological Organization. Available at: <https://public.wmo.int/en/media/news/wmo-updates-guidelines-multi-hazard-impact-based-forecast-and-warning-services> [Accessed 1 March 2021].

United Kingdom Met Office (UKMO) (2017) What are the National Severe Weather Warning Service Impact tables? [online]. Met Office. Available at: <http://www.metoffice.gov.uk/guide/weather/severe-weather-advice> [Accessed 26 March 2021].

United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) (2019). Asia-Pacific Disaster Report 2019

_____ (2021). Asia-Pacific Disaster Report 2021 (forthcoming)

MODULE 2

IMPACT-BASED FORECASTING FOR TYPHOONS

Viet Nam experiences frequent typhoons (tropical cyclones), which can incur significant impacts on people and their livelihoods and result in huge economic losses. Strategic use of weather forecasts and climate indicators, together with exposure and vulnerability information, can inform early warnings that stimulate early action and reduce disaster impacts. This module helps users to understand various datasets on exposure and vulnerability that can be used in conjunction with typhoon forecasts to garner important insights for disaster risk management. The module also demonstrates how to identify exposure and vulnerability hotspots and assess potential impacts from typhoons using examples within a Viet Nam context.

Objective: To produce impact-based forecasting for typhoons.

Module 2 provides guidance to produce impact-based forecasting using typhoon forecasts with examples from Viet Nam

Contents

- Introduction to data layers
- Preparing hazard layers
- Assessing population exposure to typhoons
- Assessing the vulnerability of the population exposed to typhoons
- Assessing agricultural exposure to typhoons
- Assessing energy powerplants exposure to typhoons
- Assessing critical infrastructure exposure to typhoons
- Assessing economic stock exposure to typhoons
- Assessing possible convergence with COVID-19 and potential impacts on the health system

Introduction to data layers

The three required categories of data used for impact-based forecasting are hazards, exposure, and vulnerability data layers.

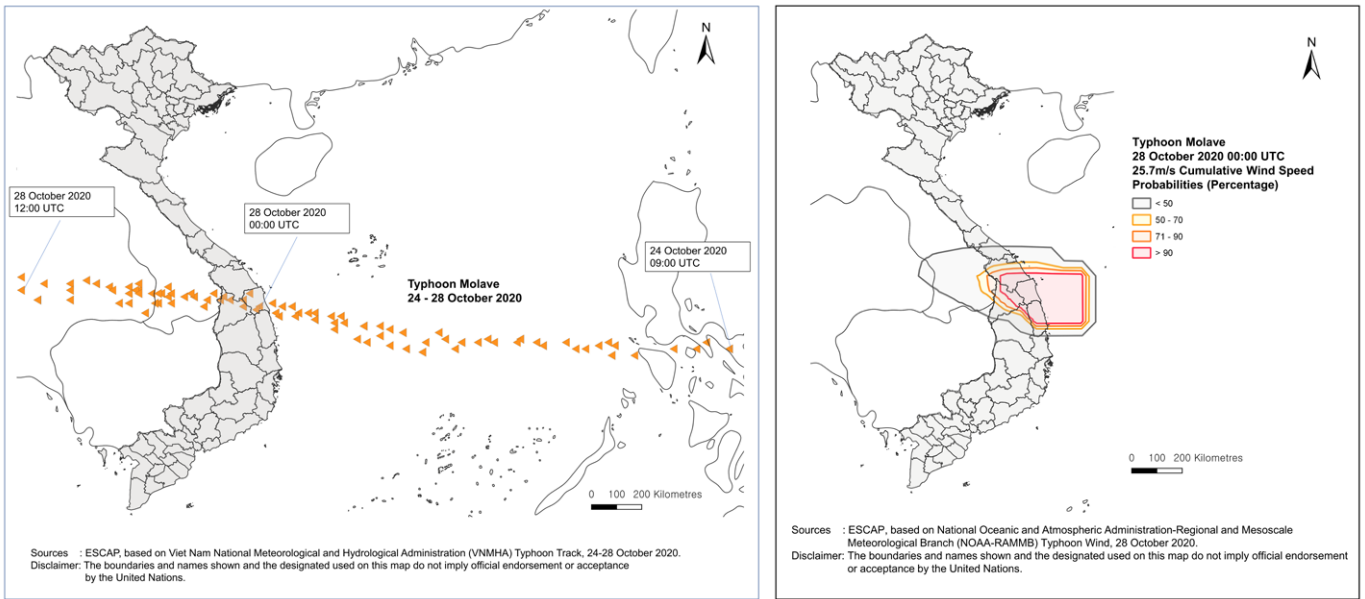
- **Hazards** data should comprise the geographic coverage and magnitude of the hazards as this enables delineation of the areas of concern. Examples of such data would include weather forecasts or flood maps that identify the potential heights of floodwaters under various flood return periods. Given the focus of this module, a case study of Typhoon Molave is employed. Two maps describing the hazards are used: firstly, a map consisting of typhoon track and maximum wind speeds is used as the example hazard layer. The threshold wind speeds for each category of severity should be identified, and the spatial extents of each category delineated in GIS vector format. Secondly, probabilistic forecasts¹ for maximum rainfall associated with the typhoon, in GIS raster format.
- The **exposure data** layer should answer the question: where are the entities of concern? These entities may be the general population or critical infrastructures, such as power plants, telecommunication towers, and key transportation hubs (e.g., maritime ports or airports). Focus can also be given to the capacities of facilities providing access to basic services (such as health and education) to ensure that these facilities will not be overburdened. Other exposure data may be on the distribution of fishery, aquaculture, and agricultural production, or similar production data relevant to economic wellbeing. In this module, we examine exposure data related to population distribution, agricultural production, as well as the characteristics of facilities related to energy infrastructure and healthcare.
- The final data layer relates to the condition or state (**vulnerability**) of the exposed entities. For example, it would be useful to know where certain vulnerable groups (i.e. elderly populations) within the exposed population are located for more targeted interventions and early warnings. Hazard incidence may have a disproportionate impact on such population groups. This module showcases how vulnerability data can be used to identify potential hotspots for targeted interventions. This data can cover population structure (e.g., female, children, and elderly populations) and human development indicators such as the Subnational Human Development Index (SHDI). Other vulnerability indicators include access to basic services and high burdens on local healthcare system capacities.
- Other contextual data required for the analysis include vector data (**shapefiles**) delineating the national and subnational boundaries of the country of interest. In this manual, we make use of shapefiles delineating the national, provincial, and district division boundaries of Viet Nam.

Preparing hazard layers

The basic hazard data layers would be weather forecasts produced by NMHS agencies. This data depicts the spatial extent and magnitude of the event, such as the total amount of rainfall or maximum wind speeds. For this module, data from Viet Nam Meteorological and Hydrological Administration (VNMHA) and the National Oceanic and Atmospheric Administration (NOAA) are used to demonstrate some examples. The examples are based on Typhoon Molave, which made landfall on 28 October 2020 and caused an estimated total of US\$430 million in damages (Figure 1).² In the following example, the typhoon wind field map was redrawn from NOAA data, and thus may contain some inaccuracy.

1. A probabilistic forecast consists of a set of probabilities representing the probability of occurrence of a set of potential future events, as opposed to a deterministic forecast, which "predicts" one specific outcome as the forecast. For example, a 70% probabilistic forecast for 100mm rainfall over 24 hours indicates a 70% probability of 100mm of rainfall occurring over 24 hours.
2. <https://www.bloomberg.com/news/articles/2020-11-01/vietnam-estimates-typhoon-molave-caused-430-million-of-damage>

Figure 1: Typhoon Molave tracks (left) and forecasted maximum wind speed categories map at a select point in time (right)

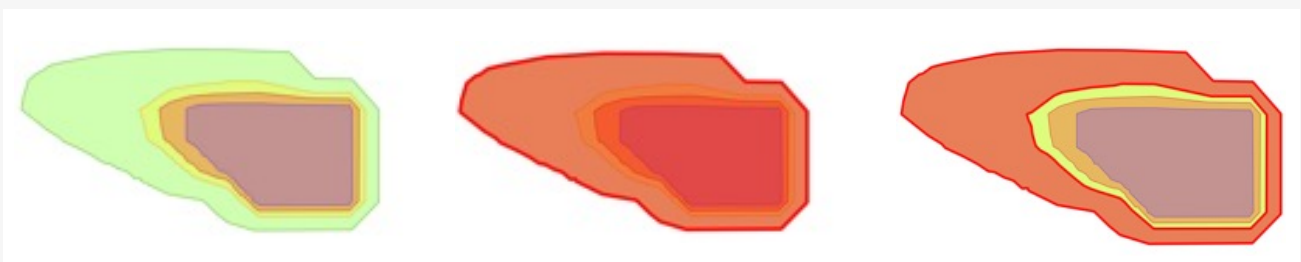


Data Source: VNMHA and NOAA

How to:

- ✓ In this example, the NOAA image characterizing a snapshot of Typhoon Molave conditions was converted to raster data using the *Raster* → *Georeferencer* tool in QGIS (Figure 2, left). Annex III of this manual contains additional detail on this process.
- ✓ This was converted to vector data by creating a new Shapefile layer and adding polygons in accordance with the newly georeferenced raster layer.
- ✓ The resulting shapefile consists of multiple overlapping vectors, each indicating a different wind speed category (Figure 2, center).
- ✓ These vectors can be processed to be non-overlapping vectors by first using the Polygon Self-Intersection tool in QGIS, and subsequently removing the overlapped portions of the vectors by editing the attribute table of the layer (Figure 2, right).

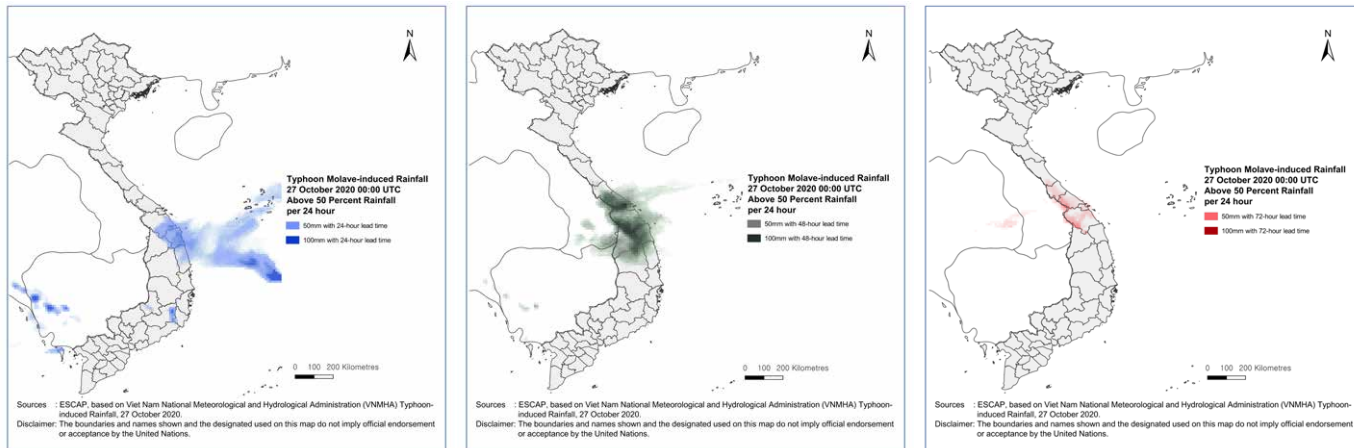
Figure 2: View of typhoon wind speed categories (left), with overlapping polygons (center) and non-overlapping polygons (right)



Data Source: NOAA

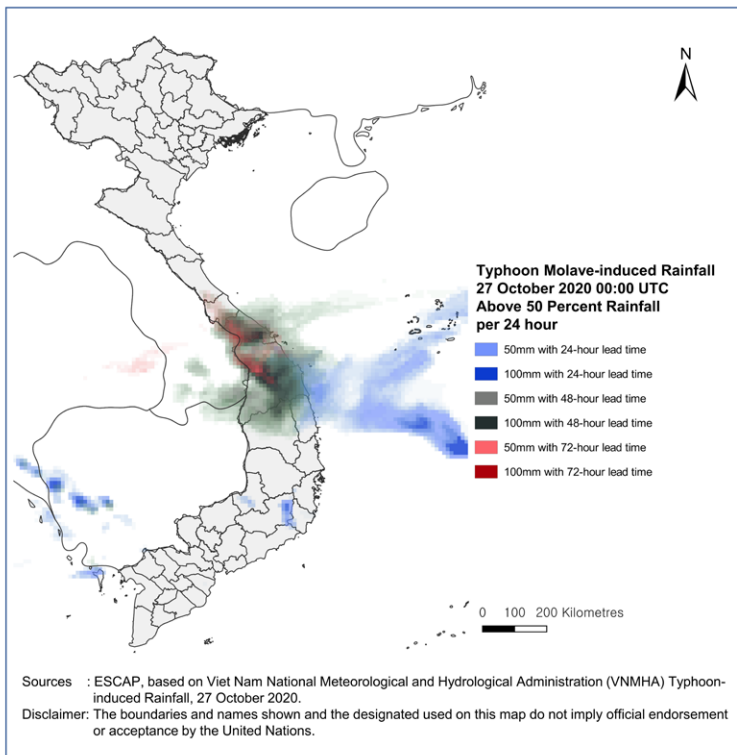
Similarly, the exposure to extreme rainfall associated with typhoon occurrence can be quantified. The following examples make use of probabilistic forecasts for rainfall associated with Typhoon Molave provided by the VNMHA in .NC file format (Figures 3). These data layers can be combined to produce a single map containing all hazard types, to identify areas where multiple extreme rainfall events coincide (Figure 4).

Figure 3: Probabilistic forecast for 50 mm and 100mm rainfall over 24 hours with 24 hour lead time (left), 48 hour lead time (center), and 72 hour lead time (right)



Data Source: VNMHA

Figure 4: Probabilistic forecast for 50 and 100 mm rainfall over 24 hours, with 24 hours, 48 hours and 72 hours lead time combined

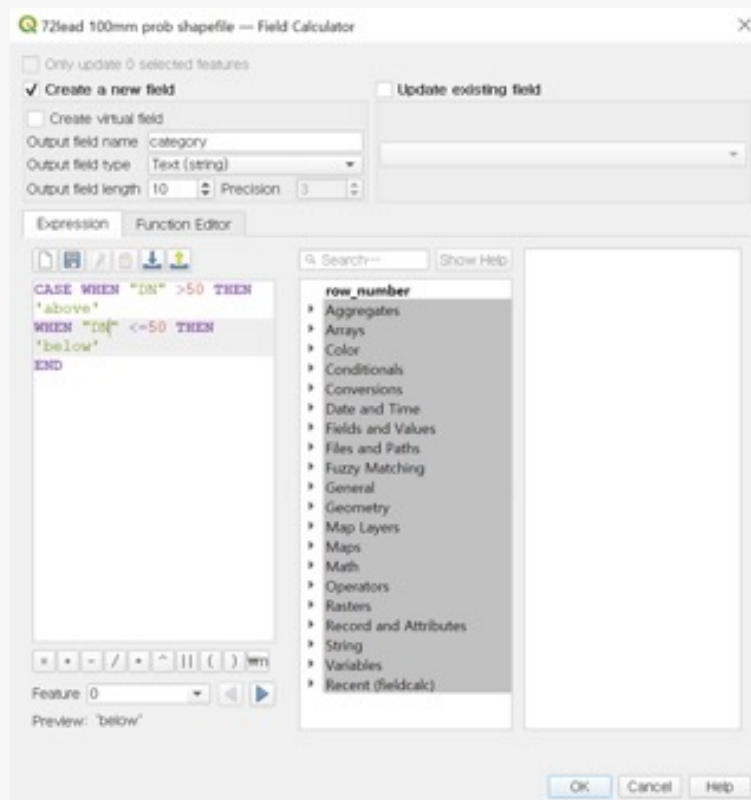


Data Source: VNMHA

How to:

- ✓ To process the multiple probabilistic rainfall layers, the *Vector* → *Polygonize* tool can be used to convert each raster image to vector data.
- ✓ Subsequently, the field calculator is used on the newly vectorized features to assign labels to each polygon based on predefined categories using the CASE expression (Figure 5).
- ✓ In this example, rainfall probabilities above 50% are categorized as high probability, and 50% and below as low probability.
- ✓ Subsequently, the newly vectorized data layers can be merged (*Vector* → *Merge* tool) to form a single data layer.

Figure 5: The expression used in the Field Calculator for categorizing the rainfall probabilities



The column “DN” stands for “Digital Number”, indicating the vector record of the corresponding raster value. In this example, the DN column indicates the probability of rainfall exceeding a certain threshold.

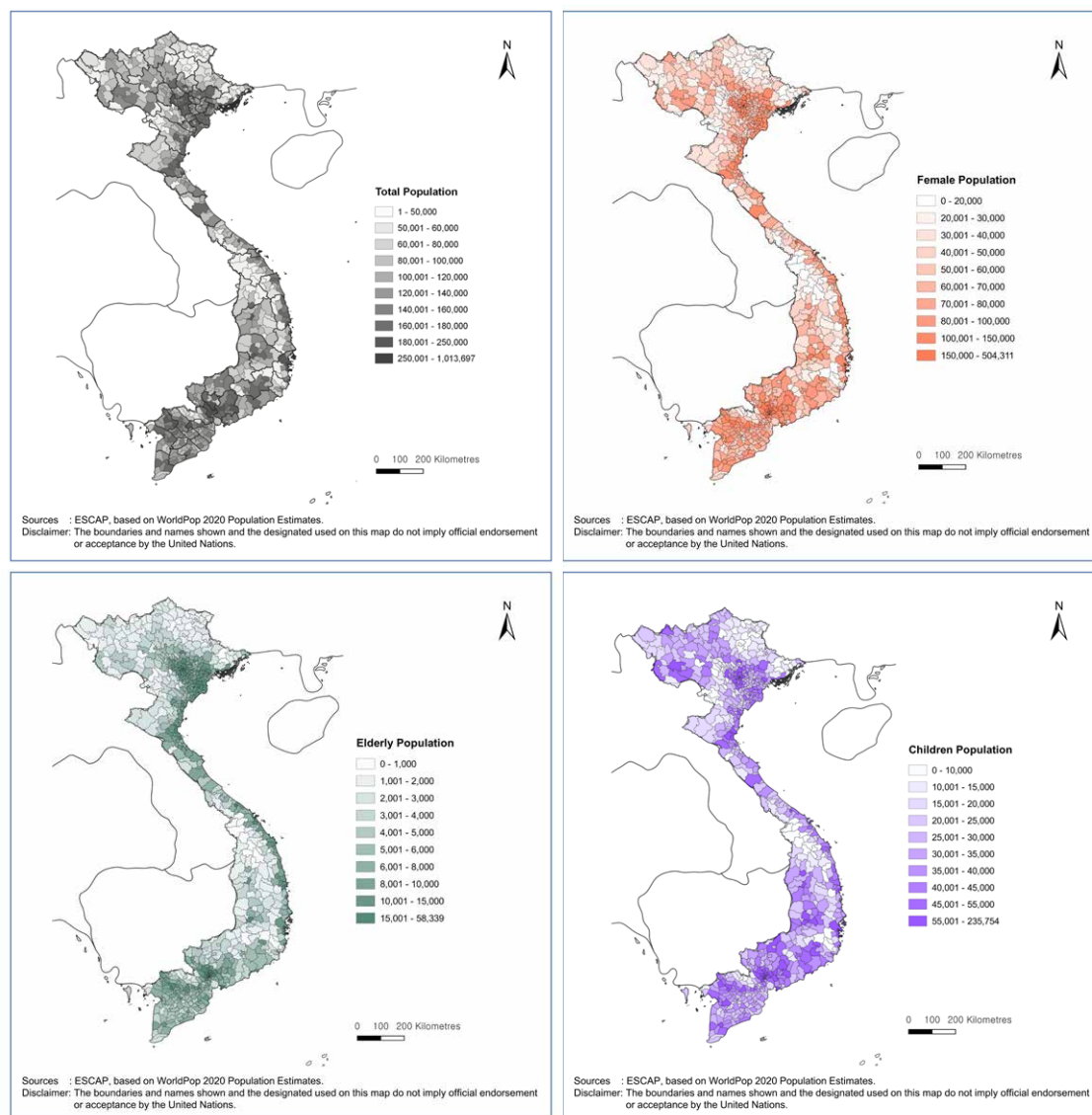
Assessing population exposure to typhoons

(a) Preparing the population exposure data layers

The exposure and vulnerability datasets should convey the spatial distribution of entities of interest. This example examines the exposure and vulnerability of populations and vulnerable population groups. Such information can be derived from government datasets (e.g., census or other national statistical data).

In this manual, Worldpop gridded population data is used.³ The Worldpop database further contains estimated population breakdown by gender and age groups. For example, there are data layers for male and female populations aged 65 to 70, 70 to 75, and so on. (Figure 6). To obtain the spatial distribution of population groups such as female, children (i.e., aged 15 and below), and the elderly (i.e., aged 65 and above), the disaggregated data sets should first be merged by summing the values in each data layer.

Figure 6: Spatial distribution of the overall population (upper left), female population (upper right), the elderly population (lower left), and population of children (lower right)



Data Source: Worldpop

3. Lloyd, Sorichetta & Tatem, 2017

How to:

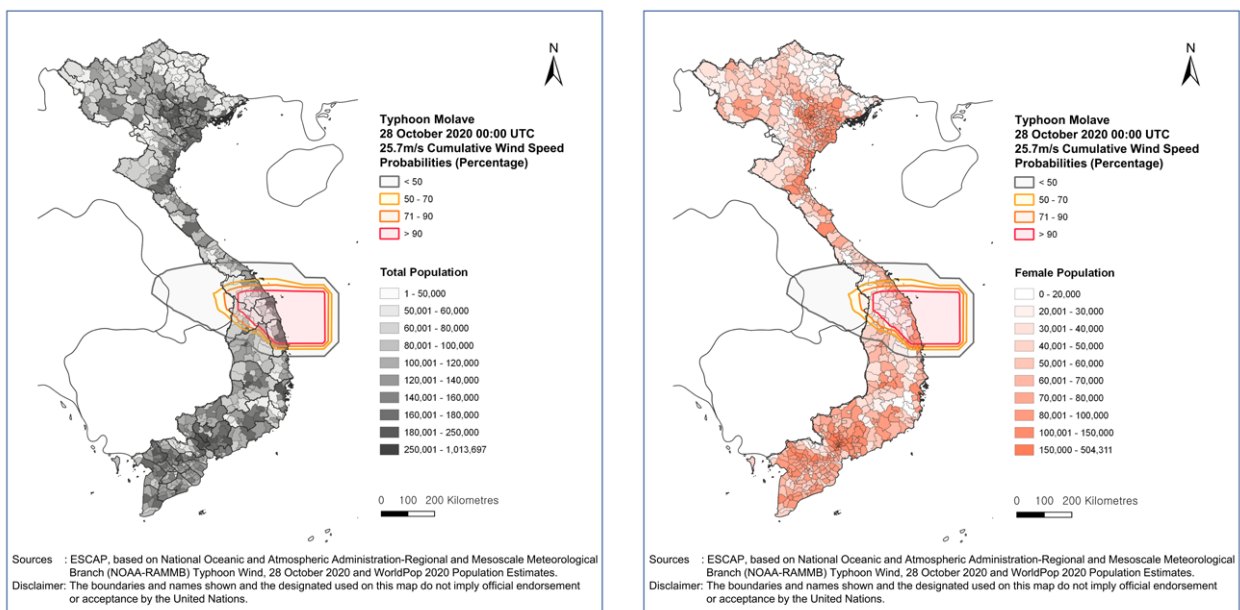
- ✓ To aggregate the population values, the *Raster* → *Merge* tool in QGIS can be used on the individual raster files.
- ✓ Subsequently, the Zonal Statistics tool can be used on the gridded population datasets and the administrative boundary shapefiles, with “*Sum*” selected as the Statistic to Calculate, to sum the grid cell values (indicative of the size of population) within each underlying vector data feature of interest.
- ✓ In this case, each data feature in the administrative shapefile layer should represent an administrative area. This adds a column to the hazards data layer containing total population size in each administrative area.

