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Economic Resilience and Vulnerability Assessment of Local Economies in the Visayas and Mindanao Regions to Hydrometeorological Disasters

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***Abstract*: The Philippines, located on the "typhoon belt," is constantly battered by hydrometeorological disasters such as tropical storms, storm surges, and flooding. Despite being susceptible to hazardous conditions, the country lacks data pertinent to local economic resilience and vulnerability indicators, explaining the high social and economic losses whenever disastrous events occur. This study assessed the economic resilience and vulnerability levels of the two main islands of the Philippines, the Visayas and Mindanao, at the regional level for the period 2000–2022 and examined their connection to the severity of the impact of hydrometeorological disasters. Composite indices were formed, namely the economic resilience index (ERI) and vulnerability index (VI). The two indices were examined using three analytical methods: matrix, trend, and mapping. The researchers conducted an econometric analysis using the pooled data regression, with the vulnerability and economic resilience variables as the explanatory variables and the impact of disasters as the dependent variable. The panel data showed that the economic resilience factors, education cohort survival, number of beds in health institutions, and ownership of living places negatively affect the impact of disasters. In contrast, the local government revenue positively impacts the disasters. The vulnerability variables frequency of disasters, rainfall volume, wind intensity, population density, and agricultural land use contribute to the impact of disasters. By strengthening their economic resilience, the various regions can lessen the effects of disasters based on the matrix and trend analysis. Therefore, the government should enhance the economic resilience of areas vulnerable to hydrometeorological disasters.**

***Keywords*: economic resilience, hydrometeorological disasters, vulnerability.**

1. Introduction

The Philippines is one of the countries with the highest risk of natural disasters. According to the World Risk Index Report, the country ranked third among over 170 countries from 2011 to 2019 and first in 2022, which illustrates the general idea that the advent of a disaster depends both on how severely natural disasters affect a society and on how vulnerable a society is to its impacts. This persistent high ranking of the Philippines indicates that it is a country with a high risk of disaster and shows there has been little progress in the past years to lessen the effects of disasters.

In this study, the researchers focused on hydrometeorological disasters, which covered tropical cyclones, thunderstorms, coastal storm surges, and floods. The Philippines, located in what is often described as the ‘typhoon belt’, is one of the countries in the world that experiences cyclones the most frequently. Five of the 19–20 cyclones that pass through the Philippine Area of Responsibility (PAR) each year are destructive. In addition to this, it was projected that by the year 2050, the increase in annual mean temperatures in the country would range from 1.8°C to 2.2°C, which can potentially lead to more severe and higher occurrences of tropical storms and typhoons [8].

Observing the three main island groups in the Philippines, Luzon, Visayas, and Mindanao, it can be observed in vulnerability studies that Luzon has the most vulnerable regions to tropical cyclones in the country. However, Visayas and Mindanao are equally becoming increasingly at risk due to a rising number of tropical cyclones approaching the southern half of the country. This is especially true given climate change, where most regions of the country can expect higher rainfall during the rainy season, which can lead to more frequent and severe floods. The expected increases in rainfall will be the greatest over the Visayan Islands [68].

Thus, the aims of this study are to (1) assess how the identified economic resilience factors and vulnerability factors affect the impact of hydrometeorological disasters on local economies in Visayas and Mindanao and (2) address the gap in knowledge on the level of economic resilience and vulnerability of the regional administrative economies in Visayas and Mindanao to the effects of hydrometeorological disasters. Meanwhile, it can be utilized as an assessment of how the measures may help in policy formulation, addressing how to strengthen economic resilience against hydrometeorological disasters or manage the current level of vulnerability in Visayas and Mindanao.