(b) Visualizing areas with high population exposure to hazards

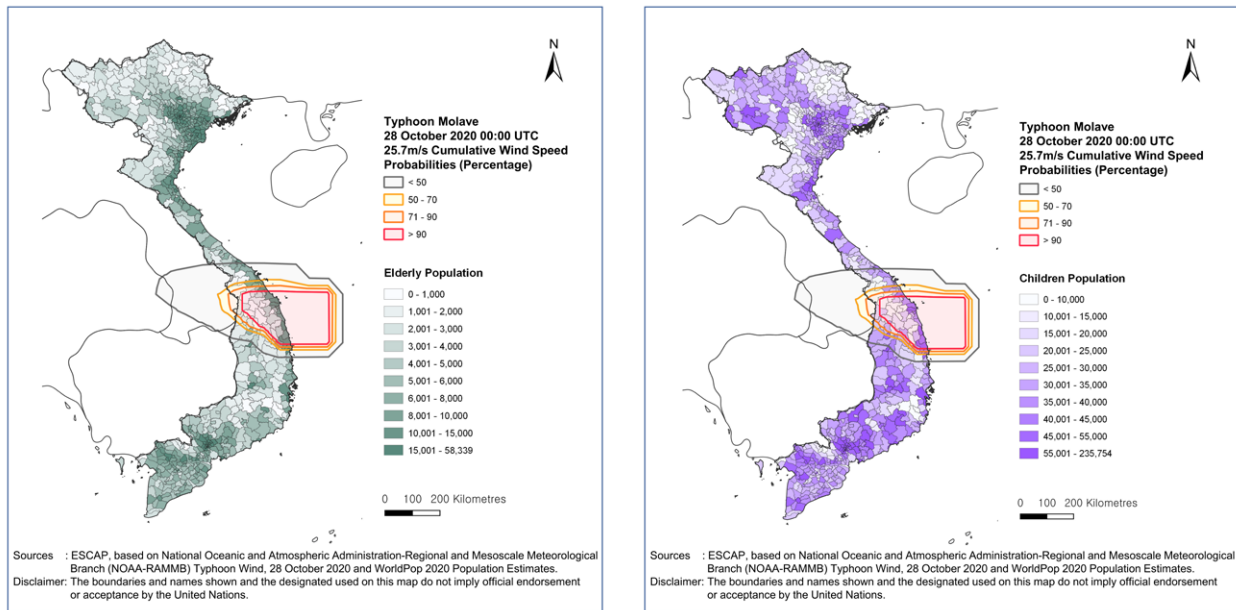
Once the hazard layer and demographic layer are prepared, the hazard maps can be overlaid with the population distribution maps to identify areas with large populations exposed to a hazard. As a hazard poses a higher risk if the hazard extent overlaps with more exposed entities, this helps identify the urgency of implementing measures to manage the potential hazard.

As an example, Figure 7 identifies areas likely to face strong winds with the distribution of total population and population subgroups across the country. In this case, a large population size along the coast is likely to face 25.7 m/s wind speeds from Typhoon Molave.⁴

Figure 7: Hazard extents overlaid with population distribution maps



4. Scale 10 in Beaufort scale



Data Source: Worldpop and NOAA

(c) Calculating the size of the population exposed to hazards

To identify the areas with large population exposure, it is possible to calculate the total population (or sub-groups of the population) residing in the areas expected to face strong winds. The exposed population can be assessed as a proportion of the total population to contextualize the magnitude of exposure. In the case presented here, as of 27 October 2020, approximately 4.5 million people (or 4.55% of the total population) have a more than 50% probability of facing 25.7 m/s wind speeds (Figure 8).

Figure 8: Total population in each category of forecasted extreme wind speed probability

Probability (%) of strong wind (25.7m/s)	Population exposed	Total population	% of population exposed
> 90	2,412,500	97,411,255	2.48%
71 - 90	874,091		0.90%
50 - 70	1,134,937		1.17%
< 50	2,627,150		2.70%

How to:

- ✓ Using the categorized vector data for probabilistic rainfall categories, apply the *Zonal Statistics* tool using the gridded population datasets and the hazards layer.
- ✓ Next, apply the Zonal Statistics tool with “Sum” selected as the Statistic to Calculate.
- ✓ This adds a column to the hazards data layer containing total population size in each hazard category.

How to:

- ✓ To estimate the sizes of the population exposed to extreme winds, use the *Zonal Statistics* tool with the gridded population data and the forecasted extreme wind speed probability layer.
- ✓ In this case, the hazards layer consists of features corresponding to the spatial extents of ranked 25.7 m/s wind speed probabilities).
- ✓ The population in each vector feature can then be summed to obtain the sizes of populations exposed to each wind speed probability (Figure 9).

Figure 9: Number of population groups exposed

Probability (%) of strong wind (25.7m/s)	Population exposed	Female (%)	Children (%)	Elderly (%)
> 90	2,412,500	1,285,118 (53.3)	610,637 (25.3)	141,424 (5.9)
71 - 90	874,091	410,900 (47.0)	213,793 (24.5)	41,600 (4.8)
50 - 70	1,134,937	602,119 (53.1)	312,810 (27.6)	66,836 (5.9)
< 50	2,627,150	1,386,955 (52.8)	706,693 (26.9)	151,661 (5.8)

(d) Identifying administrative areas with high hazard exposure

As shown above, using probabilistic forecasts for extreme rainfall with multiple lead times makes it possible to visually identify the regions with a high potential of sustained extreme rainfall. However, it may be of further interest to decision-makers to know the names of administrative areas (e.g., districts or provinces) that face a substantial threat, as risks and recommended mitigative actions can then be conveyed to the relevant subnational and local officials.

Beyond simply identifying the names of districts or provinces that face each type of hazard, it is also necessary to identify locations where these threats can concatenate, thereby with a higher probability of being affected. This information can be presented in the form of a matrix whereby the areas facing a low (e.g., 50 mm/24 hours for the next 48 hours) or high (e.g. 100 mm/24 hours for the next 48 hours) sustained exposure to hazards can be categorized and shown as in Table 1.

Table 1: (Selected) Regions facing high probabilities of above 50mm rainfall per day

		48-hour lead time	
		50 mm / 24 hr	100 mm / 24 hr
24- hour lead time	50 mm / 24 hr	Thua Thien Hue, Quang Nam, Quang Ngai, Kon Tum, Gia Lai, Da Nang city, Binh Dinh	Thua Thien Hue, Quang Nam, Quang Ngai, Kon Tum, Gia Lai, Da Nang city, Binh Dinh
	100 mm / 24 hr	Quang Nam, Quang Ngai, Kon Tum, Binh Dinh	Quang Nam, Quang Ngai, Kon Tum, Binh Dinh

How to:

- ✓ To identify the names of regions facing high risk, use the *Dissolve* tool on the categorized probabilistic rainfall data, with the Dissolve Field input specified as the “*Category*” column.
- ✓ Then, the *Intersect* tool is used to identify the administrative regions that intersect with each probabilistic rainfall category (Figure 10).
- ✓ The output may be transferred to a spreadsheet (or similar software) in which the provinces facing 50mm and 100mm probability rainfall over the 24-hour and 48-hour lead times are identified (see Table 1 example output).

Figure 10: View of attribute table of the Viet Nam province data layer, with each province assigned a forecasted maximum rainfall category

	ADM1_EN	Category
3	Quang Nam	High
4	Quang Ngai	High
5	Kon Tum	High
6	Gia Lai	High
7	Da Nang city	High
8	Binh Dinh	High
9	Thua Thien Hue	Low
10	Soc Trang	Low
11	Tay Ninh	Low

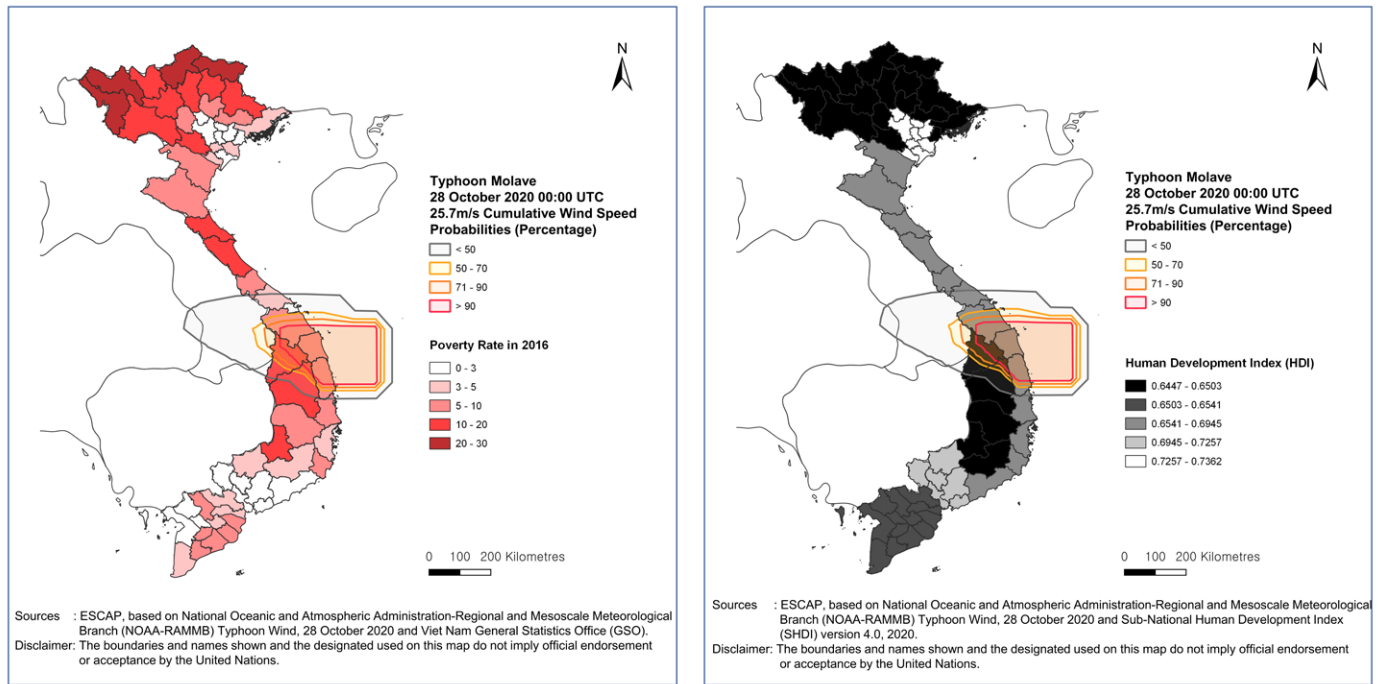
Assessing the vulnerability of the population exposed to typhoons

Beyond identifying the exposure of the population to hazards, it would be helpful to understand the vulnerability characteristics of the population exposed, such as the elderly (as demonstrated above), or other socio-economic vulnerability (such as poverty rates or SHDI). Indicators that reflect socio-economic vulnerabilities may be used to identify the distribution of vulnerable populations in a country. In this example, data on poverty rates and SHDI is utilized (Figure 11). This data was gathered on a sub-national (provincial) level from the Viet Nam General Statistics Office and the United Nations Development Programme (UNDP) respectively and mapped into a vector format.

How to:

- ✓ The same steps as performed in the fisheries/aquaculture production and livestock density calculations may be used to generate a list of provinces that face both severe hazard exposure and contain large vulnerable population groups.

Figure 11: Poverty rate (left) and HDI (right), overlaid with Typhoon Molave



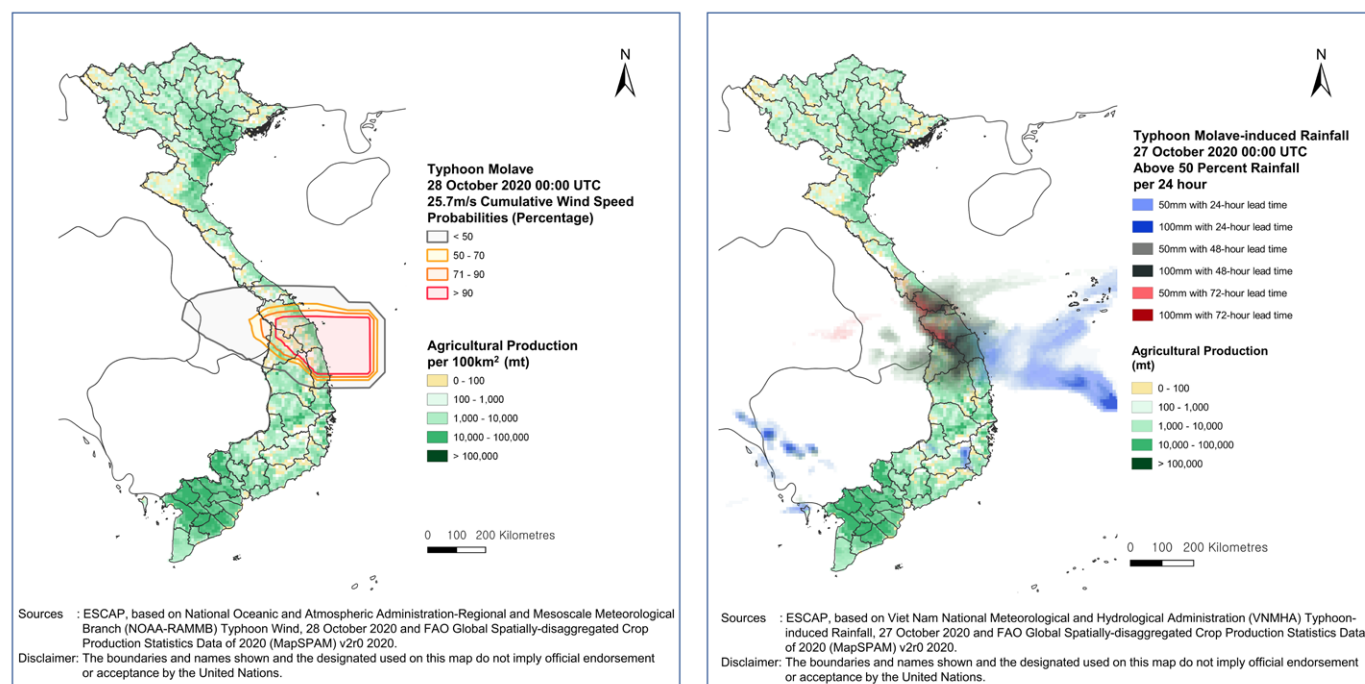
Data Source: Viet Nam General Statistics Office and UNDP

Due to the lack of higher resolution data on these indicators, provincial/sub-national level data is used in this manual for demonstration purposes. If more disaggregated data is available, such as from government records or census for sub-districts or communities, then higher resolution vulnerability maps can be produced for use in conjunction with hazard maps. This can help further identify areas with a high concentration of vulnerable groups which can be targeted for disaster mitigation and response measures.

Assessing agricultural exposure to typhoons

Impact-based forecasting can also provide information on potential impacts on agricultural and maritime production. Data on the spatial distribution of agricultural production and value (or alternative indicators) is required. This example uses data by the Spatial Production Allocation Model (SPAM) of the Food and Agriculture Organization (FAO), which produces gridded data on estimated agricultural production and value, based on the type of agricultural products. These maps may be overlaid with the hazards data to visually display the exposed regions (Figure 12). If available, data records held by agricultural ministries or agencies can be used in lieu of global datasets, as locally or nationally collected data is expected to be more accurate.

Figure 12: Agricultural production data overlaid with hazard data



Data Source: Spatial Production Allocation Model by the FAO

Figure 13: Areas exposed in terms of agricultural production to extreme rainfall

Lead time	mm/day (50% probability or more)	% of areas exposed in terms of agricultural production
24-hour lead time	50	4.74%
	100	1.41%
48-hour lead time	50	8.11%
	100	4.44%
72-hour lead time	50	1.79%
	100	0.08%

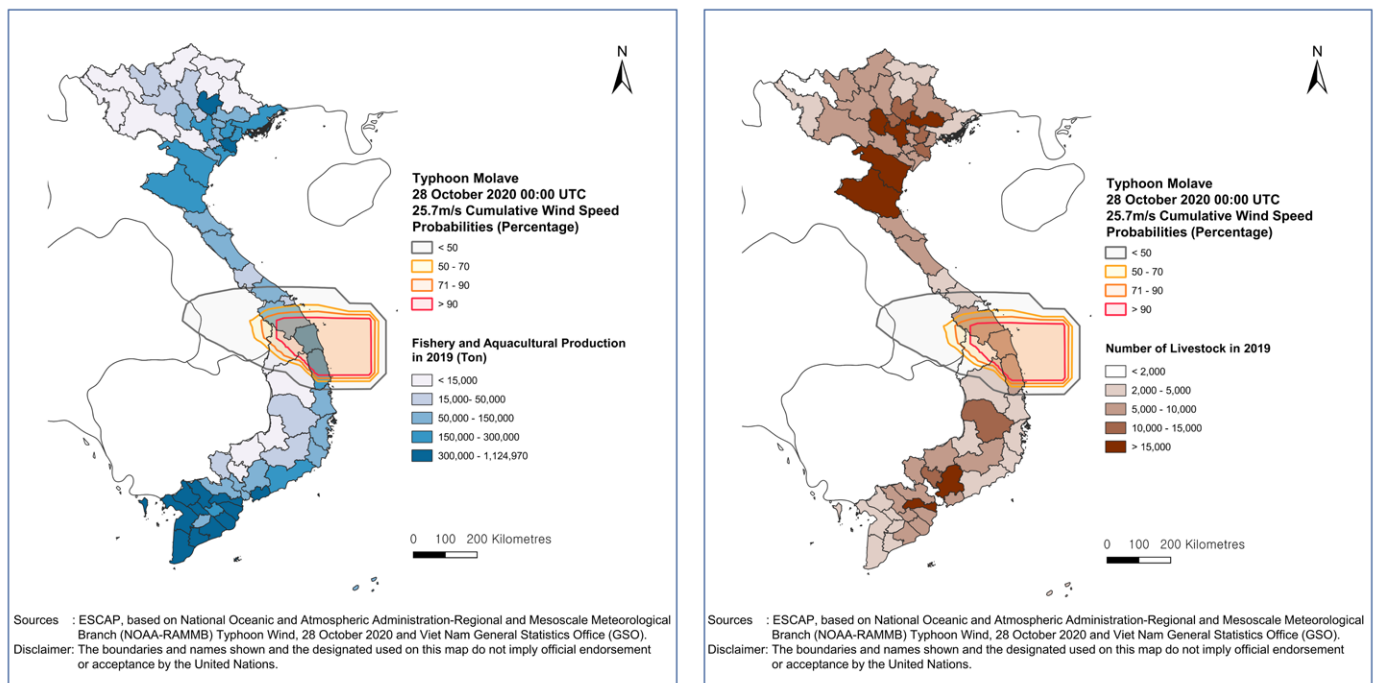
Figure 13 shows the estimated percentage of agricultural areas exposed to extreme rainfall, in terms of agricultural production quantity. It was found that areas attributed with 6.2 percent, 12.6 percent, and 1.8 percent of agricultural production are exposed to 50mm or more rainfall (50% or higher probability) with 24-, 48- and 72-hour lead times respectively. It shall be noted that the agricultural production data used in this example consists of yearly estimates, and therefore does not reflect the specific local agricultural conditions at the time of typhoon landfall. However, given the lack of higher resolution data, this analysis can shed light on potential impacts on the agricultural sector.

How to:

- ✓ As the SPAM data is in the same format as the Worldpop data explained above, the same steps for analysis can be performed to calculate the amount of agricultural value exposed to each category of wind speed and probabilistic rainfall forecast.
- ✓ This entails using the Zonal Statistics tool to sum the value of agricultural production in each hazard vector (e.g., administrative region).
- ✓ The same steps may be performed with the agricultural production data to identify exposed agricultural production values.

Other examples of datasets that may be used to characterize exposure are production data on fishery and aquaculture production or spatial distribution of livestock density (Figure 14). Fishery and aquaculture production and the number of livestock in the areas expected to be hit by Typhoon Molave were at medium levels. Provinces on the coast had from 15,000 to 150,000 tons of fishery and aquaculture production, and raised between 5,000 and 10,000 livestock in 2019. As some provinces may span across multiple wind speed probabilities, those provinces may be displayed multiple times. For example, the Kon Tum, Binh Dinh, Gia Lai, and Quang Nam provinces extend across all wind speed probability categories. Of these, the Binh Dinh and Quang Nam provinces contain the highest concentration of livestock. Da Nang City is revealed to be fully situated in the least severe wind speed category, as well as with the lowest concentration of livestock, thereby indicating both low hazard and livestock exposure.

Figure 14: Fishery and aquaculture (left) production and livestock (right)



Data Source: Viet Nam General Statistics Office

How to:

- ✓ To obtain the list of provinces under each hazard category, the *Intersection* tool under *Vector* → *Geoprocessing Tools* in QGIS is used.
- ✓ In this example, the livestock data layer was used as the Input Layer and the wind speed category layer as the Overlay Layer.
- ✓ The results of this process are shown in Figure 15, with each province displayed alongside each wind speed probability to be endured.

Figure 15: View of truncated table output from the Intersection tool QGIS

ADM1_EN	ADM1_VI	ADM0_VI	Livestock values	Wind Speed Category
Da Nang City	Da Nang City	Viet Nam	414	1
Kon Tum	Kon Tum	Viet Nam	1783	1
Kon Tum	Kon Tum	Viet Nam	1783	2
Quang Nam	Quang Nam	Viet Nam	7593	2
Binh Dinh	Binh Dinh	Viet Nam	9111	3
Kon Tum	Kon Tum	Viet Nam	1783	3
Kon Tum	Kon Tum	Viet Nam	1783	4
Quang Nam	Quang Nam	Viet Nam	7593	4

How to:

- ✓ Similar steps may be followed with the fishery and aquaculture production (or other data in vector format) to obtain the location names and level of wind speed exposure faced.
- ✓ The same procedure shall also be followed to obtain the location names and the expected category of forecasted extreme rainfall.

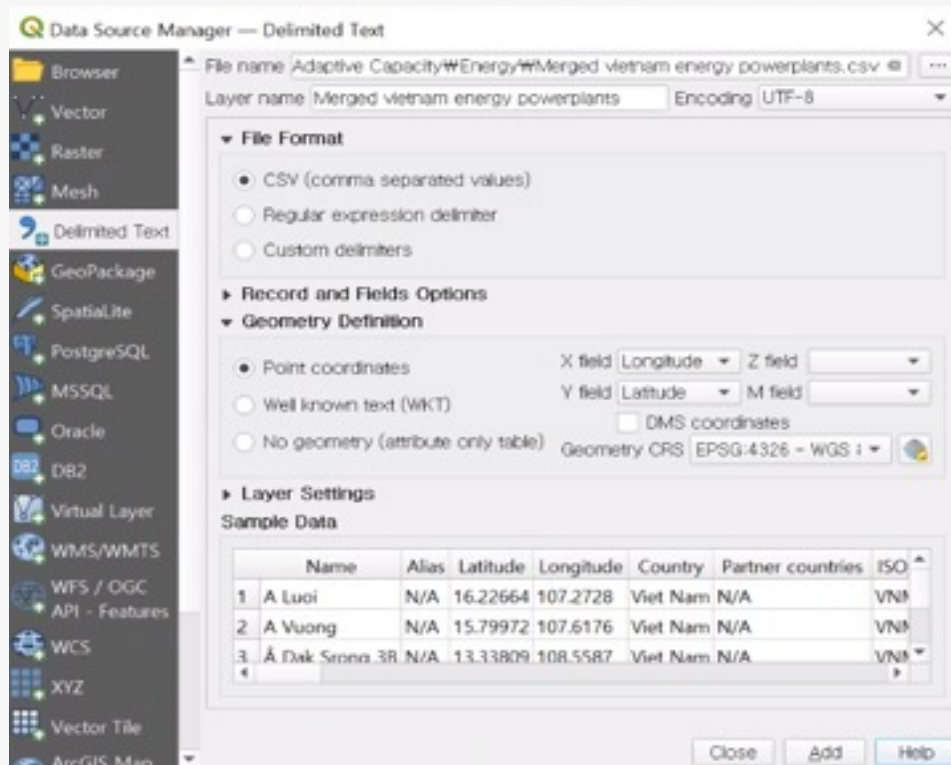
Assessing energy powerplants exposure to typhoons

Potential impacts of climate hazards on critical infrastructures that provide essential services necessary for the effective functioning of government and society can be also assessed. One example is energy infrastructure such as powerplants, using a dataset available from the Asia Pacific Energy Portal (<https://asiapacificenergy.org/>) of ESCAP. This dataset is available in spreadsheet format and contains information on location coordinates, generation type (e.g., hydropower, thermal), and generation capacities of powerplants.

How to:

- ✓ The first step to utilizing this dataset is to import the spreadsheet into QGIS, using the *Delimited Text* tab in the QGIS Data Source Manager (Figure 16).
- ✓ After inputting the spreadsheet file name, the file format (i.e., a comma-separated values file) and geometry definition shall be specified.
- ✓ In this case, the X field is indicated by the Longitude column while the Y field is the *Latitude* column).
- ✓ The coordinate reference system (CRS) for this particular dataset is EPSG:4326 which may be specified as the Geometry CRS.
- ✓ This loads the spreadsheet data into QGIS in vector format, containing point geometry and characteristics for each power plant in the country.

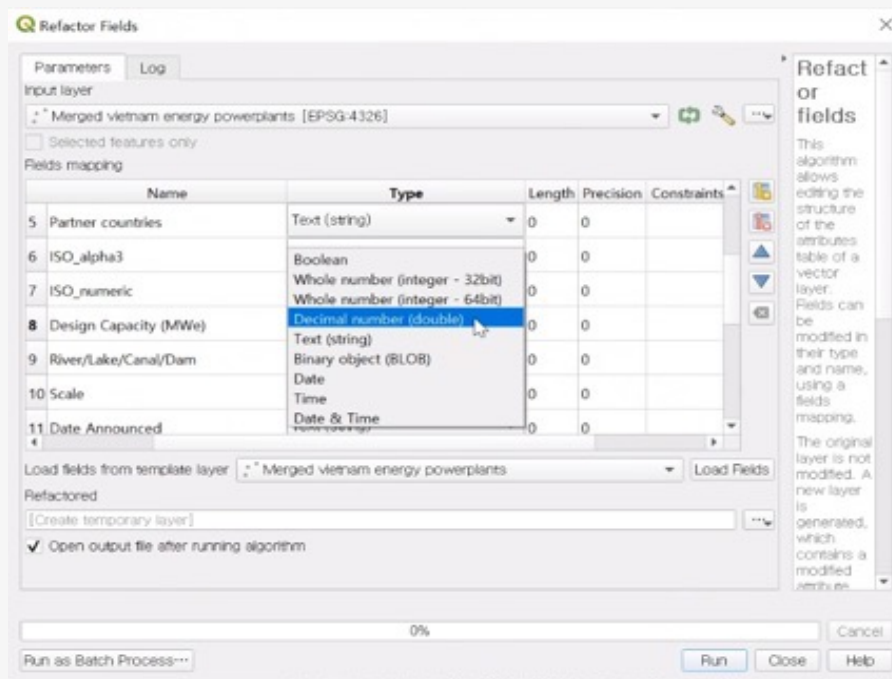
Figure 16: View of command prompt for importing a spreadsheet into QGIS



How to:

- ✓ For the dataset used in this example, a check shall first be performed to ensure that the data fields are represented by the appropriate data types.
- ✓ This can be done by opening the *Properties* window of the layer and selecting the Fields tab.
- ✓ The rows of the resulting table indicate the columns of the data layer's attribute table as well as the corresponding data types.
- ✓ In this example, the power generation capacity column (entitled "DesignCapacity") was loaded as a string type (i.e., text) instead of an integer or float (i.e., numerical) type.
- ✓ Using the *Refactor fields* tool in QGIS enables changing the data type for this column into a float type, which will enable the summing of exposed power generation capacities shown later in this example (Figure 17).

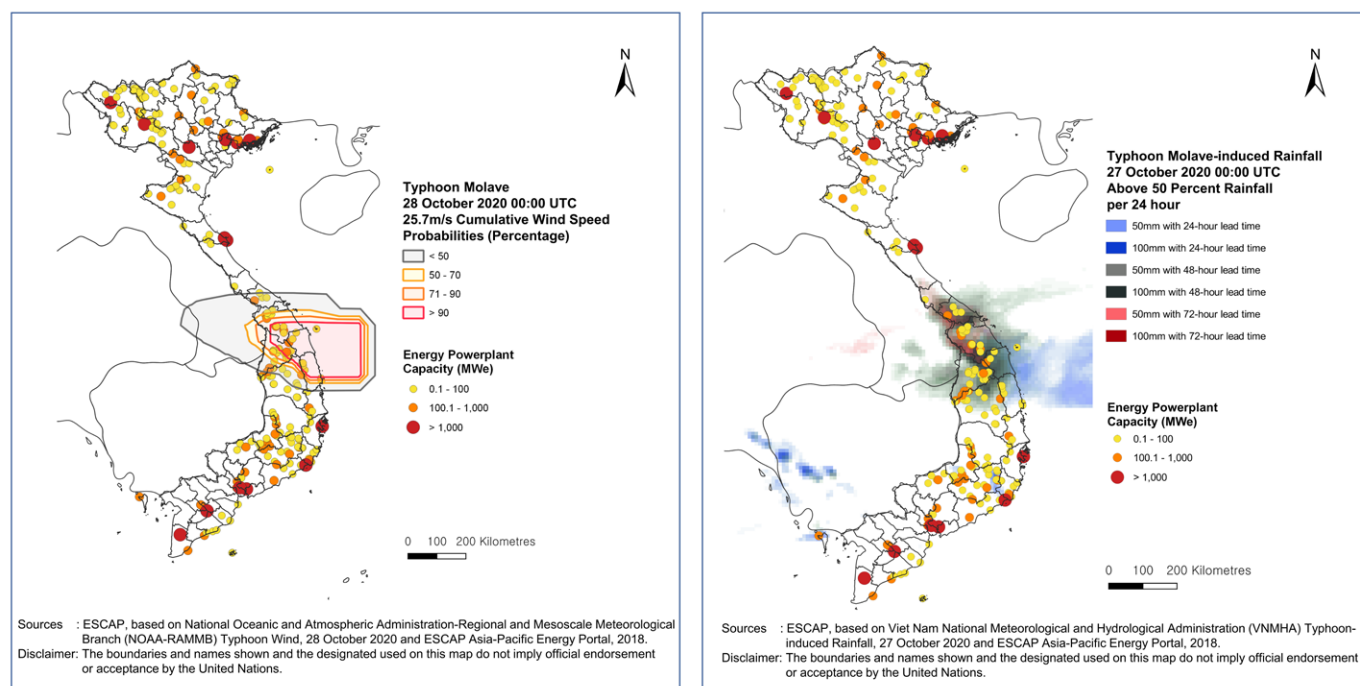
Figure 17: The Refactor fields tool in QGIS allows modification of data types



- ✓ With the power plants data layer ready (Figure 18), the *Join attributes by location* tool may be used to identify the category of hazard exposure faced (if any) by each power plant.
- ✓ The power plants data layer is input as the Base Layer, while the hazards category data is input as the Join Layer. Lastly, the *intersects* option under Geometric Predicate is checked.
- ✓ If a power plant is located in a hazard region, this process tags each power plant with the specific hazard exposure category.
- ✓ This output can be loaded into a spreadsheet or other such software that allows the summing of the exposed capacities under each hazard category (Figure 19).

When the powerplants data layer is overlaid with the hazard layer (wind and rainfall), it can give information on how many powerplants are expected to be impacted by the typhoon in addition to the capacities of these powerplants (Figure 18 and 19). In the case below, several small and medium-sized power plants are in the areas expected to face strong winds, with more powerplants are to receive a substantial amount of rainfall due to the typhoon.

Figure 18: Power generation plants exposed to Typhoon Molave



Data Source: Asia-Pacific Energy Portal of ESCAP (for powerplant data)

Figure 19: Exposed capacity of energy powerplants to strong winds

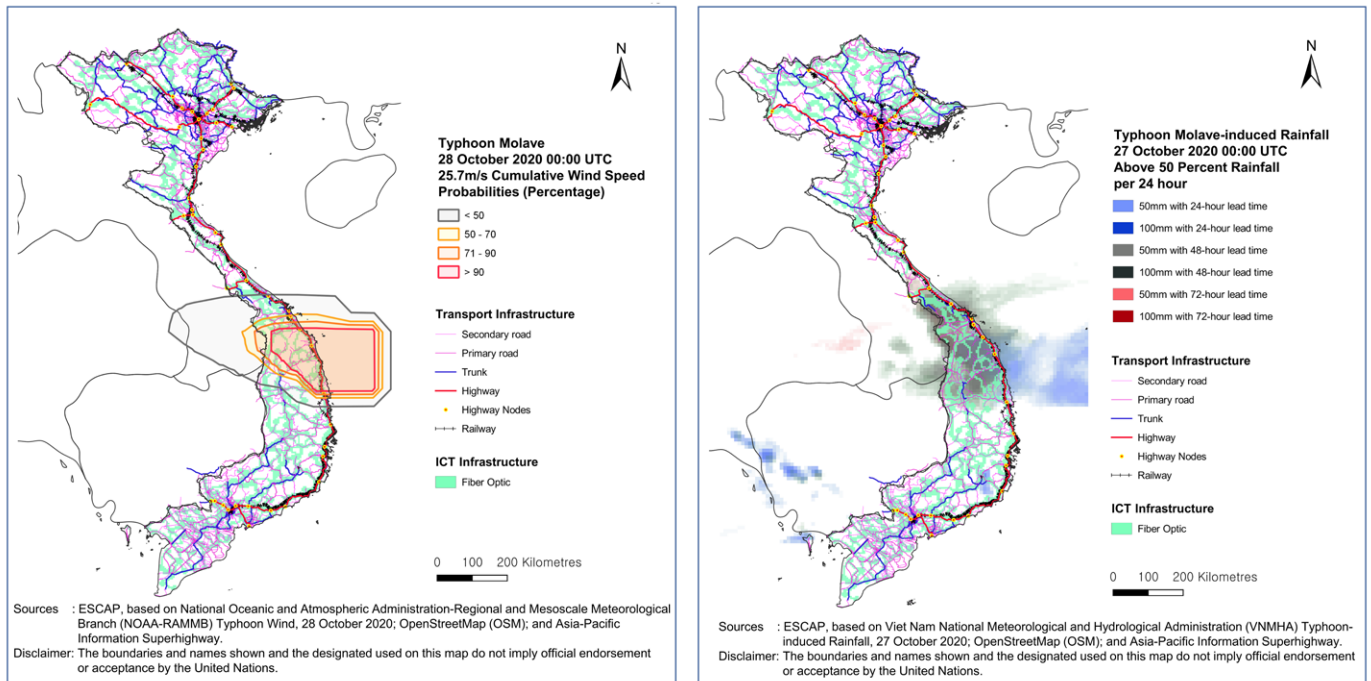
Probability (%) of strong wind (25.7m/s)	No. of hydro powerplants exposed	% of total	Capacity of powerplants exposed	% of total
> 90	19	6.96%	999	1.69%
71 - 90	8	2.93%	115	0.19%
50 - 70	7	2.56%	735	1.24%
< 50	14	5.13%	1,617	2.73%

Figure 19 shows that there are a total of 34 power generation plants that are exposed to more than 50% probability of 25.7 m/s wind speeds. These 34 plants make up approximately 3% of the total energy generation capacity of the country. Additionally, there are 14 power generation plants exposed to less than 50% probability of 25.7 m/s winds.

Assessing critical infrastructure exposure to typhoons

Like the exposure of energy infrastructure, exposure of other critical infrastructure can also be assessed. For example, Figure 20 shows the hazard maps overlaid with transportation and ICT infrastructure. Given available data on the types and lengths of road segments, the total length of each type of road segment exposed to each hazard category can also be calculated. In this example, transportation infrastructure data obtained from OpenStreetMaps and ICT infrastructure data from Asia-Pacific Information Superhighway are used.

Figure 20: Transportation infrastructure exposed to Typhoon Molave

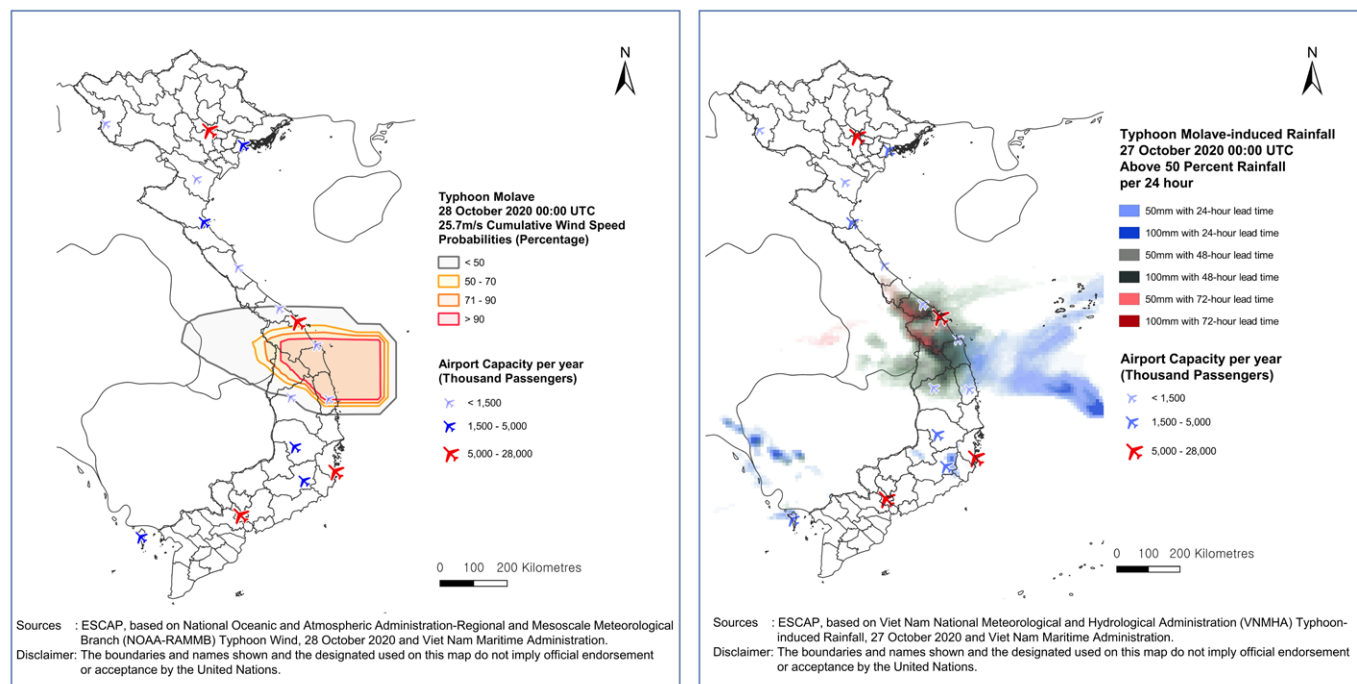


Data Source: OpenStreetMaps and Asia-Pacific Information Superhighway

Additionally, to understand the exposure of airports to the typhoon, a dataset from the Airport Cooperation of Viet Nam JSC is used, which conveys the location and capacities (in the number of passengers) for each airport in Viet Nam. These maps are then overlaid with the hazard maps as shown in Figure 21. These layers can be further processed to identify the specific airports in the hazard areas, as well as the total airport capacities that are exposed to hazard impacts.

In the case of Typhoon Molave, 1 airport with around 1.5 percent of the total capacity of Viet Nam (in terms of the number of passengers) was likely to experience strong winds (over 90 percent probability), while 2 airports with 11.7 percent of the total capacity of Viet Nam faced a less than 50 percent probability of being exposed to strong winds.

Figure 21: Exposure of Airports to Typhoon Molave



Data Source: Airport Cooperation of Viet Nam JSC

Figure 22: Airport capacity exposed to strong wind from Typhoon Molave

Probability (%) of strong wind (25.7m/s)	No. of Airports exposed	% of total	Capacity of Airport exposed (passengers/year)	% of total
> 90	1	4%	1,200,000	1.48%
71 - 90	0	0%	0	0.00%
50 - 70	1	4%	0	0.00%
< 50	2	8%	9,500,000	11.69%

How to:

- ✓ The airports dataset is a vector data layer with each airport represented by a point location. Thus, the *Join attributes by location* tool in QGIS may be used with the airports dataset and the vector layers representing the hazards to identify which airports fall under which hazard categories.
- ✓ The outputs of this process can be exported to a spreadsheet, where the airports can be grouped to sum the total exposure per hazard category (Figure 22).

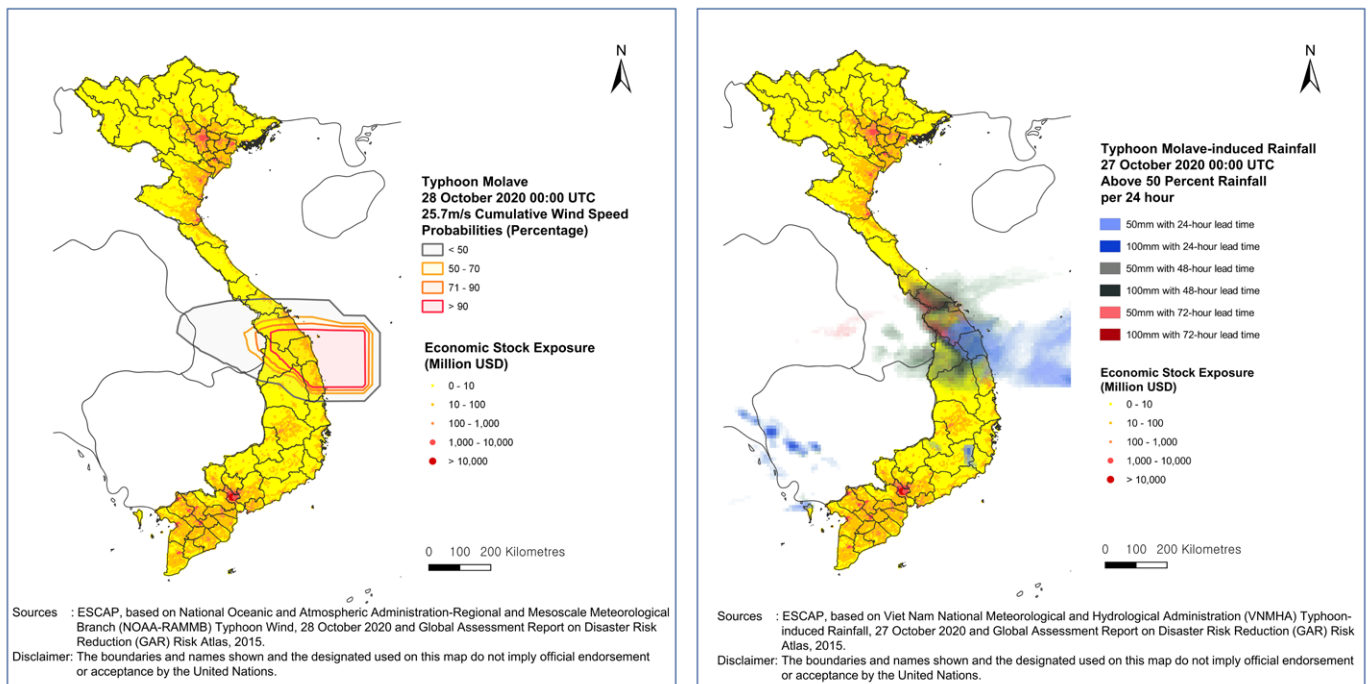
Assessing economic stock exposure to typhoons

Estimated economic damage from Typhoon Molave was reported to be approximately USD\$430 million. Economic exposure information is important for disaster management authorities, other ministries, and local municipalities as it can inform where mitigation and response measures should be targeted.

Valuation data on economic stock across the country is required for this step. In this example, exposed economic stock data from GAR 2017 Atlas Risk Data and Software Download Facility (<https://risk.preventionweb.net/capreviewer/>) is used. This dataset consists of vector data similar to the powerplants data presented above. This dataset can be overlaid with the hazard data to visually display the economic stock exposure.

In the case of Typhoon Molave, areas with medium levels of economic stock were expected to experience strong winds and a large amount of rainfall (Figure 23). As shown in Figure 25, it was calculated that approximately USD\$ 9.5 billion worth of economic stock was exposed to high probabilities (exceeding 50%) of strong winds (25.7 m/s). This makes up 1.95% of the total economic stock in the country.

Figure 23: Economic stock exposure overlaid with Typhoon Molave



Data Source: Global Assessment Report 2015 for economic stock

How to:

- ✓ As the data used in this example is in the format of vector data, a similar method to that used to process the power plants data shall be used.
- ✓ First, the *Join attributes by location* layer shall be used to identify the hazard category encapsulating each point representing the total value of the economic stock (Figure 24).
- ✓ The output shall be grouped by the hazard category (i.e., low or high rainfall probability) and the values summed to obtain the final calculations for the total value of economic stock exposed to each hazard category (Figure 25).

Figure 24: Join Attributes by Location tool (left) on the economic exposure data to obtain the hazard category faced by each point representing economic stock (right)

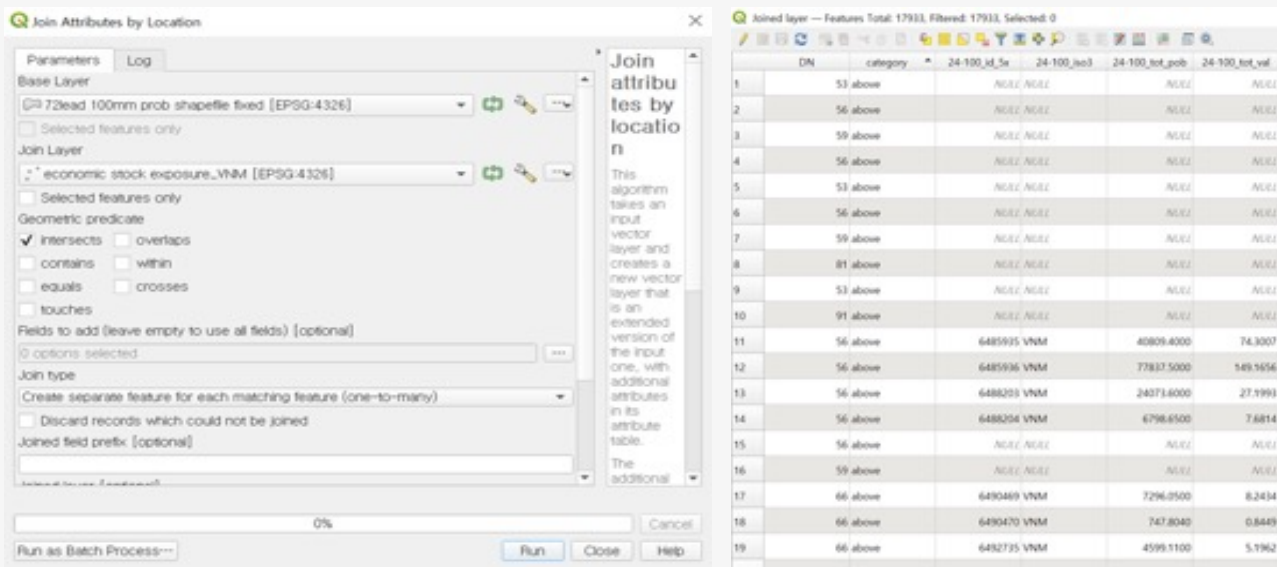


Figure 25: Total economic exposure facing each hazard category

Probability (%) of strong wind (25.7m/s)	Economic Stock Exposed (Million US\$)	% of Total Economic Stock
> 90	2,608	0.54%
71 - 90	5,041	1.04%
50 - 70	1,805	0.37%
< 50	4,303	0.89%

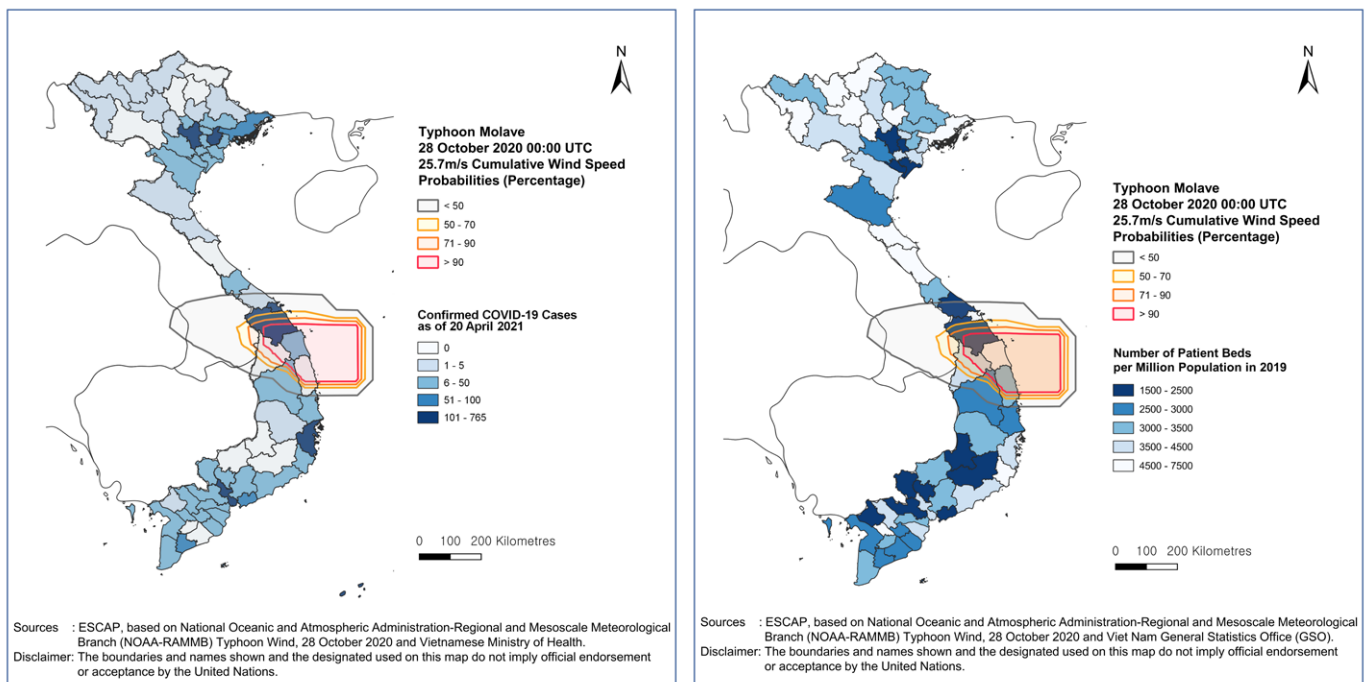
In addition to economic stock data, buildings data may also be used to evaluate total building stock exposed to the typhoon hazard.