2. Review of Related Literature

The vulnerability variables of this study are expected to increase the impact of hydrometeorological disasters on the local economies of the Visayas and Mindanao regions as they

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increase the economy's exposure to external shocks. Therefore, the vulnerability factors exhibit a positive relationship to the impact of hydrometeorological disasters. The vulnerability factors of disaster frequency, average rainfall volume, and wind intensity are commonly studied in disaster research as they are important in determining the impact of a disaster. Studies have shown that an increase in the frequency of disasters, as well as higher rainfall volume and wind intensity, can lead to greater vulnerability and more severe impacts on lives, livelihoods, and infrastructure. For instance, livelihood disruptions [35], [75], a higher likelihood of disaster-related factors flooding [14], rising economic damages [60], and temporary poverty [25] were intensified by the frequency of hydrometeorological disasters. The average rainfall volume will likewise increase the number of fatalities due to the landslides and floods it can induce [73], while at the same time destroying properties, infrastructures, and agricultural crops [17], [18], [24]. In addition to this, studies conducted showed that wind intensity contributed directly to several factors, namely: affected population rate, direct economic losses rate, affected houses and crops rate, and asset damages [29], [33], [72]. This was opposed by a study, which found that fatalities do not have a significant relationship with wind intensity [73]. A study also indicated that poor resilience levels of areas, which can be described as those with irrational economic plans and poor stability of infrastructures, increase the frailty against intense winds of hydrometeorological disasters [58].

Population density is also an important vulnerability factor in disaster research, especially in coastal areas, where they can increase the risk of loss of life and property damage. A study has shown that densely populated areas are more vulnerable to the impact of disasters, particularly hurricanes and typhoons, which can cause significant damage to infrastructure, homes, and livelihoods [56]. High concentrations of people within an area hinder evacuation, which increases injuries and fatalities [5], [26], [37], [65]. Similarly, households with many individuals residing in them are highly vulnerable since they have little to no funds for emergency situations [34].

Forest cover loss and agricultural land use are other important vulnerability factors, as they can increase the risk of landslides and soil erosion, which can lead to significant damage to infrastructure and houses. Studies have shown that areas with high rates of forest cover loss and agricultural land use are more vulnerable to landslides and soil erosion during heavy rainfall events, which can result in loss of life and damage to property. The loss of forest cover contributes to the impact of hydrometeorological disasters, especially due to deforestation activities [48]. Studies mentioned the role of forests in minimizing the catastrophic impacts of floods caused by storms [7], [45], [62]. Forest cover contributes to the recovery capacity of a particular region [54]. Lack of replacement for trees damaged by previous storms increases the vulnerability of the area, unlike areas with sufficient forest cover that can possess high soil water retention levels [1], [67]. Agricultural regions are more vulnerable to the impacts of hydrometeorological disasters [13], [36]. This is due to their heavy reliance on climate-sensitive industries with lower adaptive capacities. Such disasters can significantly affect the productivity, sustainability, and livelihoods of farmers and rural communities, causing soil erosion, topsoil loss, waterlogging, infrastructure damage, and yield losses. Climate change is anticipated to exacerbate these impacts, leading to lower agricultural productivity, yield losses, and poverty. Thus, these vulnerability factors should be considered in disaster risk reduction efforts and emergency management planning, as they can help identify areas of high risk and guide resource allocation and recovery operations. Understanding the impact of these factors on disaster vulnerability can help mitigate the negative effects of disasters and increase community resilience.

Contrarily, the economic resilience variables of this study are expected to decrease the impact of hydrometeorological disasters on the local economies of the Visayas and Mindanao regions as they increase the economy's coping ability with external shocks. Thus, the indicators for economic resilience exhibit a negative relationship to hydrometeorological disasters. For instance, families with higher average incomes and savings may be better able to withstand the financial impact of a disaster. Families with higher incomes are better equipped to absorb the impact of disasters, such as loss of income or property damage, and they have higher safety demands [48], [69]. Several studies have shown that wealthier households with secondary sources of income and less dependence on agriculture are more resilient to disasters, while low-income households with a high dependence on agriculture are more vulnerable to economic losses from disasters [13], [22], [35], [51]. However, the people with low income tend to suffer greater losses in relative terms [20]. Families with higher savings are better prepared to cope as it provides a cushion for families to fall back on in times of need [49], [52], [61]. Savings can be used to pay for basic needs, smooth consumption, and rebuild assets. Promoting the concept of personal savings can increase preparedness for disasters [31]. Moreover, a higher marginal propensity to save before disasters can decrease the risk of being unemployed [4].