Assessing possible convergence with COVID-19 and potential impacts on the health system

Simultaneous occurrence of multiple disaster events can amplify the adverse impacts of the disasters on lives and damages on a community. One such example is the occurrence of Typhoon Molave during the ongoing COVID-19 pandemic. In this case, vulnerabilities in an already strained health system can be exacerbated by the typhoon event. Health ministries may need to identify potential impact on the health system to prepare measures in advance.

In the example below, data on confirmed COVID-19 cases was overlaid with the hazards layers to identify convergence of the natural disaster with the pandemic (Figure 26). To review the capacity of the health system responding to these challenges, the number of patient beds per capita was also overlaid with the typhoon forecast. The same steps as performed in the fisheries/aquaculture production and livestock density calculations can be applied here to identify the provinces facing severe hazard exposure and healthcare system vulnerability.

Figure 26: Confirmed COVID-19 cases and number of patient beds with Typhoon forecasts



Data Source: Vietnamese Ministry of Health for COVID-19 data, and Viet Nam General Statistics Office for number of patient beds
 * Note: Data for confirmed COVID-19 cases is not at the time of Typhoon Molave making landfall. Instead, data as of 20 April 2021 is used, simply for demonstration purposes.

Within the areas expected to face strong winds, the areas of Binh Dinh and Quang Ngai (located center of the Category 1 wind speed hazards) have a relatively low number of COVID-19 cases and a relatively high number of patient beds per capita. This indicates that local health system capacity in the province of Binh Dinh would be less burdened, in comparison to the neighboring province of Quang Nam (located on the north edge of the Category 1 wind speed hazard), which appears to have very low numbers of patient beds per capita and a relatively high number of COVID-19 cases. This indicates that more attention may be dedicated to the possible convergence of typhoon impact with the pandemic and lack of health capacity in Quang Nam.

References

Food and Agriculture Organization (FAO) (2010). Global Spatially-disaggregated Crop Production Statistics Data of 2020 (MapSPAM) v2r0 2020. Available at: <https://www.mapspam.info/data/> (Accessed in April 2021).

Global Data Lab (2020). Subnational Human Development Index (HDI) Version 4.0-2020. Available at: https://globaldatalab.org/shdi/download_files/ (Accessed in April 2021).

Lloyd, C., Sorichetta, A. & Tatem, A. (2017). High resolution global gridded data for use in population studies. *Sci Data* 4, 170001 . <https://doi.org/10.1038/sdata.2017.1>

National Oceanic and Atmospheric Administration-Regional and Mesoscale Meteorological Branch (NOAA-RAMMB) (2020). Typhoon Molave Experimental 50-kt Wind Speed Probabilities. Available at: https://rammb-data.cira.colostate.edu/tc_realtime/storm_wind_speed_probabilities.asp?storm_identifier=wp212020 (Accessed in April 2021).

OpenStreetMap (OSM) (2013). Road Networks. Available at: <http://download.geofabrik.de/asia.html> (Accessed in April 2021).

United Nations Development Programme. (2015). Human Development Index (HDI). Human Development Reports. [online] Available at: <http://hdr.undp.org/en/content/human-development-index-hdi>. [Accessed 28 February 2021].

United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) (2018). Asia-Pacific Energy Portal. Available at: <https://asiapacificenergy.org/#main/lang/en/type/0/map/1/time/%5B1990,2019%5D/geo/%5BASPA%5D/latlong/%5B20.2858,100.78682%5D/zoom/3/infra> (Accessed in April 2021).

_____ (2018). Asia-Pacific Information Superhighway. Available at: <https://www.unescap.org/our-work/ict-and-disaster-risk-reduction/asia-pacific-information-superhighway-ap>. Accessed in March 2021.

United Nations Office for Disaster Risk Reduction (UNDRR) (2015). Global Assessment Report on Disaster Risk Reduction (GAR) Risk Atlas Flood Hazards 25 and 100 years Return Period. Available at: <https://risk.preventionweb.net/capraviewer/> (Accessed in April 2021).

_____ (2015). Global Assessment Report on Disaster Risk Reduction (GAR) Risk Atlas Economic Stock Exposure to Disasters. Available at: <https://risk.preventionweb.net/capraviewer/> (Accessed in April 2021).

Viet Nam General Statistics Office (GSO) (2017). Poverty Rate by Province in 2016. Available at: <https://www.gso.gov.vn/en/homepage/> (Accessed in April 2021).

_____ (2020). Fishery and Aquacultural Production by Province in 2019. Available at: <https://www.gso.gov.vn/en/homepage/> (Accessed in April 2021).

_____ (2020). Number of Livestock by Province in 2019. Available at: <https://www.gso.gov.vn/en/homepage/> (Accessed in April 2021).

_____ (2020). Number of Patient Beds by Province in 2019. Available at: <https://www.gso.gov.vn/en/homepage/> (Accessed in April 2021).

Airports Cooperation of Viet Nam JSC (2021). Airport Capacity. Available at: <https://vietnamairport.vn/cang-hang-khong> (Accessed in April 2021).

Viet Nam Meteorological and Hydrological Administration (VNMHA) (2020). Typhoon Molave-induced Rainfall forecast data.

Vietnamese Ministry of Health (2021). Cumulative Confirmed COVID-19 Cases.

WorldPop (2018). National Boundaries. Available at: <https://www.worldpop.org/geodata/summary?id=24462> (Accessed in April 2021).

_____ (2020). 2020 Estimates Population data. Available at: <https://www.worldpop.org/geodata/summary?id=50068> (Accessed in April 2021).

MODULE 3

IMPACT OUTLOOKS USING SEASONAL FORECASTS

Floods and droughts have frequently incurred significant human and economic losses in Viet Nam. The devastating impacts of these can be mitigated to a significant extent by strengthening early warning systems and building the resilience of communities and individuals. Impact-based forecasting has good potential to contribute to this initiative by facilitating better use of hydro-meteorological information for decision-making processes. Against this background, this module focuses on the strategic use of seasonal weather and climate forecasts to inform early action that can address the impacts of potential hazards. Through the steps outlined in this module, users can identify potential areas for attention by using seasonal forecasts, hazard maps, as well as exposure (e.g., population, infrastructure, and agricultural assets) and vulnerability (e.g., Human Development Index) data.

Objective: To produce impact outlook for upcoming seasons.

Module 3 guides users on how to produce impact outlooks using seasonal forecasts with examples from Viet Nam

Contents

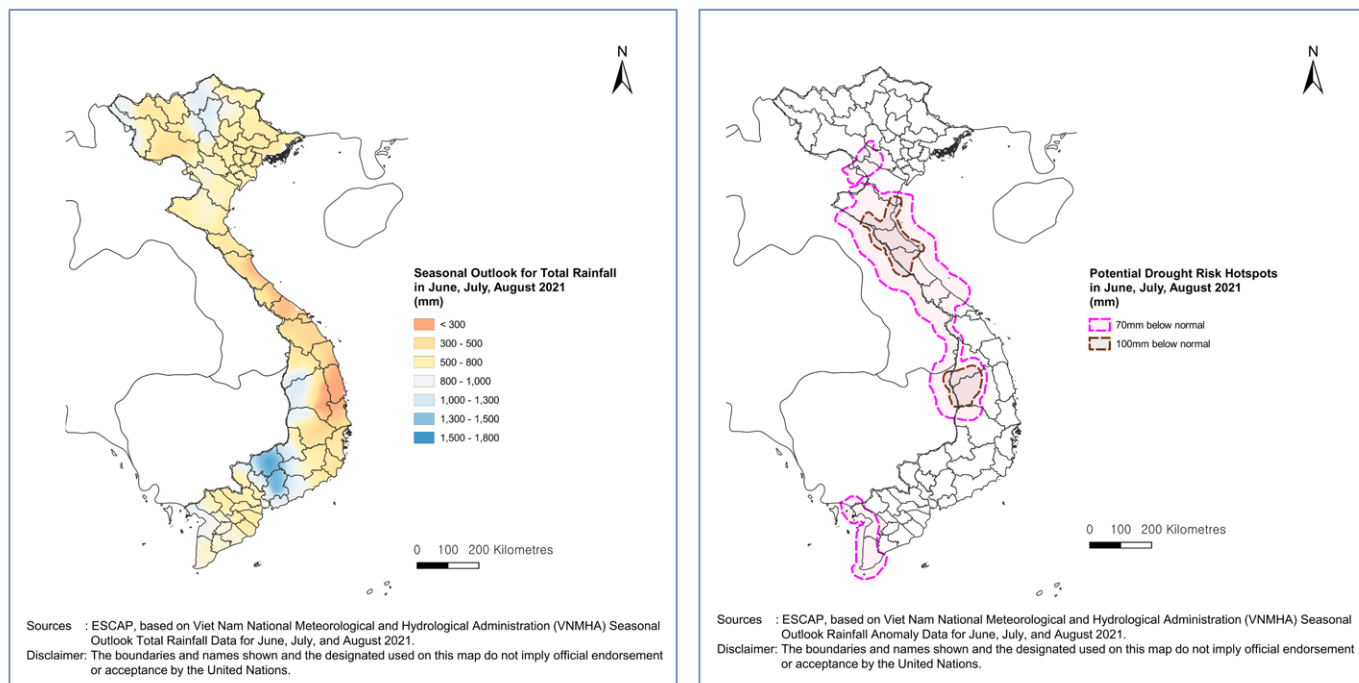
- Preparing the seasonal forecast data layer
- Assessing population exposure to potential drought risk
- Assessing agricultural exposure to potential drought risk
- Assessing hydropower plants exposure to potential drought risk
- Assessing possible convergence with the COVID-19 and waterborne diseases

Preparing seasonal forecast data layer

The basic hazard layer consists of seasonal forecasts from the Viet Nam National Center for Hydro-Meteorological Forecasting (NCHMF) of the Viet Nam Meteorological and Hydrological Administration (VNMHA). This data depicts the spatial extent and characteristics of the forecasted seasonal weather patterns. In this example, the seasonal forecast for total rainfall provided by the VNMHA for June, July, and August 2021 is utilized (Figure 1, left).¹ In addition to seasonal rainfall forecasts, it uses seasonal forecasts for rainfall anomalies² from the VNMHA (Figure 1, right). These figures represent the probabilistic forecasts for expected rainfall in the upcoming months.

1. A seasonal forecast is given as the probability of exceeding a certain threshold. In this manual's example of total rainfall forecast, the forecast is the probability exceeding 50% of rainfall falling within a specific threshold.
2. The values represent the amount of rainfall below historically expected rainfall that has a probability exceeding 50%.

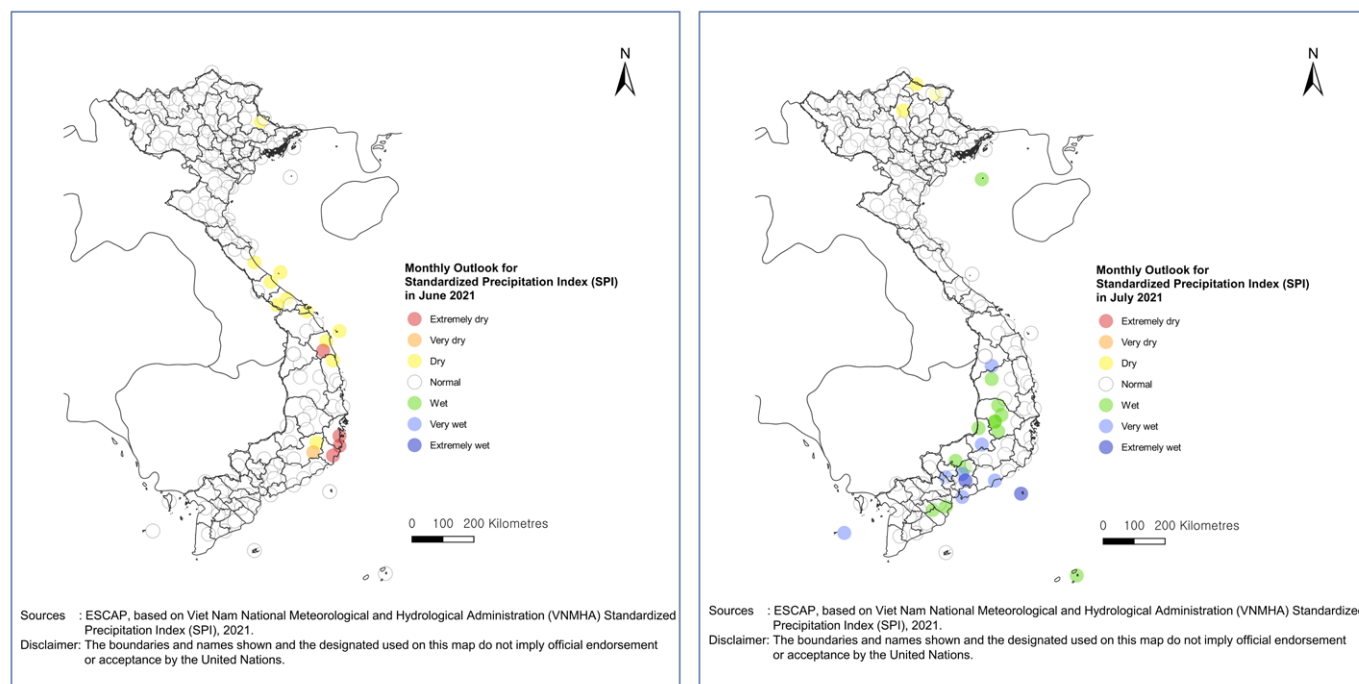
Figure 1: Seasonal forecast for total rainfall and anomaly in JJA 2021



Data Source: VNMHA

Building further upon rainfall anomaly data is the Standardized Precipitation Index (SPI),³ which is a widely used index to characterize meteorological drought on a range of timescales. As an example, the SPI for June and July of 2021 in Viet Nam is shown in Figure 2.

Figure 2: SPI data mapped over Viet Nam for June and July 2021

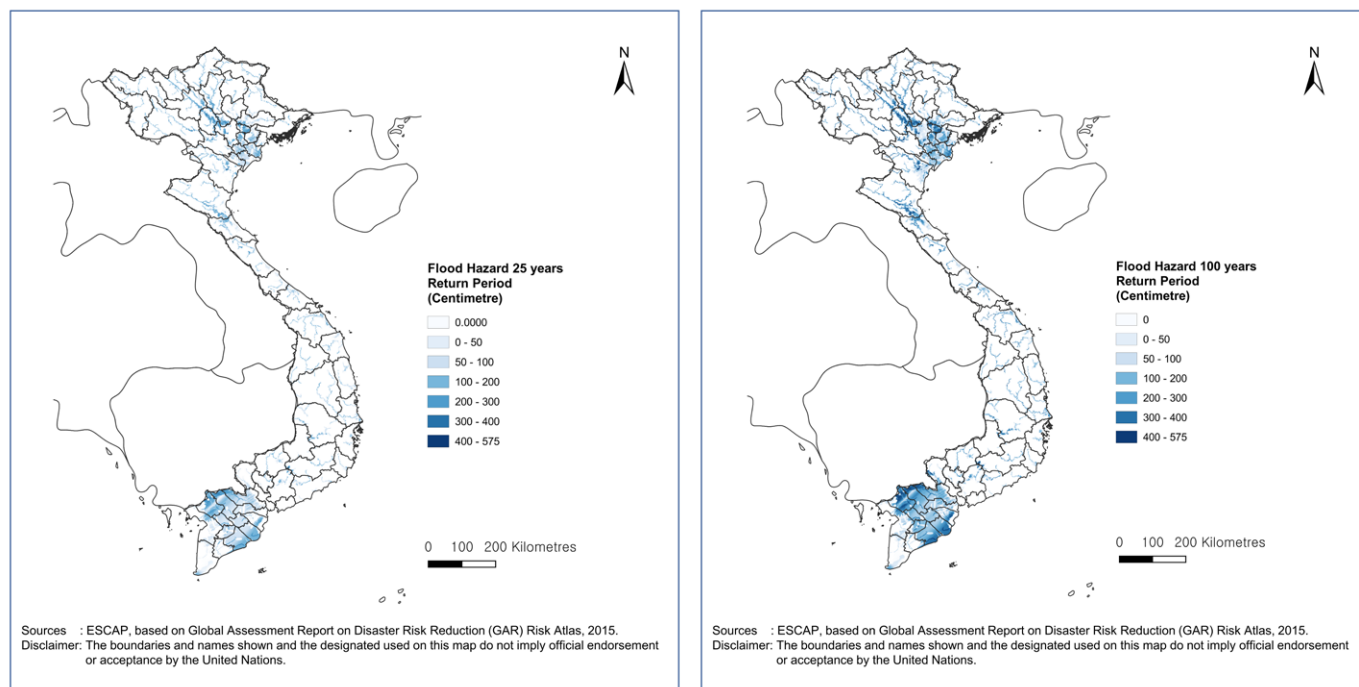


Data Source: VNMHA

3. The SPI is a measure that compares the observed total precipitation amount for an accumulation period of interest (e.g. 3 months) against the long-term historic rainfall record for the same period.

However, it is insufficient to assess potential flood and drought risk only with total rainfall and rainfall anomalies, as below or above-normal rainfall over some months is not in itself a concern. It must also be considered how the adverse impacts of below-normal rainfall may be amplified in areas with high drought risk. Similarly, the impact of above-normal rainfall may also depend upon contextual factors and local 'riskscapes' that can cause the concatenation of multiple events that result in high disaster impacts. For example, high-risk conditions are created when above-normal rainfall is expected in areas facing high flood risk (Figure 3).

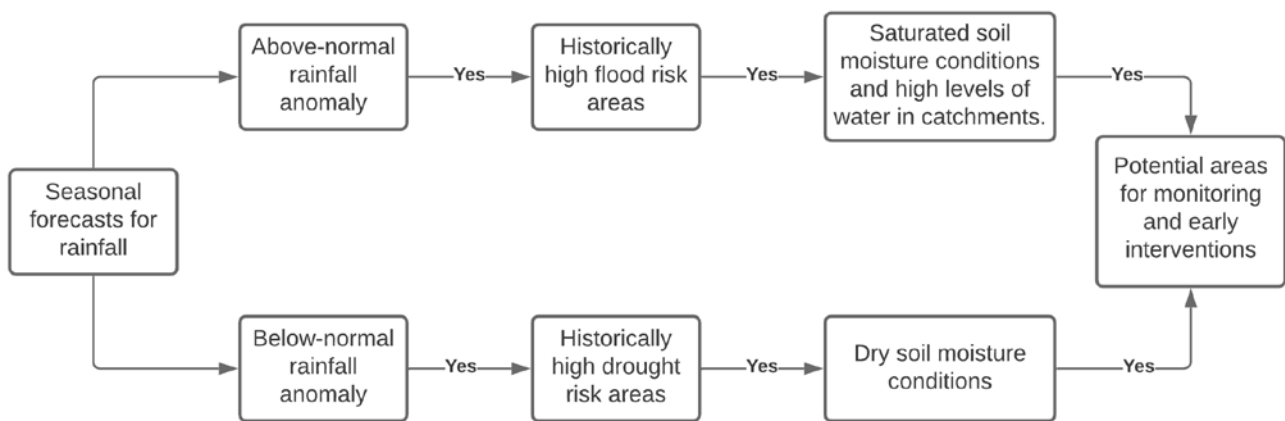
Figure 3: Flood hazard maps



Data Source: The GAR Atlas Risk Data Platform, Available at <https://risk.preventionweb.net/capviewer/>

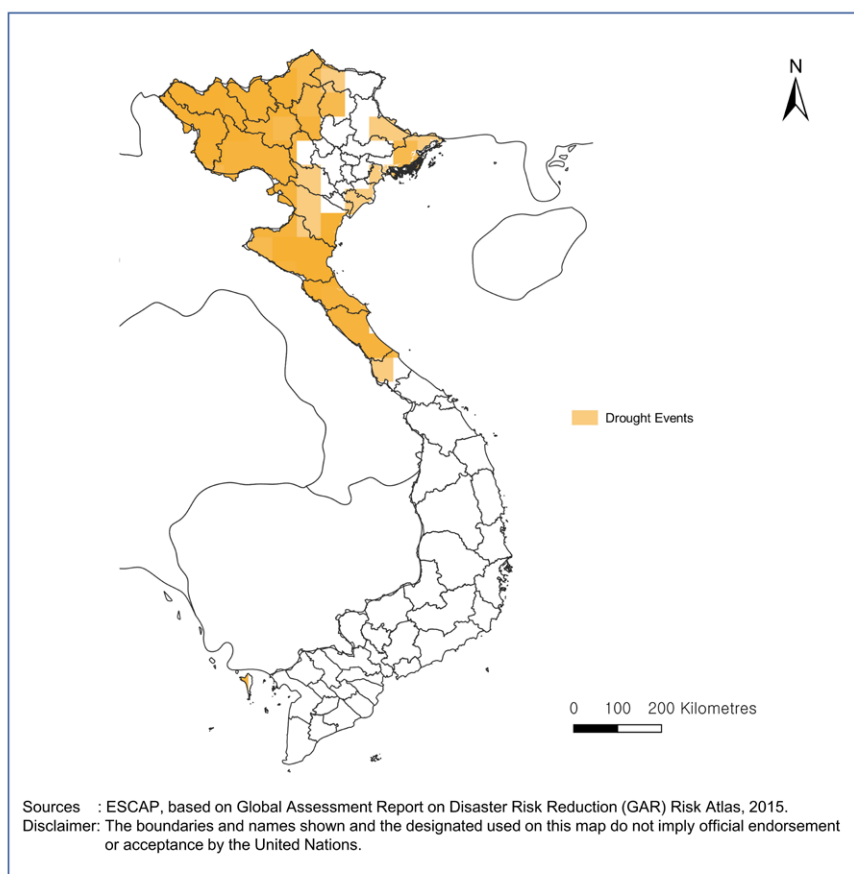
Thus, it is necessary to evaluate seasonal forecast datasets in tandem with local hazard risk data to better assess disaster risks faced. This consideration is summarized in the diagram in Figure 4.

Figure 4: Decision-making process for assessing seasonal impacts



In this manual, historical drought risk data is used (Figure 5). This manual showcases how to assess the potential impacts of below-normal rainfall occurring over areas that have endured historical drought events.

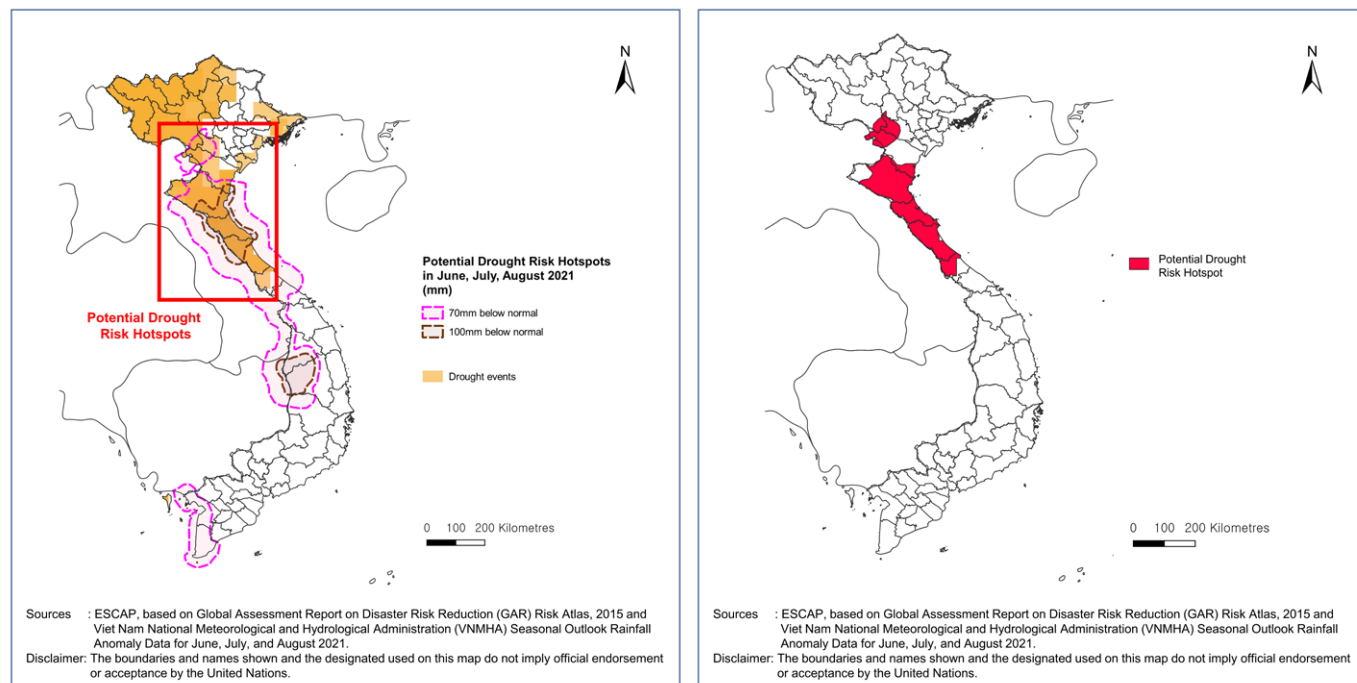
Figure 5: Drought hazard map



Data Source: The GAR Atlas Risk Data Platform, Available at <https://risk.preventionweb.net/capviewer/>

By overlaying the rainfall anomaly map over the historical drought risk map, potential drought risk hotspots may be identified, as shown in the left figure of Figure 6. During the summer of 2021, large areas near Vinh city are expected to receive 70mm to 100mm below normal rainfall. These coincide with areas where drought events have historically higher frequency.

Figure 6: Identification of drought risk hotspots



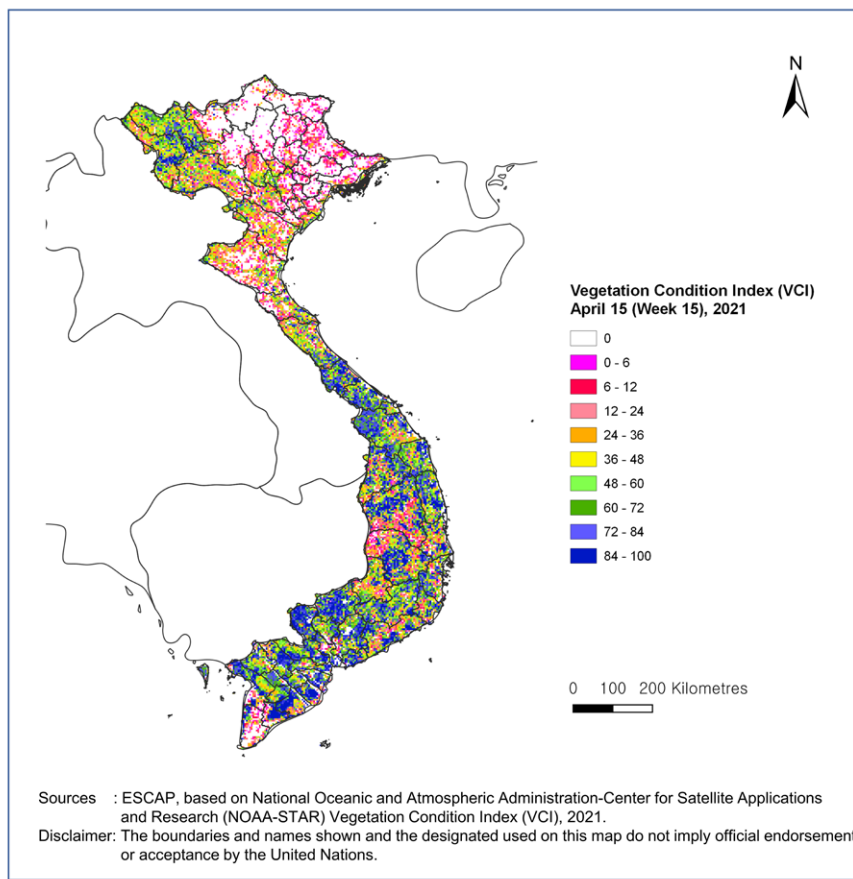
Data Source: VNMHA and The GAR Atlas Risk Data Platform

How to:

- ✓ In this example, as both the historical drought risk map and rainfall anomaly map are available in vector format, the *Vector* → *Clip* function is used, with the historical drought risk map used as the Input layer and the rainfall anomaly map as the Overlay layer.
- ✓ The resultant layer shall consist of a vector encapsulating the overlapping areas representing potential drought risk hotspots that consist of areas that have suffered droughts historically and are expected to experience 70mm below-normal rainfall (Figure 5, right).

In addition, to understand the current ground conditions of the potential drought risk hotspots identified above, the vegetation condition index (VCI), which has been widely used for drought monitoring, is checked in Figure 7. It is shown that most areas within the identified hotspots have relatively low VCI as of mid-April 2021, thus further increasing drought risk.

Figure 7: Vegetation Condition Index (VCI) on 15 April 2021



Data Source: NOAA

With the drought risk hotspot identified, the potential impacts of drought risk can be identified and quantified, as shown in the following sections of this manual.

Assessing population exposure to potential drought risk

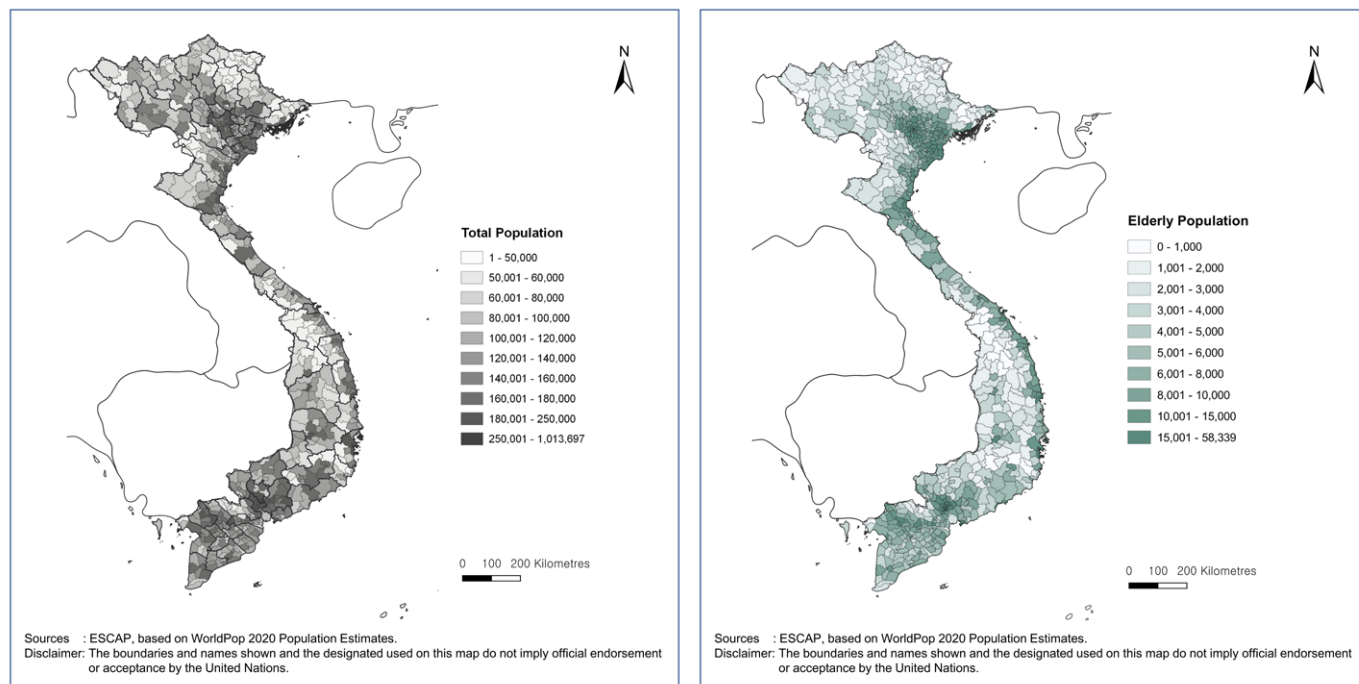
As shown in Module 2, the exposure and vulnerability datasets should convey the spatial distribution of entities of interest. For this example, the estimated population in Worldpop gridded data is used again.⁴

How to:

- ✓ To obtain the spatial distribution of population groups such as women, children (i.e., aged 15 and below), and the elderly (i.e., aged 65 and above), the disaggregated data sets shall first be merged using the *Raster Merge* tool in QGIS on the individual raster files.
- ✓ To process the population data, the *Zonal Statistics* tool was used alongside the Viet Nam municipal boundaries to sum the grid cell values and determine the population size per municipality (Figure 8).

4. Lloyd, Sorichetta & Tatem, 2017

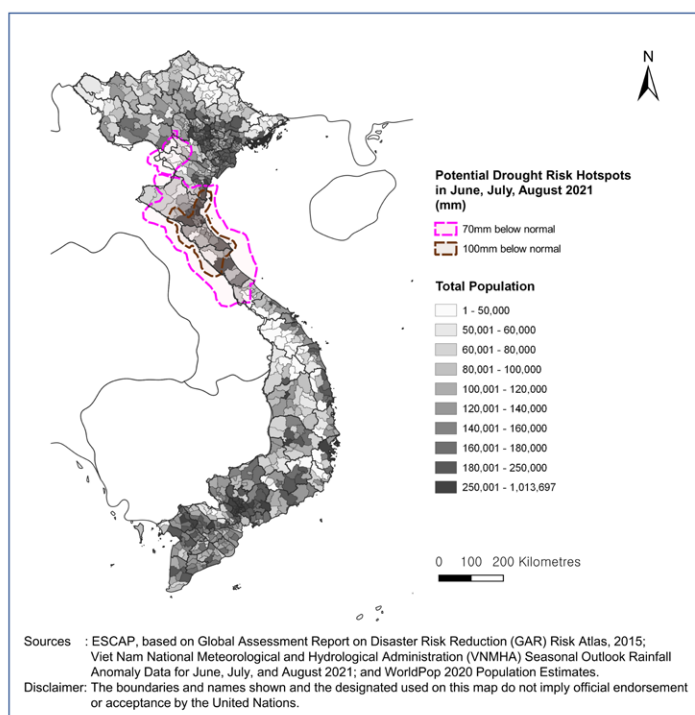
Figure 8: Spatial distribution of the total population and elderly population



Data Source: Worldpop

To identify the population facing potential drought risk, the population layers prepared in the previous step may be overlaid with extents of potential hotspots. Figure 9 shows a visualization of the population density in the potential drought risk hotspots, which may be used to inform the urgency and design of measures to address this risk.

Figure 9: Population distribution map overlaid with potential drought risk hotspots

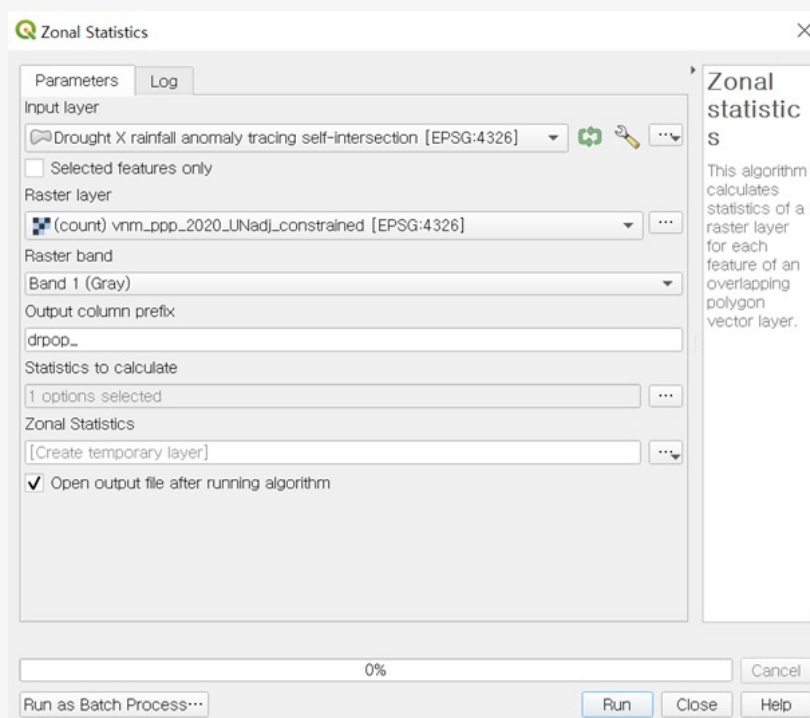


Data Source: Worldpop and VNMHA

How to:

- ✓ To determine the size of the population facing below-normal rainfall as delineated by the seasonal forecast data layer, the *Zonal Statistics* tool may be used with the initial gridded population data, in conjunction with the seasonal forecast data, which consists of vectors (i.e., polygons indicating spatial extents of rainfall anomaly categories).
- ✓ In this example, the two vectors we use encapsulate the areas facing a forecast of 70mm and 100mm below-normal rainfall over June, July, and August 2021. The population within the rainfall anomaly category vector shall be summed to obtain the population size exposed to each category (Figure 10).

Figure 10: The Zonal Statistics tool is used on the gridded population data to calculate the population in the areas under each rainfall anomaly category



With that said, it is also useful to quantify the population size living in these areas. The population size within the hotspot areas is estimated to be approximately 6 million people (or 6.2 percent of the total population) as in Figure 11. This method provides decision-makers with advanced information on drought impacts which can be used to monitor drought developments and plan for appropriate measures.

Figure 11: Number of populations exposed to potential drought risk

Rainfall Anomaly in JJA 2021	Population exposed	Total Population	% of population exposed
70mm below normal	2,449,597	97,411,255	2.51%
100mm below normal	3,605,301		3.70%

How to:

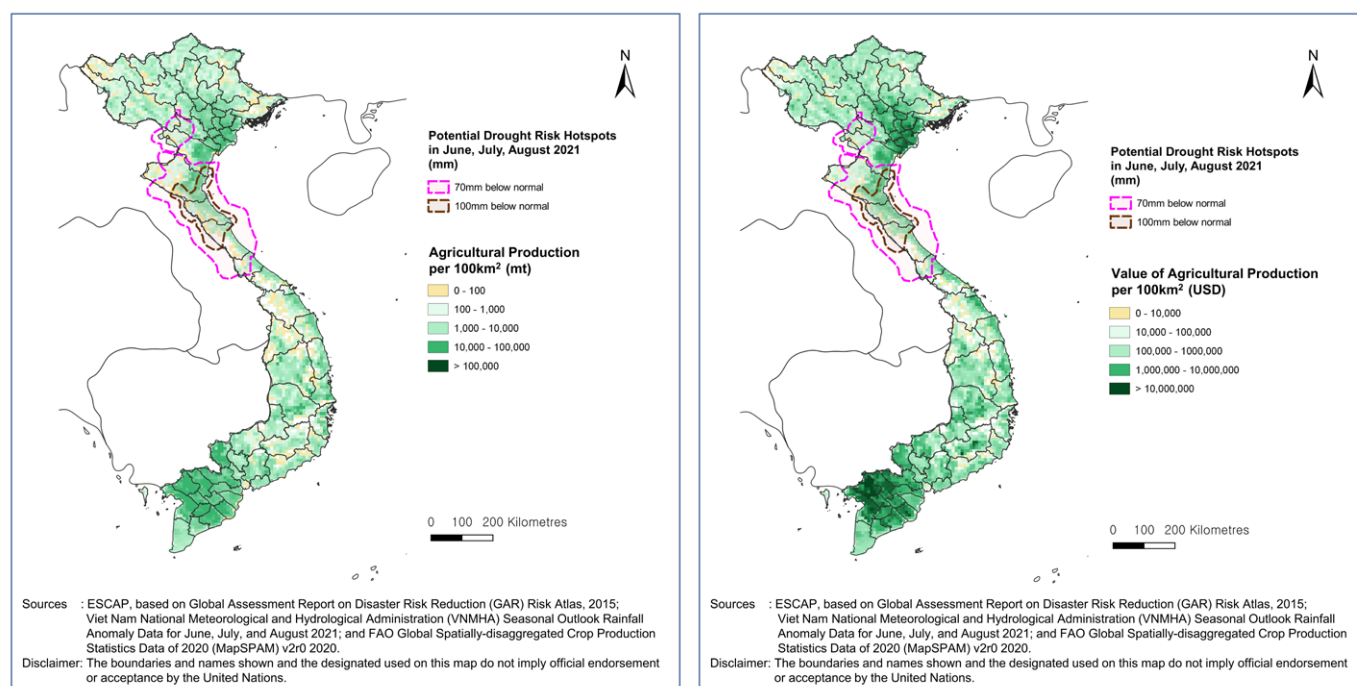
- ✓ To obtain a list of the regions in each rainfall anomaly category, the Intersection tool under *Vector* → *Geoprocessing Tools* in QGIS may be used, with the province population layer was used as the Input Layer and the rainfall anomaly layer as the Overlay Layer.
- ✓ The results of this process will consist of rows representing each province and the expected rainfall anomaly, thereby enabling categorization of the provinces according to each exposure category.

Assessing agricultural exposure to potential drought risk

To identify the value or amount of agricultural production exposed, data on the spatial distribution of agricultural production and value is required. Rainfall anomalies are known to have deleterious impacts on agricultural yields, which are potentially amplified in areas facing high drought risk. Thus, ministries and agencies focused on agricultural production may use this analysis to guide farmers on certain pre-emptive measures to manage potential drought risk (e.g., incentivizing planting of crops that are resistant to dry weather).

Like Module 2, this module utilizes data by the Spatial Production Allocation Model (SPAM), which produces gridded data on estimated agricultural production and value, based on the type of agricultural products. These can be overlaid with the hazards data to visually display the exposed regions (Figure 12). If available, data records held by agricultural ministries or agencies can be used in lieu of global datasets, as locally or nationally collected data are expected to be more accurate.

Figure 12: Agricultural production (quantity and value) exposed to potential drought risk



Data Source: VNMHA and FAO

The figure shows that some areas within the 100 below-normal rainfall category contain major agricultural areas in terms of agricultural production quantity and value.

Figure 13: Areas exposed in terms of agricultural production to potential drought risk

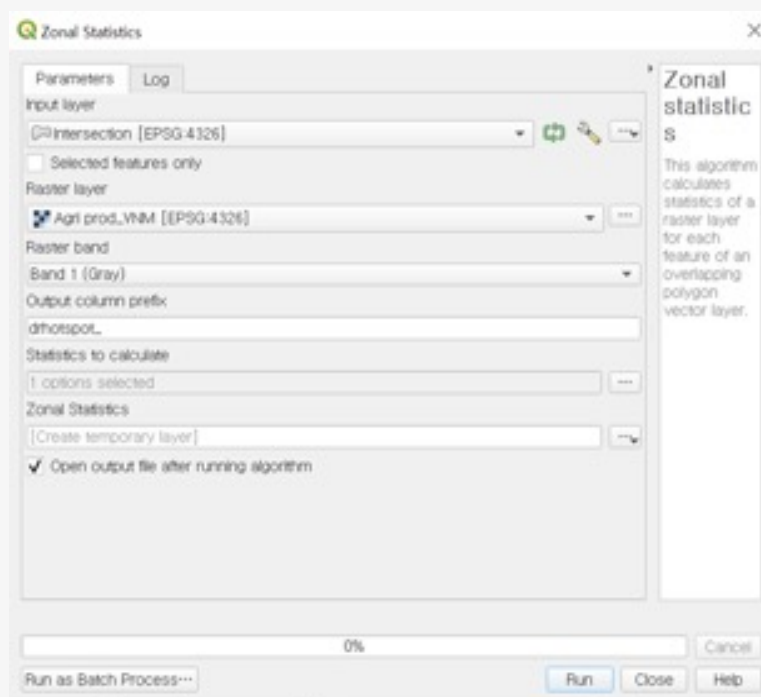
Rainfall Anomaly in JJA 2021	% of areas exposed in terms of agricultural production
70mm below normal	3.44%
100mm below normal	3.21%

It is also possible to estimate the percentage of areas in potential drought risk hotspots. Figure 13 shows the percentage of agricultural areas exposed in terms of production quantity. The calculated values show that the percentage of areas exposed to potential drought risk is responsible for approximately 6.65 percent of the total national agricultural production. Even though the actual agricultural production quantity and value varies year by year, it may nonetheless be helpful for decision-makers to know that the areas that typically produce 6.65 percent of annual national agricultural production face potential drought occurrence this year.

How to:

- ✓ To calculate the total agricultural exposure, the *Zonal Statistics* tool can be used on the gridded agricultural assets data with the rainfall anomaly layer (i.e., vector data with polygons indicating spatial extents of different rainfall anomaly categories) (Figure 14).
- ✓ The agricultural assets in each rainfall anomaly category shall be summed to obtain the total value of agricultural assets exposed to each rainfall anomaly category.

Figure 14: The Zonal Statistics tool is used on the gridded population data to calculate the population in the areas under each rainfall anomaly category

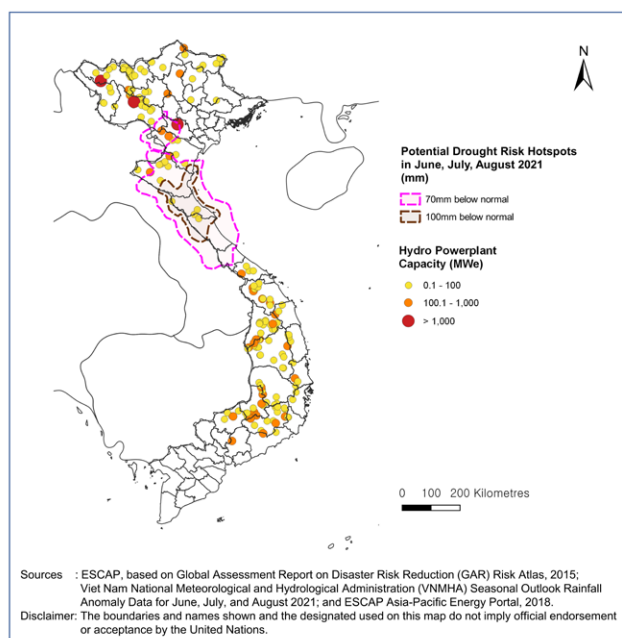


Supporting water management

Drought risks can have severe impacts on the stable operations of hydropower plants. This is an issue of high concern for energy ministry and power companies, as it is essential to ensure stable electricity generation for the effective functioning of governments and societies. In Viet Nam, 34.9 percent of electricity production was from hydropower plants in 2018.⁵ When water resources are not sufficient for the operation of hydropower plants due to prolonged dry conditions, a stable supply of electricity can be challenged. It is therefore important for the energy ministry and power companies to understand these potential risks and to prepare alternative solutions as appropriate.

In this example, the powerplants dataset from the Asia Pacific Energy Portal of ESCAP is used. This dataset is available in spreadsheet format and contains information on power plant location coordinates, generation type (e.g., hydropower, thermal), and generation capacities (Figure 15).

Figure 15: Hydropower plants overlaid with the rainfall anomaly map



Data Source: Asia-Pacific Energy Portal

How to:

- ✓ Like the method described in Module 2 of this training manual, the first step to utilizing this dataset is to import the spreadsheet into QGIS, using the *Delimited Text* tab in the QGIS *Data Source Manager*.
- ✓ After inputting the spreadsheet file name, the file format (i.e., a comma-separated values file) and geometry definition and coordinate reference system (CRS) shall be specified.
- ✓ This loads the spreadsheet data in vector format into QGIS, containing point geometry and characteristics for each power plant in the country.

5. ESCAP, Asia Pacific Energy Portal, <https://asiapacificenergy.org/>

- ✓ After ensuring that the data fields are represented by the appropriate data types using the *Refactor fields* tool, the power plants data layer is ready for analysis.
- ✓ Using the *Join attributes by location* tool, with the power plants data layer input as the Base Layer, the rainfall anomaly data as the Join Layer, and with the *Intersects* option under “Geometric predicate” checked (Figure 16).
- ✓ This process tags each power plant location with the value of rainfall anomaly (if any) faced. This output can then be loaded into a spreadsheet or similar software that allows the summing of the exposed capacities under each hazard category (Figure 17).