The number of health professionals and the number of beds in health institutions are critical factors in disaster resilience as they determine the ability of a community to respond to health emergencies [33]. Communities with more health professionals and beds are better equipped to handle the medical needs of disaster victims and reduce injuries and casualties [21], [59]. Hospital resilience is also essential for disaster recovery, so continual training, proper health financing, restructuring of physical facilities, and partnerships with volunteers can play a crucial role in mitigating [3], [32]. Next, education cohort survival is an indicator of the quality of education and the ability of the workforce to adapt to changing circumstances [49]. It can also influence risk perception, skills, knowledge, poverty, health, and access to information [33], [42], [59]. A study also found that the higher the number of illiterate individuals in a vulnerable community, the higher the potential casualties [77]. However, some studies have shown no link between education and resilience to natural disasters, as adaptation also happens unconsciously [10], [38], [64].

Local government revenue is an important factor as it determines the ability of a community to provide essential services, such as disaster response and recovery [49], [53]. Communities with higher revenue are better equipped to respond to disasters and help their residents recover, especially in rural areas [35], [70]. Proper budget allocation and financial build-up for disaster risk reduction and collaboration between institutions and the government are crucial for economic resilience [2], [46], [50], [55]. Sturdy house materials and ownership can also play a role in the resilience of a community, as well-maintained homes can withstand the effects of a disaster better than poorly constructed ones. Quality or sturdy materials such as bricks and cement that are employed in the construction of infrastructures and houses play a key role in improving the quality of housing, reducing the amount of damage received from hydrometeorological disasters [15], and in developing resistance against wind and rain [12]. Historical exposure to such natural hazards is one of the reasons why some regions have developed better quality infrastructure and higher housing resilience, while poverty contributes to poor to average housing quality in some places [23]. Owning a living place is crucial for enhancing resilience and coping with floods in Pakistan and Sri Lanka [13], [30]. Living place ownership also plays a significant role in determining poverty and vulnerability to flood risk [63]. Overall, the peace of mind aspect of owning a home can also increase resilience in the face of natural disasters [66].

Access to drinking water and electricity are essential factors in disaster resilience, as they help maintain the basic needs of life and support recovery efforts. Electricity connectivity of households contributes directly to lessening the negative social impact of disasters [49] and increasing the chances of coping with the effects of such disasters [4]. Electric grid resilience is a crucial factor to maintain stable electricity supply during disasters [11], and this can be improved by various countries via cable reinforcement measures [76] and the establishment of microgrids per region [67]. While access to stable drinking water is crucial for economic resilience and public health, lack of access to safe drinking water sources can lead to water-borne diseases and aggravate the effects of disasters, especially in rural areas of developing countries [36], [40], [43], [49]. Conversely, access to safe drinking water improves health outcomes and economic resilience and reduces the negative effects of disasters [4]. Improving access to safe drinking water sources can be achieved through various measures, such as efficient pipe-borne water systems, truck-borne water supply, clean ponds and wells, and swamp irrigation systems, with the involvement of national water authorities and companies [57].