Figure 16: The Join Attributes by Location tool used to identify the rainfall anomaly risk faced by each hydropower plant

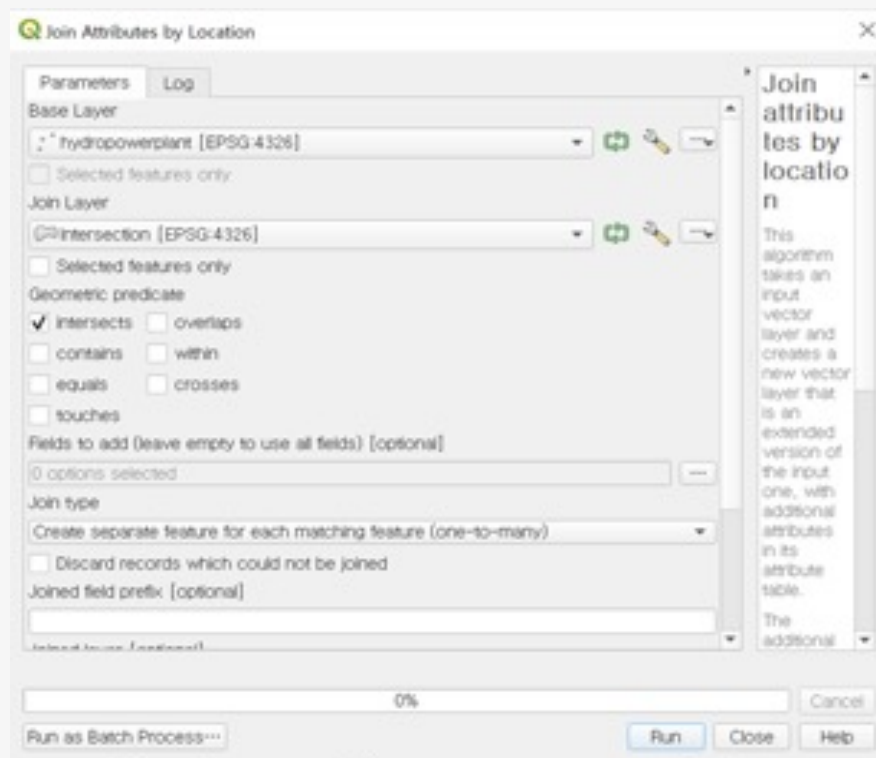


Figure 17: Total exposed hydropower production capacities to potential drought risk

Rainfall Anomaly in JJA 2021 in the hotspot	No. of hydro powerplants exposed	% of total	Capacity of hydro powerplants exposed (MWe)	% of total
70mm below normal	12	6.09%	2,657	15.30%
100mm below normal	4	2.03%	41	0.24%

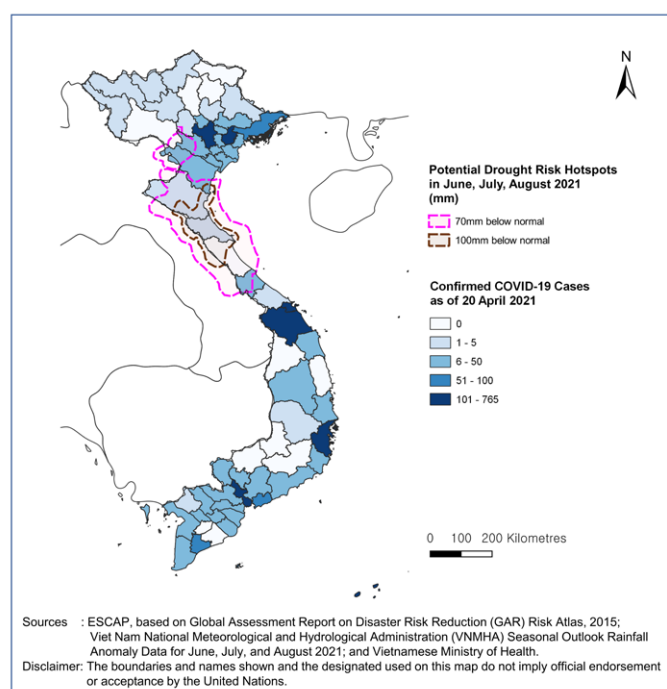
The analysis shows that 16 hydropower plants with a capacity of 15.5 percent of the total capacity are located within potential drought risk hotspots forecasted over the months of June, July, and August of 2021. Thus, water resources management in these areas should be closely monitored and reviewed.

Assessing possible convergence with the COVID-19 and impacts on waterborne diseases

Simultaneous occurrence of multiple disaster events can amplify the adverse impacts of disasters on a community. One such example is when drought events coincide with the ongoing COVID-19 pandemic. An ESCAP report found that areas with extensive poverty, malnourishment, and economic reliance on agriculture often coincide with areas with high drought risk. These were often the same areas in which the COVID-19 pandemic converged. These factors result in weakened government capacity to respond to the public health crisis (ESCAP, 2020). In this case, disaster management agencies and health ministries may need to identify potential convergence of natural disasters with the pandemic to prepare appropriate preventive and responsive measures in advance.

Figure 18 shows the drought risk hotspot and COVID-19 incidence maps overlaid. This map indicates that in the southern portion of the drought risk hotspot, the occurrence of COVID-19 cases is relatively low. However, in the northern portion of the drought risk hotspot, there appears to be a relatively high incidence of COVID-19 cases, which may be a cause for concern in the case of implementing measures against a possible drought.

Figure 18: Confirmed COVID-19 cases and drought risk hotspots



Data Source: Vietnamese Ministry of Health

* Note: Data for confirmed COVID-19 cases is as of 20 April 2021, and potential drought risk hotspots are for JJA 2021.

In addition to the pandemic, studies have established links between droughts and malaria, in some cases finding a higher incidence of malaria in the year following drought onset.⁶ Public health officials may therefore be interested in identifying locations with a historically high incidence of the disease (Figure 19). Being able to identify where areas with a shortfall of rain intersect with historically high incidence rates of malaria will enable public health officials to pre-emptively implement interventions to mitigate the propagation of the disease and prevent severe outbreaks.

6. Stanke, Kerac, Prudhomme, Medlock & Murray, 2013

In this example, areas with more than 1000 mm of total expected rainfall are identified and overlaid with the malaria maps to identify areas that may potentially experience a high risk of malaria spread. As shown in Figure 20, some areas with a relatively high incidence of malaria overlap with areas of more total rainfall. Local health officials in these areas may expect to prepare for pre-emptive measures to mitigate and manage the spread of malaria.

How to:

- ✓ Similar to the method for processing the multiple probabilistic rainfall layers in Module 2, the *Vector* → *Polygonize* tool can be used to convert the total rainfall raster image to vector data.
- ✓ Subsequently, the field calculator is used on the newly vectorized features (polygons) to assign labels to each feature based on total rainfall categories using the *CASE* expression (Figure 19).
- ✓ In this example, polygons with rainfall probabilities below 1000 mm are assigned a unique identifier and adjacent polygons with the same identifier are merged using the *Vector* → *Dissolve* tool.

Figure 19: The Field Calculator tool to identify areas with less expected total rainfall

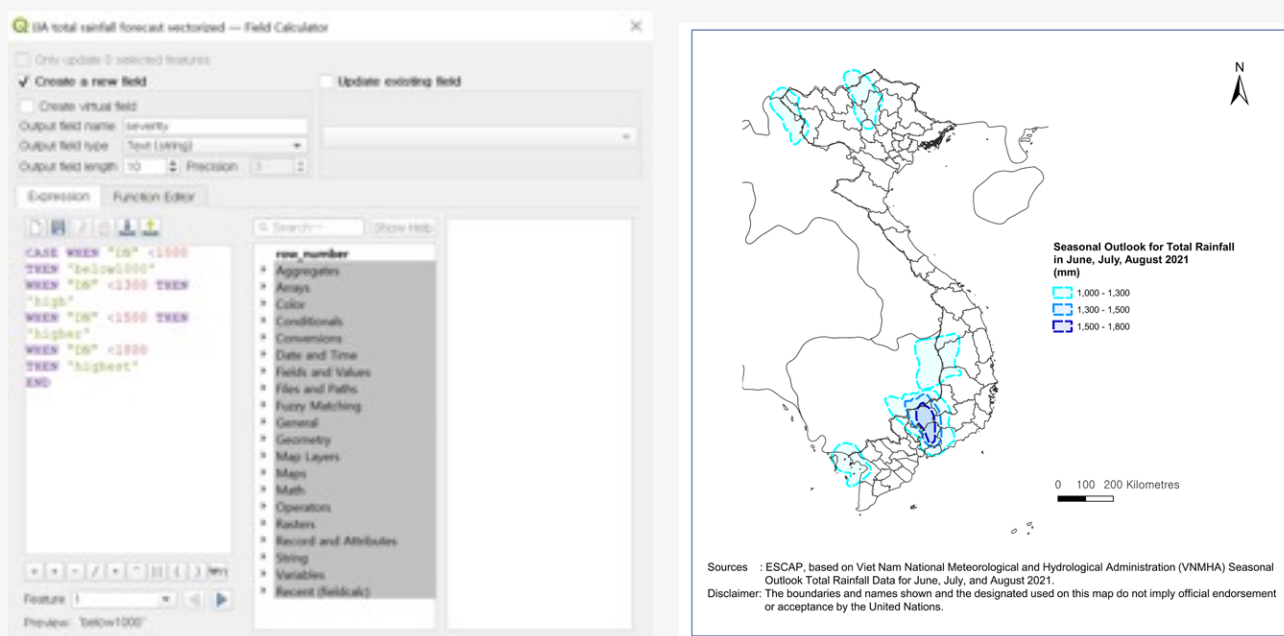
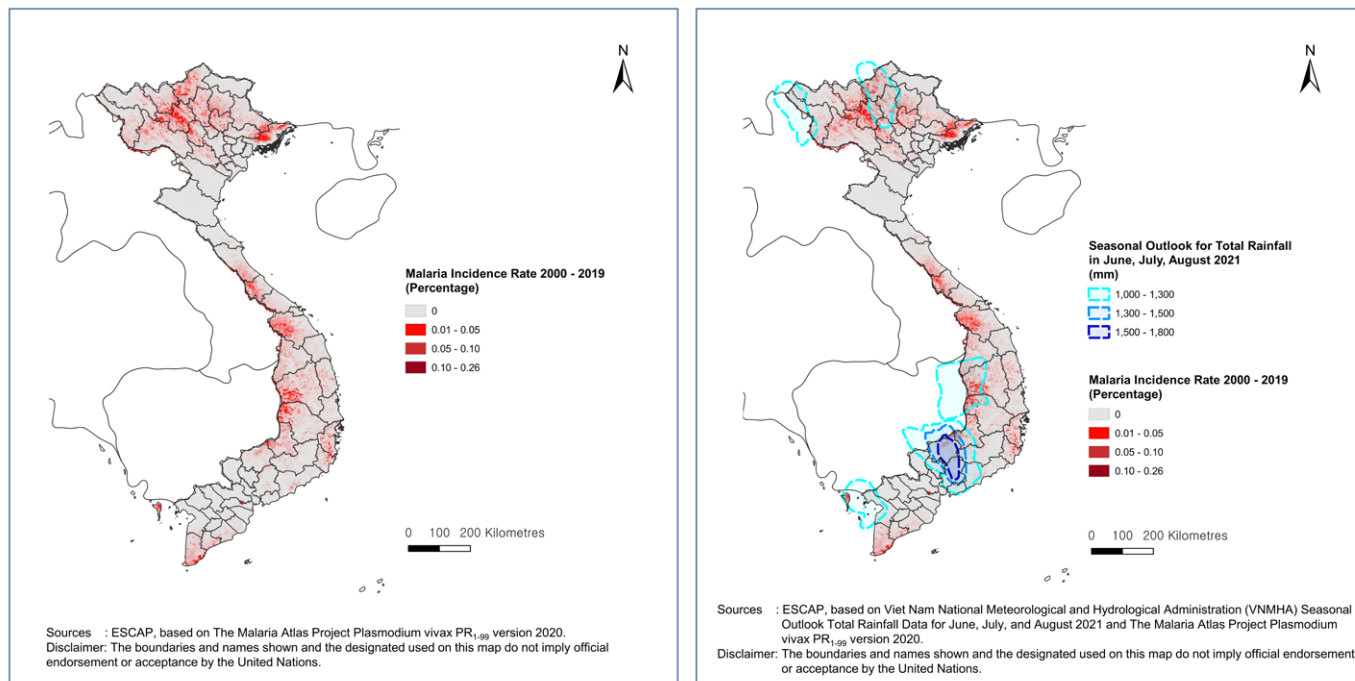


Figure 20: Spatial distribution of malaria incidence rates between 2000 and 2019



Data Source: The Malaria Atlas Project

Given that other climatic and environmental factors play a role in advancing the spread of malaria, other climatic data and inputs from health experts should be considered alongside rainfall forecasts, such as ambient temperatures as well as local conditions that facilitate water stagnation.

Another example of public health concern is the relation of rainfall anomalies to dengue incidents. Communities in Viet Nam face occasional dengue outbreaks. The coincidence of optimal temperature conditions (i.e., identified from seasonal temperature forecasts) alongside prolonged wet conditions (i.e., above-normal rainfall anomalies) can result in optimal conditions for mosquito breeding, which can escalate the spread of dengue fever. Thus, understanding the intersection between regions with above-normal rainfall anomalies and areas with high historical rates of dengue enables public health officials to take early action to mitigate the spread of the dengue virus (e.g., clearing clogged drains to ensure no buildup of stagnant water, distribution of mosquito nets).

References

- Food and Agriculture Organization (FAO) (2010). Global Spatially-disaggregated Crop Production Statistics Data of 2020 (MapSPAM) v2r0 2020. Available at: <https://www.mapspam.info/data/> (Accessed in April 2021).
- Lloyd, C., Sorichetta, A. & Tatem, A. (2017). High resolution global gridded data for use in population studies. *Sci Data* 4, 170001 . <https://doi.org/10.1038/sdata.2017.1>
- The Malaria Atlas Project (2020). Plasmodium vivax PR1-99 version 2020. Available at: <https://malariaatlas.org/explorer/#/> (Accessed in April 2021).
- National Oceanic and Atmospheric Administration-Center for Satellite Applications and Research (NOAA-STAR) (2021). Vegetation Condition Index (VCI). Available at: https://www.star.nesdis.noaa.gov/smcd/emb/vci/VH/vh_browseByCountry.php (Accessed in April 2021).
- Stanke, C., Kerac, M., Prudhomme, C., Medlock, J., & Murray, V. (2013). Health effects of drought: a systematic review of the evidence. *PLoS currents*, 5, ecurrents.dis.7a2cee9e980f91ad7697b570bcc4b004. <https://doi.org/10.1371/currents.dis.7a2cee9e980f91ad7697b570bcc4b004>
- United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) (2018). Asia-Pacific Energy Portal. Available at: <https://asiapacificenergy.org/#main/lang/en/type/0/map/1/time/%5B1990,2019%5D/geo/%5BASPA%5D/latlong/%5B20.2858,100.78682%5D/zoom/3/infra> (Accessed in April 2021).
- _____ (2018). Asia-Pacific Information Superhighway. Available at: <https://www.unescap.org/our-work/ict-and-disaster-risk-reduction/asia-pacific-information-superhighway-ap> (Accessed in April 2021).
- _____ (2020). Ready for the Dry Years: Building Resilience to Drought in South-East Asia. Available at: <https://www.unescap.org/news/double-impact-most-vulnerable-covid-19-compounding-long-term-drought-effects-southeast-asia#>
- United Nations Office for Disaster Risk Reduction (UNDRR) (2015). Global Assessment Report on Disaster Risk Reduction (GAR) Risk Atlas Drought Events. Available at: <https://risk.preventionweb.net/capreviewer/> (Accessed in April 2021).
- _____ (2015). Global Assessment Report on Disaster Risk Reduction (GAR) Risk Atlas Flood Hazards 25 and 100 years Return Period. Available at: <https://risk.preventionweb.net/capreviewer/> (Accessed in April 2021).
- _____ (2015). Global Assessment Report on Disaster Risk Reduction (GAR) Risk Atlas Economic Stock Exposure to Disasters. Available at: <https://risk.preventionweb.net/capreviewer/> (Accessed in April 2021).
- _____ (2017). Global Assessment Report on Disaster Risk Reduction (GAR) Atlas Risk Data Platform. Available at: <https://risk.preventionweb.net/capreviewer/main.jsp?countrycode=g15>. Accessed in September 2018 to January 2019.

The Malaria Atlas Project (2020). Plasmodium vivax PR1-99 version 2020. Available at: <https://malariaatlas.org/explorer/#/> (Accessed in April 2021).

Viet Nam National Center for Hydro-Meteorological Forecasting (NCHMF), VNMHA (2021). Seasonal Forecast Rainfall Anomaly Data for June, July, and August 2021.

_____ (2021). Seasonal Forecast Total Rainfall Data for JJA 2021.

_____ (2021). Standardized Precipitation Index (SPI) 2021.

Vietnamese Ministry of Health (2021). Cumulative Confirmed COVID-19 Cases by 20 April 2021.

WorldPop (2018). National Boundaries. Available at: <https://www.worldpop.org/geodata/summary?id=24462> (Accessed in April 2021).

_____ (2020). 2020 Estimates Population data. Available at: <https://www.worldpop.org/geodata/summary?id=50068> (Accessed in April 2021).

Annex I

Types and scales of data for impact-based forecasting

Spatial data can consist of the following types:

1. Vector format: Graphical representation of real-life objects.

- a. The three most common types of vector data are points, lines and polygons.
- b. Vector data is most commonly stored in Shapefiles (.shp file format) although it can also be stored in other formats (e.g., GeoJSON files).
- c. An example is a shapefile containing the buildings in the city. Each feature in the shapefile may represent the polygon footprint of the building, and may contain attributes for each feature such as size of the building, year of construction and so on.

2. Raster format: Gridded data that consists of an array of valued cells or pixels.

- a. Typically referring to image data, a raster consists of an array of cells that represent the geographic extent of an area.
- b. Cell values represent measurements of the elements in question.
- c. The resolution of the data depends on the size of the cell in the data. The smaller the cell size, the more cells needed to encapsulate an area, which leads to higher resolution data.
- d. An example of gridded population data is the WorldPop dataset, with each cell covering an approximately 100 sq. m. area, representing the estimated population size in that cell.

Map projections attempt to project the surface of the earth in spherical, 3D form onto a flat 2D surface. A coordinate reference system (CRS) defines how the two-dimensional, projected map in your GIS relates to real places on a spherical earth. The decision of which map projection and CRS to use depends on the area of study and on the analysis required. The different projections can be represented by European Petroleum Survey Group (EPSG) codes. In Viet Nam, the EPSG code for the local projected CRS is 3405.

GIS data is often provided by governments and local agencies on an administrative boundary level. For example, pending data availability, national statistics can be disaggregated into small spatial scales, such as regional, provincial, district and neighborhood-level data. Oftentimes, more information can be derived from more disaggregated data, which is essential for an endeavor such as impact-based forecasting. Table 1 contains a list of data used as examples in this Modules 2 and 3 of this training manual.

Table 1: Sources and types of data used in Modules 2 and 3

Data	Source	Data type	Source
Viet Nam National administrative boundaries	Worldpop	Polygon vector	https://www.worldpop.org/geodata/summary?id=24711
Typhoon Molave wind speed categories	National Oceanic and Atmospheric Administration	PNG image	https://rammb-data.cira.colostate.edu/tc_realtime/archive_model_data.asp?product=conwsp50&storm_identifier=wp212020
Probabilistic rainfall forecasts	Viet Nam Meteorological and Hydrological Administration	Gridded raster	Country authorities
Seasonal rainfall forecasts (total rainfall and rainfall anomaly)	Viet Nam Meteorological and Hydrological Administration	Vector	Country authorities
Historical drought risk	GAR Atlas Risk Data Platform	Polygon vector	https://risk.preventionweb.net/capraviewer/
Total population counts	WorldPop	Gridded raster	https://www.worldpop.org/geodata/summary?id=50068
Population counts for age 65+	WorldPop	Gridded raster	https://www.worldpop.org/geodata/summary?id=50532
Population counts for age 0 to 14	WorldPop	Gridded raster	https://www.worldpop.org/geodata/summary?id=50532
Population counts for women	WorldPop	Gridded raster	https://www.worldpop.org/geodata/summary?id=50532
Poverty rate	Viet Nam General Statistics Office	Province-level vector	https://www.gso.gov.vn/en/px-web/?pxid=E1143&theme=Health%2C%20Culture%2C%20Sport%20and%20Living%20standard
Human Development Index	United Nations Development Program	Province-level vector	https://globaldatalab.org/shdi/
Agricultural production and values	Food and Agriculture Organization	Gridded raster	https://www.mapspam.info/data/
Fishery and aquacultural production	Viet Nam General Statistics Office	Province-level vector	https://www.gso.gov.vn/en/px-web/?pxid=E0657&theme=Agriculture%2C%20Forestry%20and%20Fishing
Number of livestock	Viet Nam General Statistics Office	Province-level vector	https://www.gso.gov.vn/en/px-web/?pxid=E0652&theme=Agriculture%2C%20Forestry%20and%20Fishing
Power generation plans	ESCAP Asia-Pacific Energy Portal	Points vector	https://asiapacificenergy.org/
Ground transport infrastructure	OpenStreetMaps	Lines vector	www.geofabrik.de
ICT Infrastructure	ESCAP Asia-Pacific Information Superhighway	Lines vector	https://www.unescap.org/our-work/ict-and-disaster-risk-reduction/asia-pacific-information-superhighway-ap-platform
Airports	Airport Cooperation of Viet Nam JSC	Points vector	Country authorities
Economic stocks	Global Assessment Report	Points vector	https://risk.preventionweb.net/capraviewer/
Cumulative COVID-19 case counts	Viet Nam Ministry of Health	Province-level vector	Country authorities
Number of patient beds by province	Viet Nam General Statistics Office	Province-level vector	https://www.gso.gov.vn/en/px-web/?pxid=E1109&theme=Health%2C%20Culture%2C%20Sport%20and%20Living%20standard
Malaria incidence rate	The Malaria Atlas Project	Gridded raster	https://malariaatlas.org/explorer/#/

Annex II

List of potential exposure and vulnerability indicators for impact-based forecasting

The following list consists of potential data that can be used to indicate vulnerability and exposure. The higher resolution (i.e., spatially disaggregated) the data, the better it can serve the purpose of impact-based forecasting.

- Land use data, for example:
 - ✓ Land use types
 - ✓ Type of forest cover
 - ✓ Area of concentrated planted forest

- Data on local population structures, such as:
 - ✓ Population density
 - ✓ Total population counts
 - ✓ Population age and sex structures
 - ✓ Human development index
 - ✓ Poverty rates

- Critical infrastructure locations, for example:
 - ✓ Energy infrastructure: Power generation plants, transmission substations, distribution stations, transmission lines and poles
 - ✓ Water distribution stations, water pumps
 - ✓ Transportation links and hubs (e.g., highways, airports, maritime ports)

- Public health system indicators, for example:
 - ✓ Number and locations of health establishments
 - ✓ Current health expenditure
 - ✓ Number of patient beds per capita
 - ✓ Number of doctors per capita
 - ✓ Incidence of disease (e.g., malaria, dengue, HIV, COVID-19)
 - ✓ Incidence of child malnutrition

- **Economic system indicators, for example:**
 - ✓ **Economic production assets and values (e.g., agriculture, forestry, fishing, livestock)**
 - ✓ **Size of labor force**
 - ✓ **Size of unemployed population**
 - ✓ **Net turnover from businesses**
 - ✓ **Annual average capital of businesses**

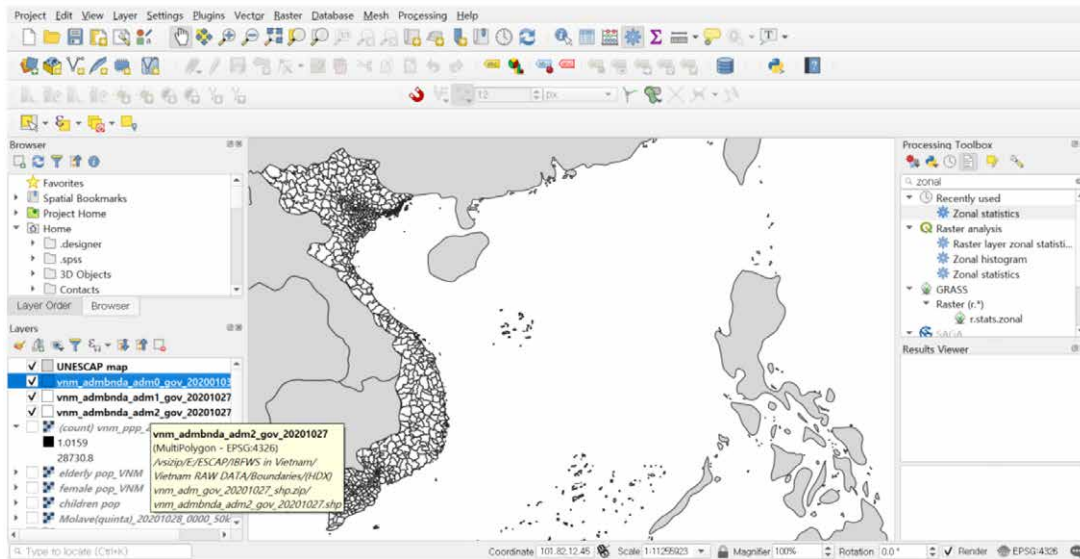
- **Education system indicators, for example:**
 - ✓ **Number or location of schools**
 - ✓ **Number of students or teachers per school location**
 - ✓ **Number of ethnic minority or female students per school locations**

Annex III

QGIS User Guide: Calculating Population Exposed to Typhoon Molave

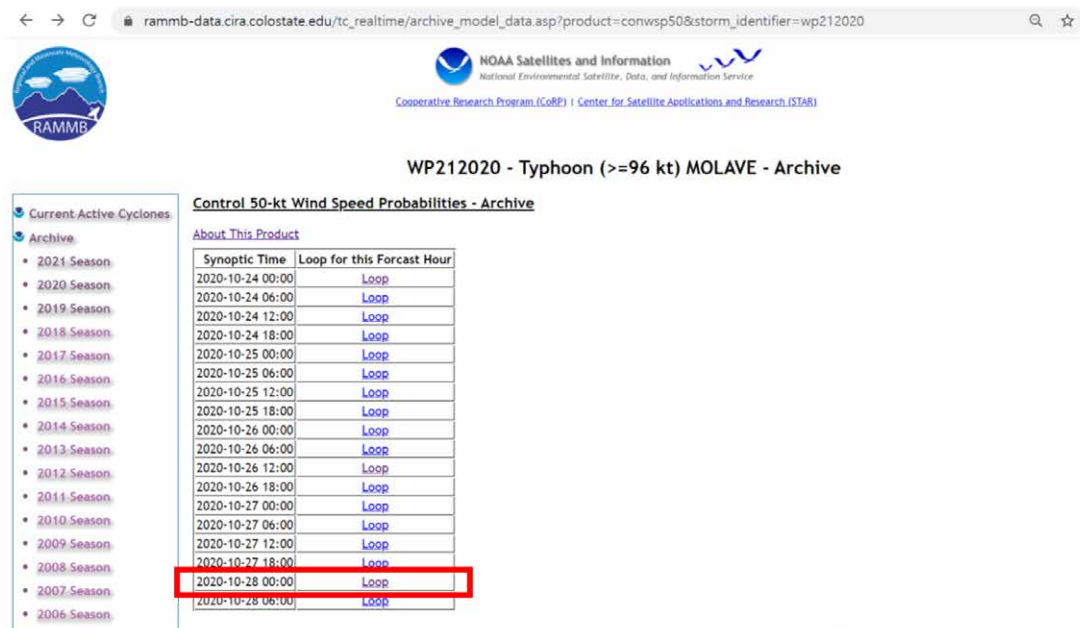
Download the national and subnational boundaries shapefiles of Viet Nam from WorldPop: <https://www.worldpop.org/geodata/summary?id=24711>, and open the files in QGIS.

1



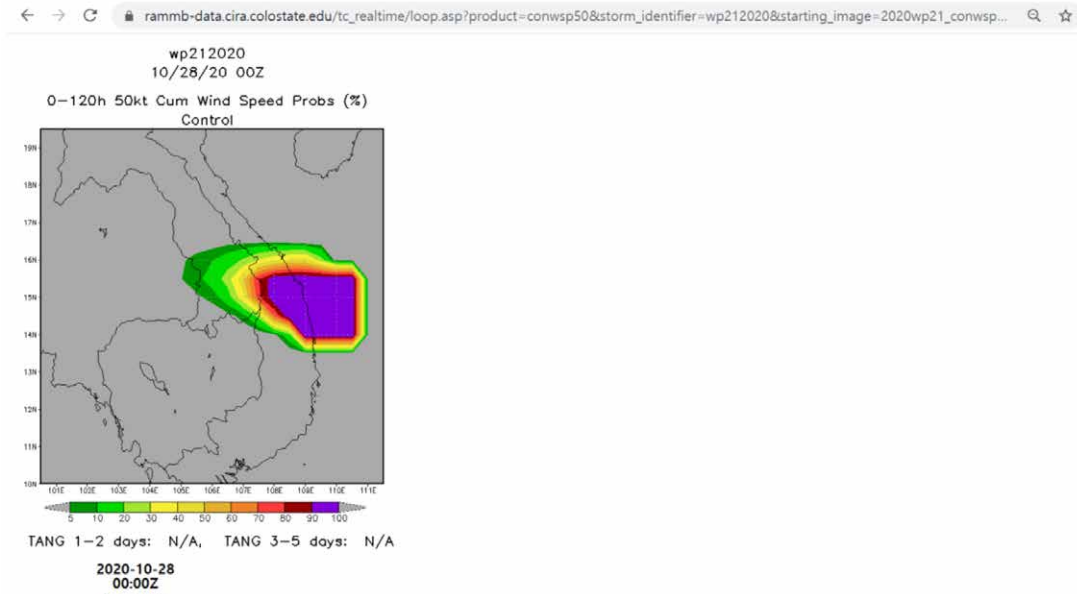
Download the Typhoon Wind Speed Probabilities Data from NOAA-RAMMB's website: https://rammb-data.cira.colostate.edu/tc_realtime/archive_model_data.asp?product=conwsp50&storm_identifier=wp212020. Browse through the loop and select the typhoon track that made landfall with the greatest exposure area. In this case, we have selected the 28 Oct 2020 00:00 UTC track.

2



Save the selected image as a PNG file.

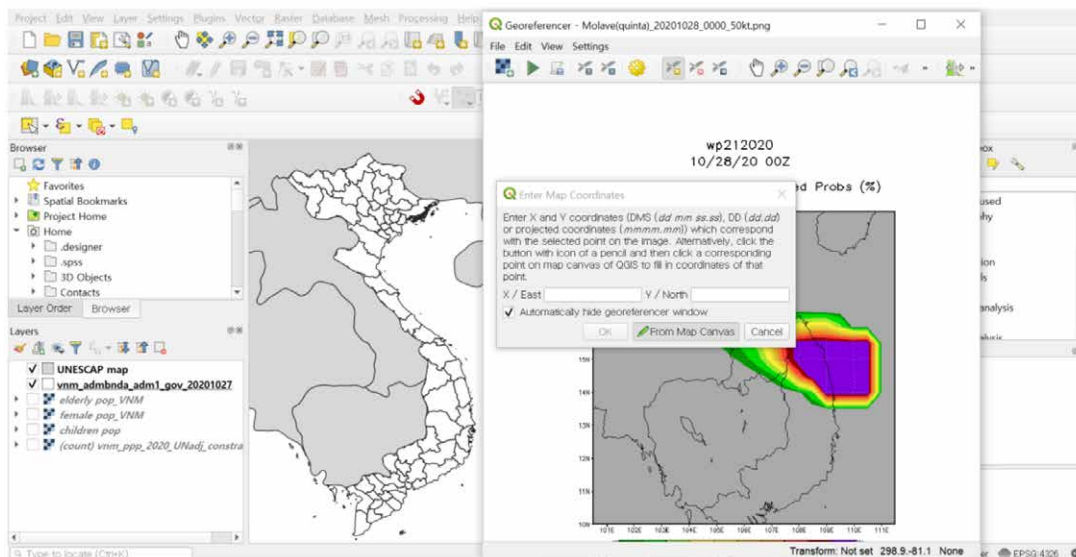
3



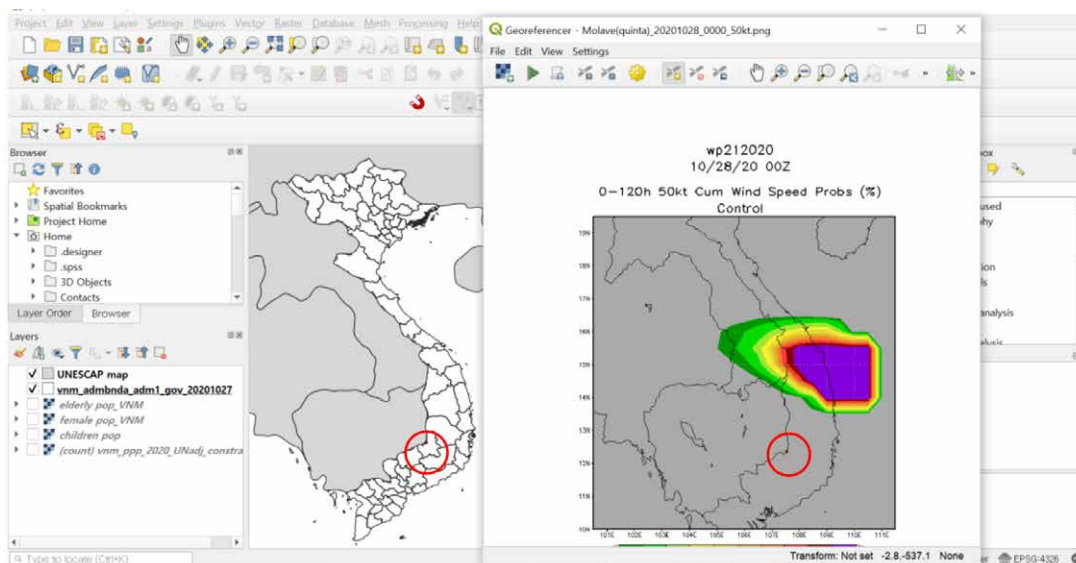
Import the PNG file using the Georeferencer tool in QGIS. Click Raster -> Georeferencer -> Open Raster.

4

Georeference the PNG file by using the 'From Map Canvas' tool. Click on a distinguishable point on the imported PNG file first, then click 'From Map Canvas,' and then click the corresponding point on the imported boundary data presented in the GIS main window. After you click the 'OK' button, you will see the red georeferenced dots in both windows. Repeat this process several times. A higher number of georeferenced points increases the accuracy of the output.

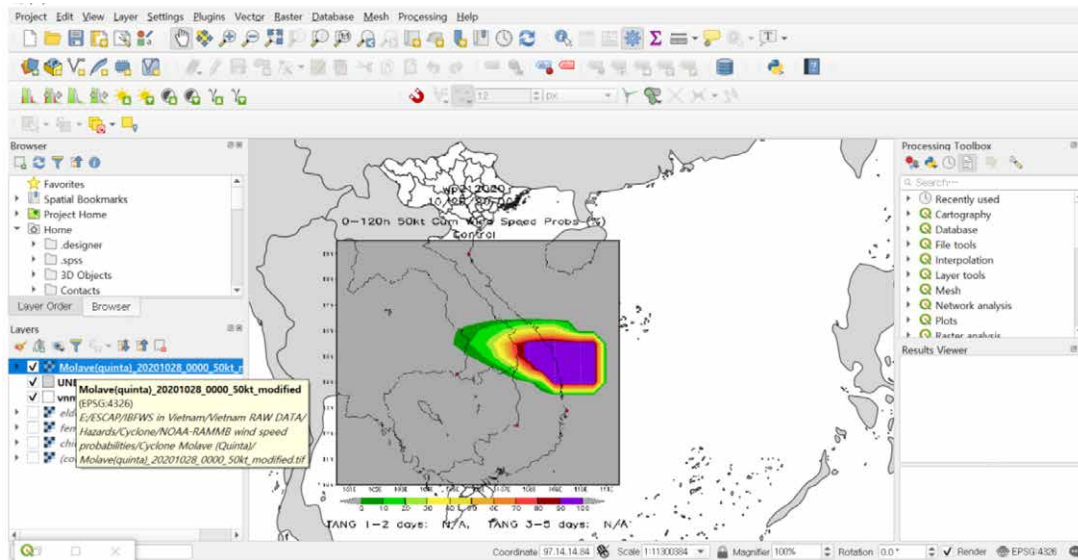
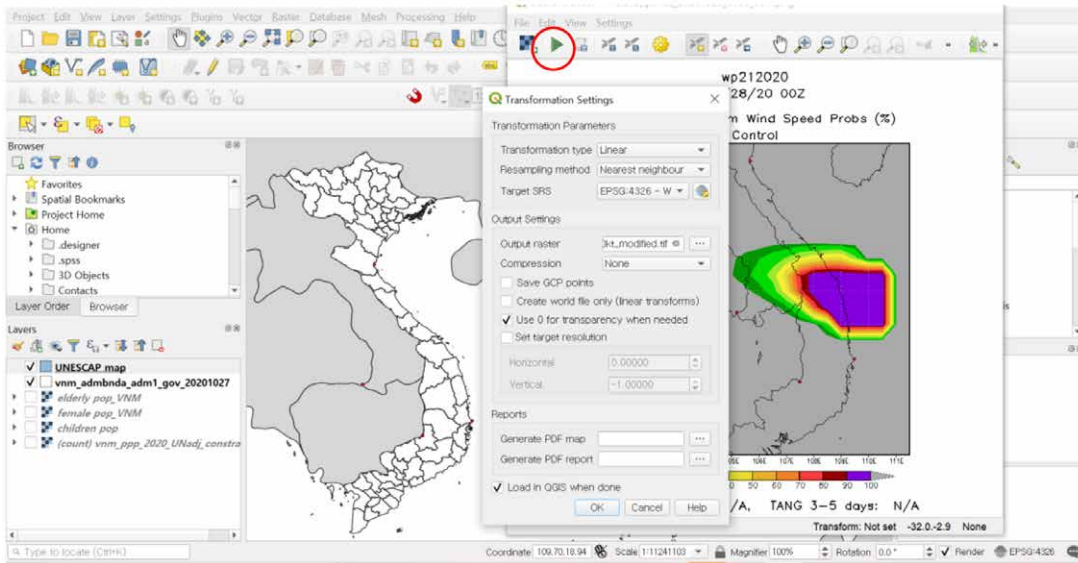


5



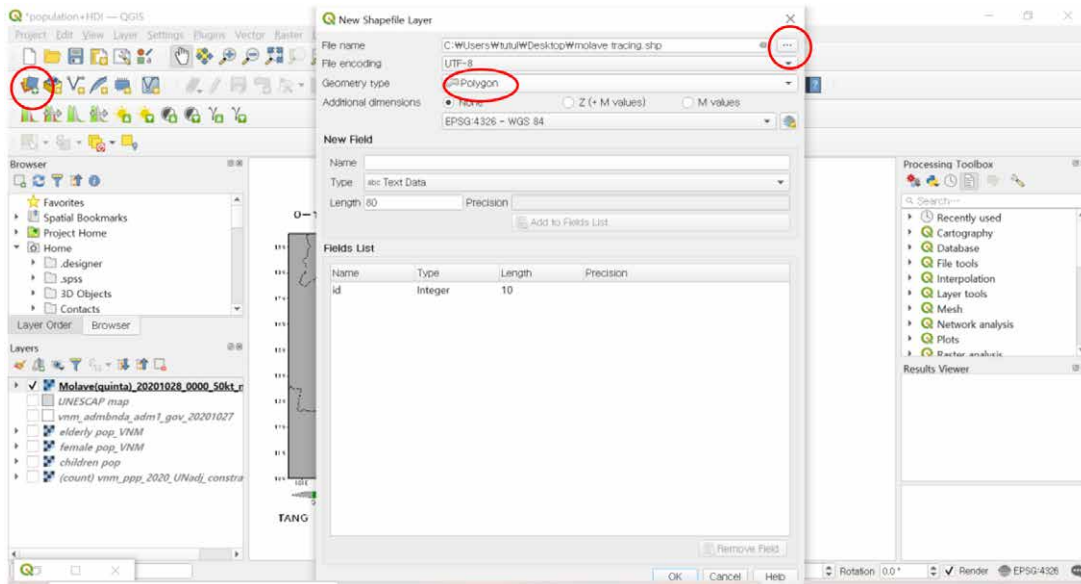
After creating several georeferenced points (at least 5 points), click on the 'Start Georeferencing' button. This will generate the newly created georeferenced tiff layer, which you will find in the Layers pane.

6



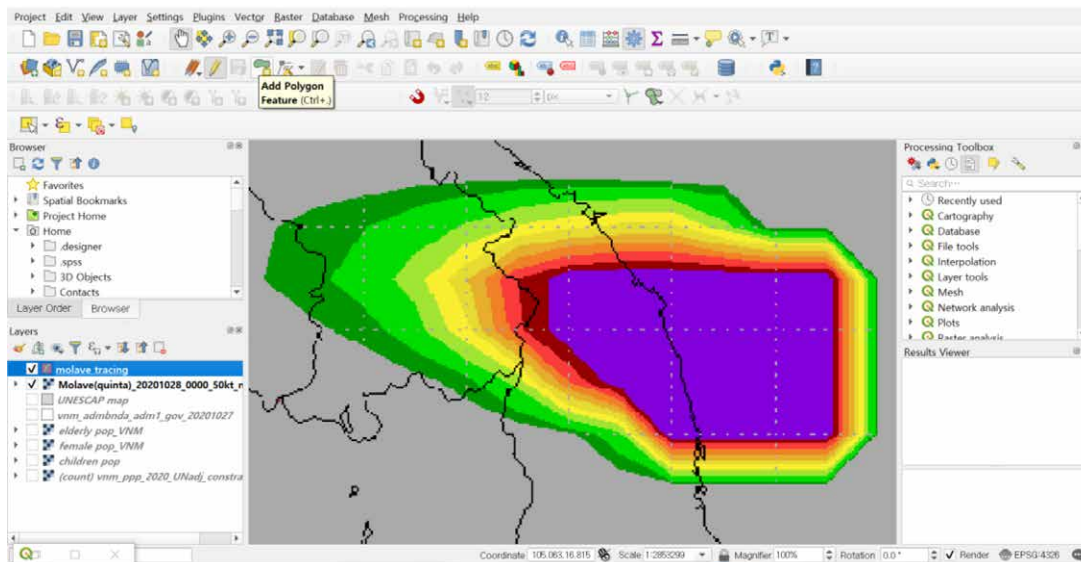
Since the objective is to extract only the typhoon wind speed track, the multiple wind speed categories must be traced by creating a new polygon. Click the 'New Shapefile Layer' button, save the shapefile, and select 'Polygon' for the geometry type.

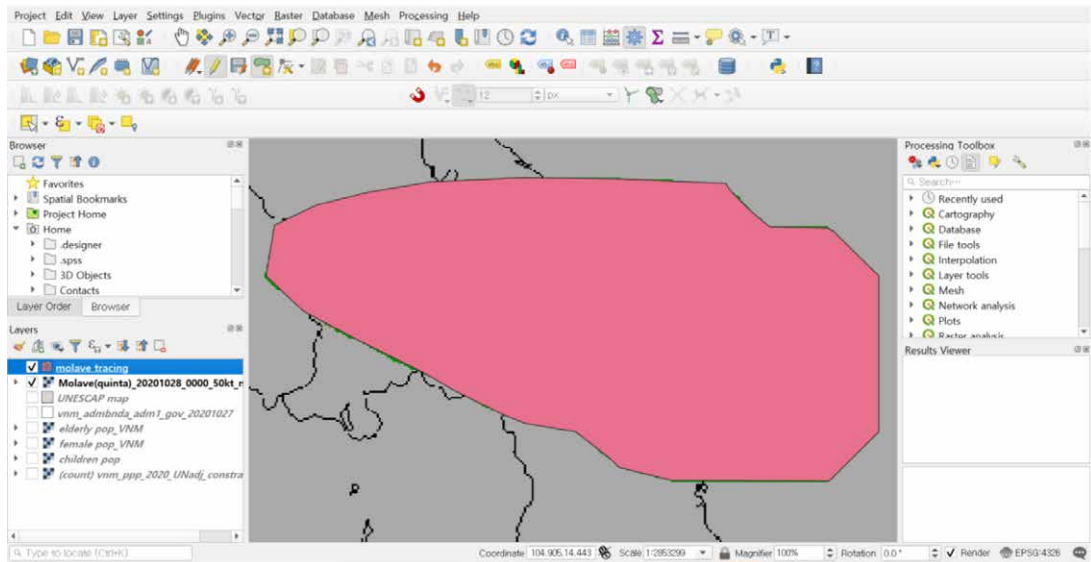
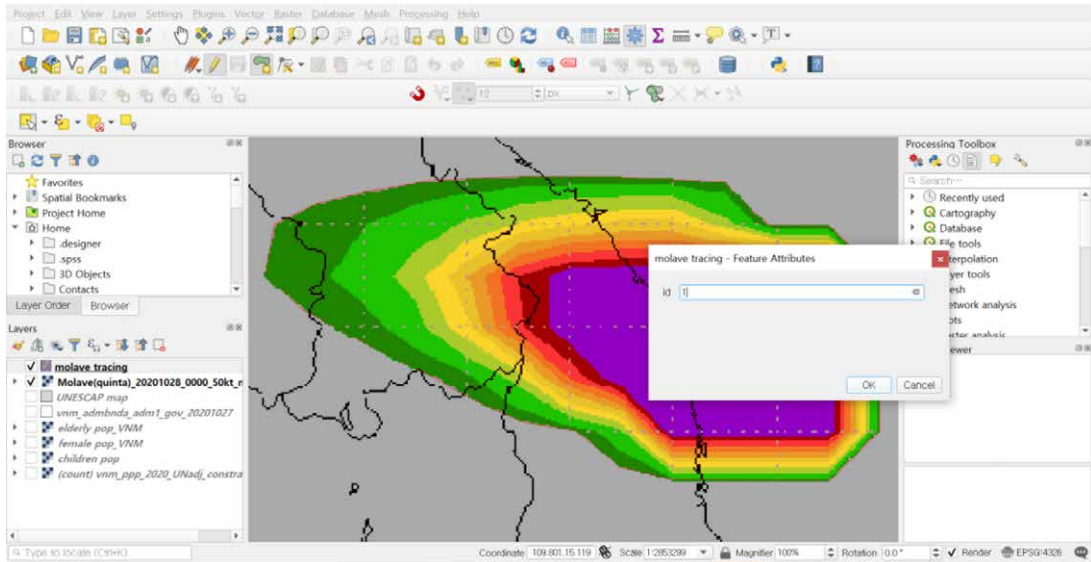
7



Enlarge the typhoon track, click the 'Toggle Editing' button, and subsequently the 'Add Polygon Feature' button. Start tracing from the outer green line (<50%). Once done, right click to finalize the tracing, and enter feature attributes in the window that pops up. Provide the feature with a unique and distinguishable label ID (e.g., 1).

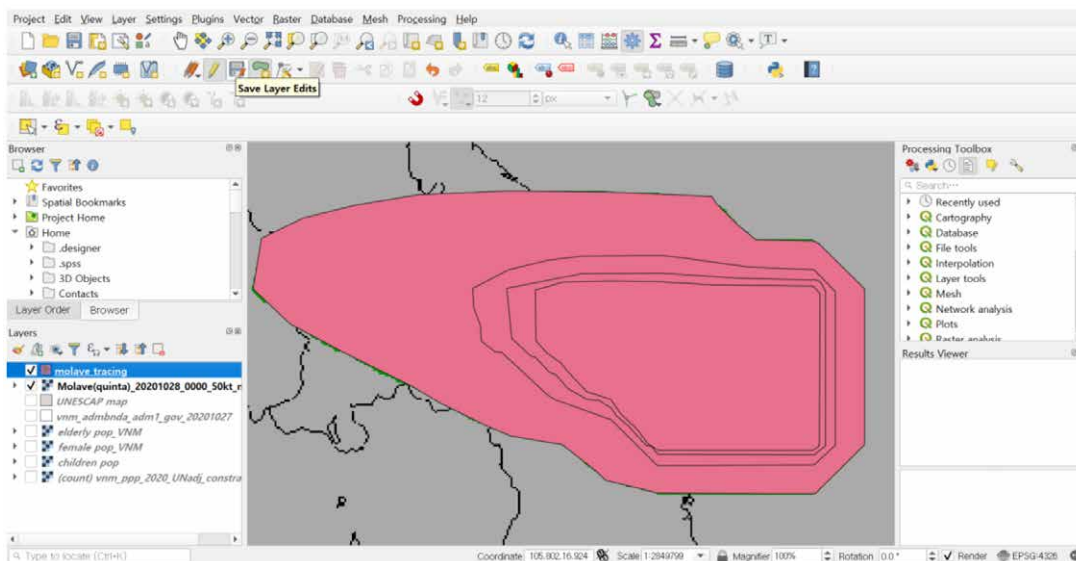
8





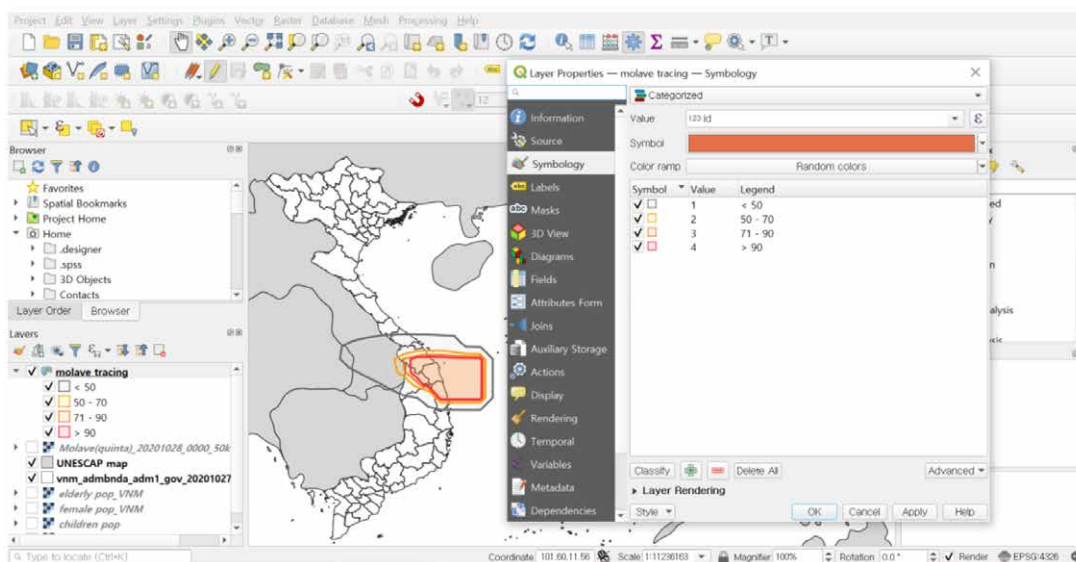
To trace the rest of the wind speed probabilities, hide the newly created polygon layer and trace the orange line (50%-70%), red line (70%-90%), and purple line (>90%) in order. Provide unique IDs to each of the newly created polygons (e.g., 2, 3, and 4). Click 'Save Layer Edits'.

9

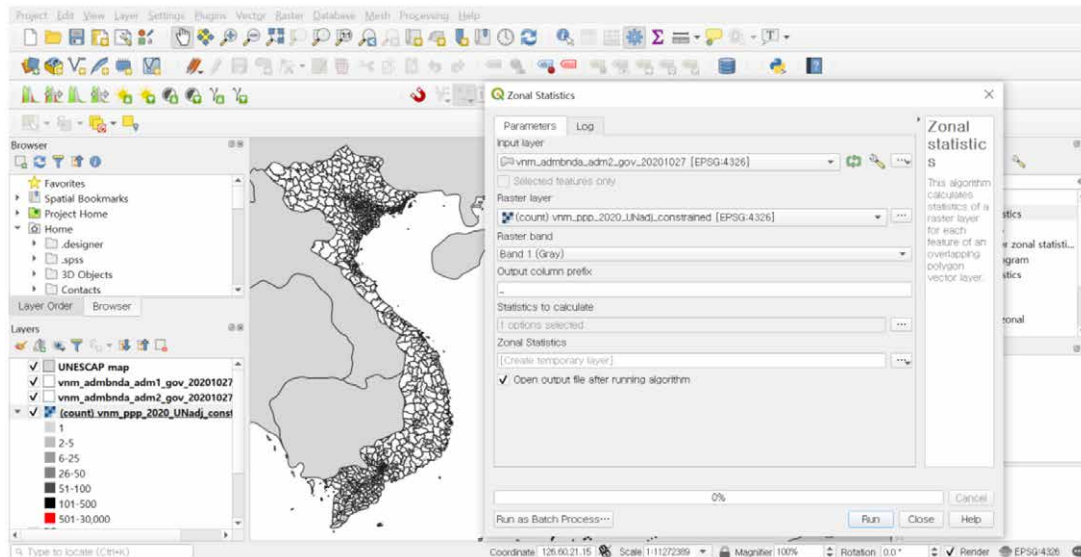


In the Layers pane, uncheck the georeferenced tiff file to show the administrative boundary layers and the newly created Molave wind speed polygon layer. Double-click the polygon layer in the Layers pane to open the layer Properties window. Under the Symbology tab, the typhoon wind speed layer can be stylized for improved visual interpretation. In this example, as the features have been categorized using unique identifiers of 1, 2, 3, and 4, the symbology style "Categorized" can be selected, with the 'id' column used in the Value field.

10

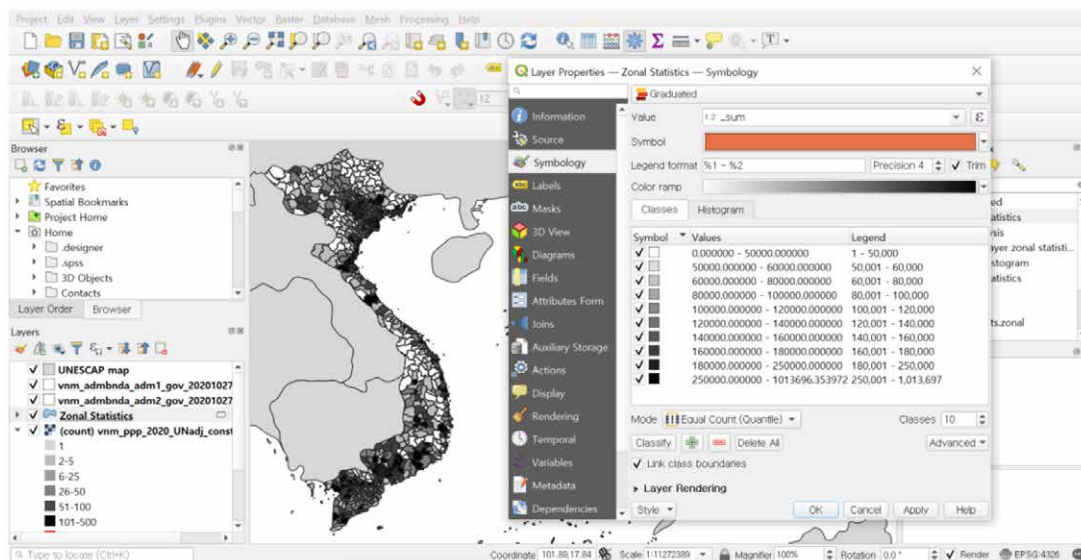


Now, obtain population data from WorldPop: <https://www.worldpop.org/geodata/summary?id=50068> and load the data into QGIS. Using the 'Zonal Statistics' tool and the administrative level 2 boundary file, the raw population data (tiff file) can be converted into a shapefile. Search the 'Zonal Statistics' tool in the QGIS processing toolbox, choose the admin-level 2 shapefile for the input layer, and the population tiff file for the raster layer. For the statistics to calculate, choose 'sum'. Click Run.

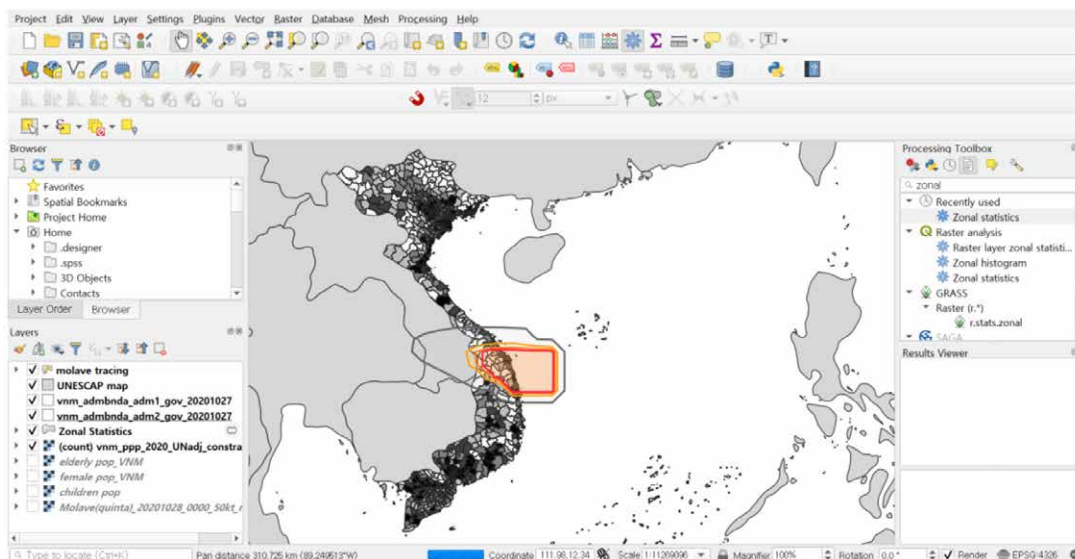


11

Subsequently, you will see the newly created temporary layer in the Layers pane, labeled as 'Zonal Statistics.' Double-click this layer to open the properties window, and revise the symbology in the Symbology tab in accordance with the example shown below. Choose 'Graduated' for the symbology style, '_sum' for the Value, and choose the desired color ramp. Lastly, visually overlay the newly created layer with the Typhoon wind speed layer by toggling on both layers in the Layers pane.

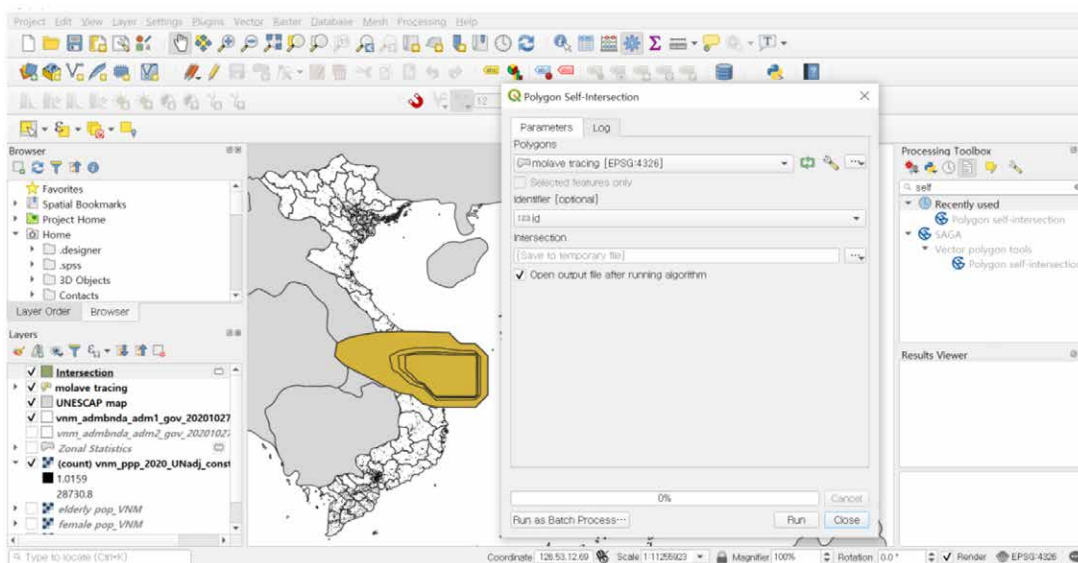


12

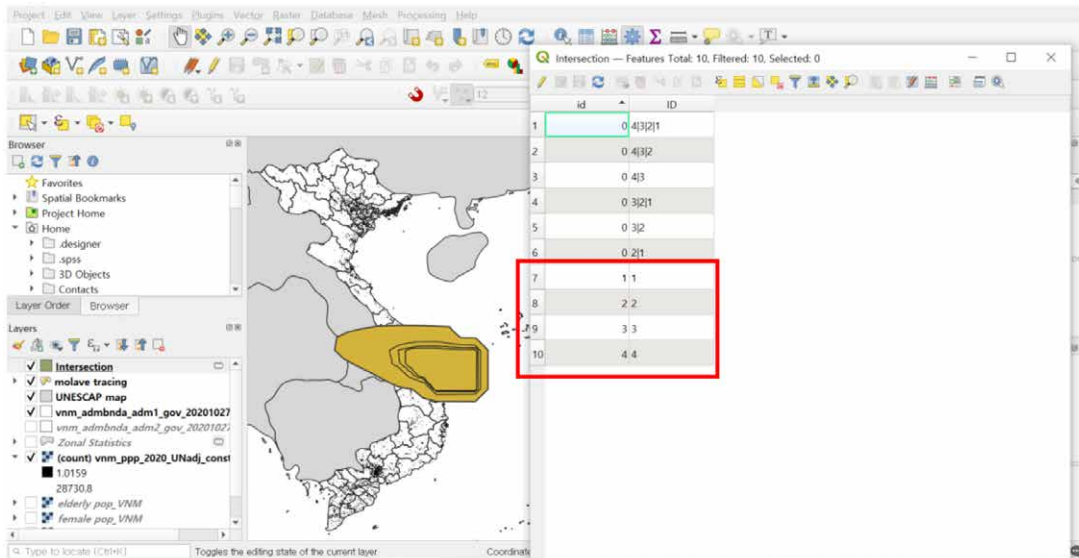


The population tiff file from Worldpop and the typhoon wind speed polygon file shall be used to calculate the population likely to be exposed to extreme winds due to Typhoon Molave. To calculate the value exposed to each category of wind speed, it is recommended to use the 'Polygon Self-Intersection' tool. The Polygon layer should be the traced Typhoon Molave wind file, with 'id' selected as the identifier. After running the tool, you will find the newly created polygon layer, labeled as 'Intersection', in the Layers pane.

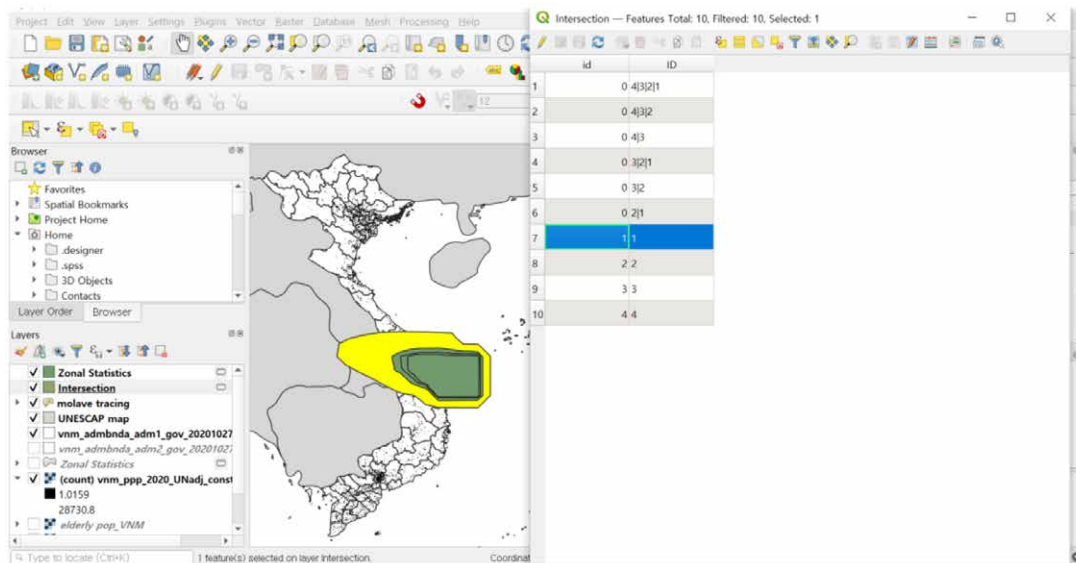
13



Upon opening the attribute table of the 'Intersection' layer (right click on the layer in the Layers pane, and select Open Attribute Table from the menu), a column in the attribute table will indicate ids 1, 2, 3, 4 where 1=1-2-3-4, 2=2-3-4, 3=3-4, and 4=4, as shown in the following figure. If you select the feature with id 1 on the attribute table, you will see the selected area in the QGIS main window highlighted in bright yellow. It is necessary to make each of the categories distinct in order to calculate the population exposed to each wind speed category.

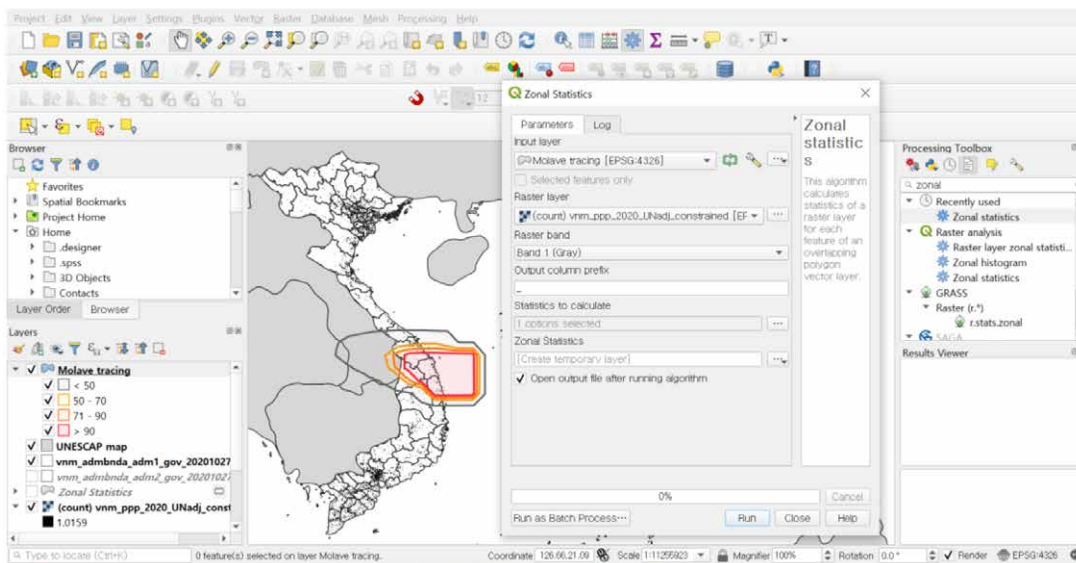


14



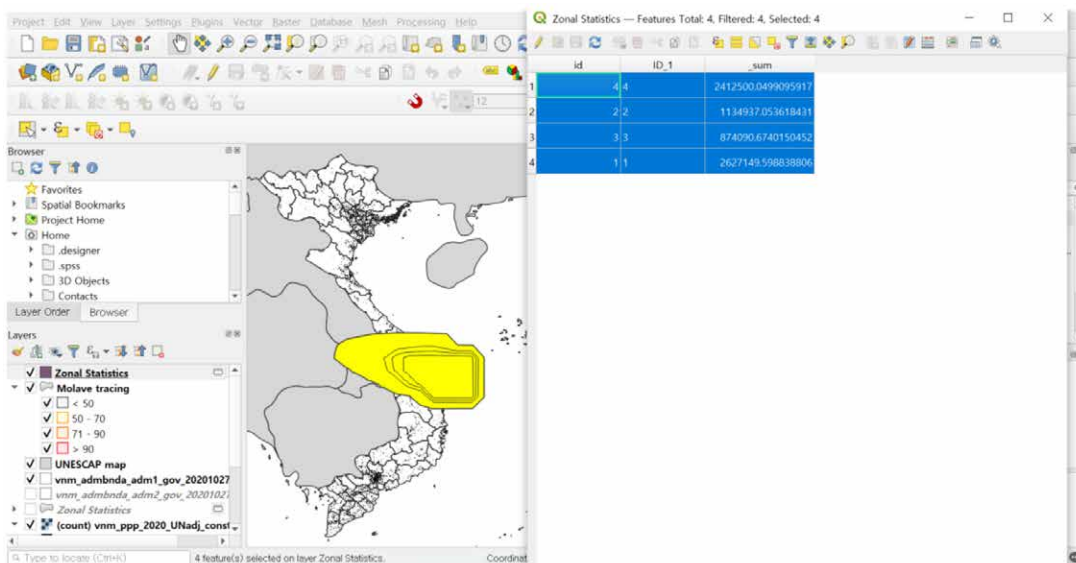
Use the 'Zonal Statistics' tool once more, by selecting the traced Molave wind file as the input layer, and the population tiff file as the raster layer. Select 'sum' for the 'Statistics to Calculate' field.

15

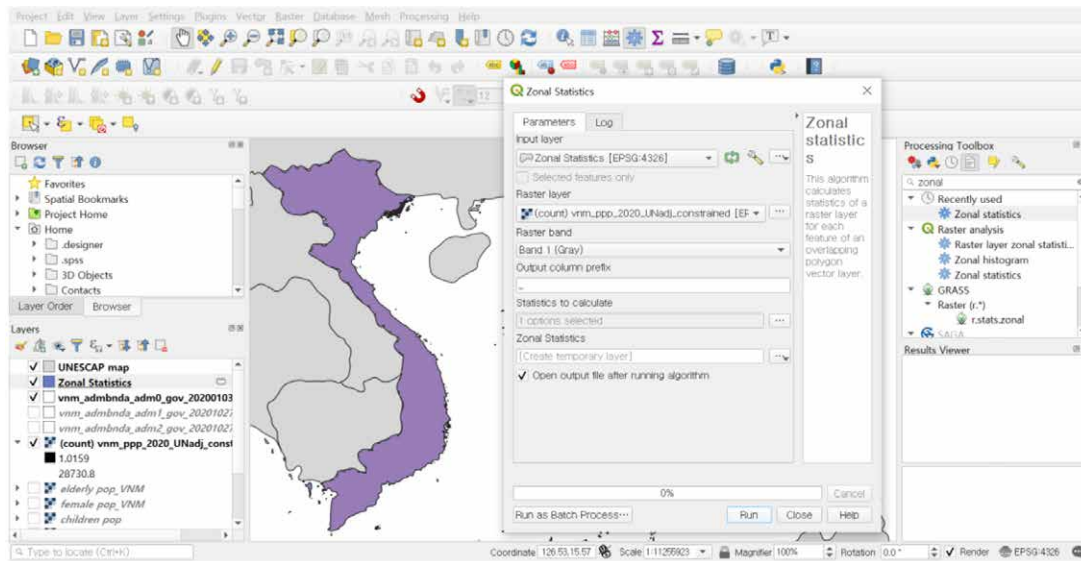


When the new 'Zonal Statistics' shapefile is created, open the attribute table and find the sum values for each wind speed category. Select all the features (Ctrl + A), and copy and paste the fields into a spreadsheet (e.g., in Microsoft Excel).

16



To get the total population values, use the 'Zonal Statistics' tool, now based on the population raw data and the admin-level 0 boundary file (i.e., national boundaries). This will yield the sum value of the population within the national boundary of Viet Nam.



After running the tool, open the attribute table of the newly created 'Zonal Statistics' layer. This will reveal the total population value (97,411,255 for Viet Nam), which can be used to complete the calculation table.

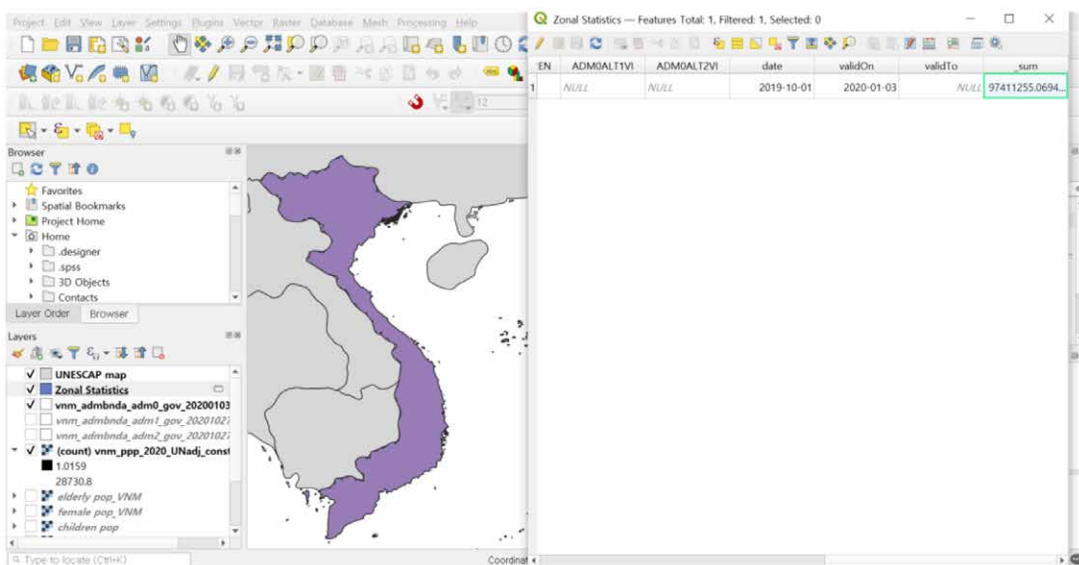


Figure 1: Total population in each category of forecasted extreme wind speed probability

Probability (%) of strong wind (25.7m/s)	Population exposed	Total population	% of population exposed
> 90	2,412,500	97,411,255	2.48%
71 - 90	874,091		0.90%
50 - 70	1,134,937		1.17%
< 50	2,627,150		2.70%

References

What Is Spatial Data? The Basics & GIS Examples: FME. Safe Software. (n.d.). <https://www.safe.com/what-is/spatial-data/>. Accessed 2 May 2021.