The GRDP and employment levels of a community can play a role in its resilience, as they can determine the overall economic vitality and ability to recover from the effects of a disaster. Communities with higher GRDP and employment are better equipped to recover from the economic impact of disasters. The use of GDP per capita as an indicator for economic resilience to disasters has been supported by studies [19], [69], [72]. A higher GDP per capita indicates higher economic resilience, as it leads to increased demand for security and more efficient risk-reduction measures. Using GRDP, high GRDP levels will likewise directly influence economic resilience [44] and the restorative capacity of regions that are recovering from the costs incurred due to the damage dealt by hydrometeorological disasters [74]. Likewise, employment levels in the regions must remain strong, as this is also vital for two elements associated with disaster resilience, namely, resistance and recovery capacity [6], [27], [28], [38], [70]. These studies have shown that regions with higher rates of unemployment before a disaster are more susceptible to human loss and have weaker economic and social conditions. To do so, social inequality must be lessened, and stable employment must be evident to avoid job loss and wage penalties [71]. Thus, the economic resilience of a community is complex and multifaceted and is affected by various factors that must be considered in disaster planning and recovery efforts. This includes income, savings, education, health, government revenue, housing, basic services, and economic vitality. All of these factors are critical to ensuring that communities can withstand and recover from disasters.

A. Research Simulacrum

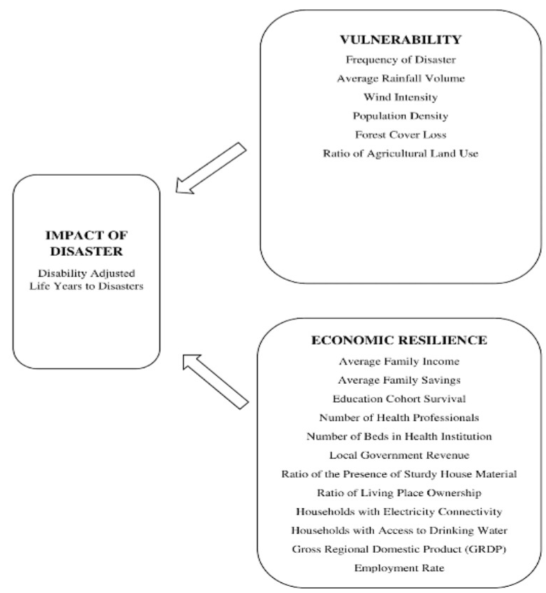


Fig. 1. Research Simulacrum of the relationship between Disaster Impact (DV), Economic Resilience (IV), and Vulnerability (IV)

According to the research simulacrum (Figure 1), it is expected that the economic resilience and vulnerability variables will either reduce or increase the impact of hydrometeorological disasters, as measured by Disability Adjusted Life Years of Disaster (DALY of Disaster). Consequently, it is possible to determine whether a region can cope more easily or would suffer more from the impact of a disaster by utilizing a composite index to characterize the economic resilience and vulnerability of local economies.

3. Methodology

This quantitative study covered the period 2000–2022, using annual data for the two main islands of the Philippines, Visayas and Mindanao. The Visayan region includes Regions VI, VII, and VIII, while the Mindanao region is divided into six, Regions IX, X, XI, XII, XIII, and the Bangsamoro Autonomous Region in Muslim Mindanao (BARMM). Data from preceding years is not available in the Philippines Statistics Authority database at the regional level, and for this reason, years prior to the 2000s were not included in the study. Moreover, the regional data of Luzon was not included in the study as the researchers wanted to focus on improving the economic resilience and lowering the vulnerability levels of the Visayas and Mindanao regions.

Secondary data for economic resilience indicators, namely, average family income, average family savings, education cohort survival rate, number of health professionals, number of beds in health institutions, government revenue, house material, ownership of living place, electricity connectivity, and access to drinking water, were obtained from the Family Income and Expenditure Survey (FIES) and the Annual Poverty Indicators Survey (APIS) of the Philippine Statistics Authority (PSA) and the Department of Health (DOH). Similarly, data for the vulnerability variable's population density, employment rate, and the gross regional domestic product (GRDP) per capita were gathered from PSA. On the other hand, secondary data for vulnerability variables, namely the frequency of disasters, mortality, affected individuals, and monetary damage, were collected from the Center for Research on the Epidemiology of Disasters (EM-DAT CRED), while the average rainfall volume and wind intensity was collected from the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA). Lastly, data regarding primary forest cover was obtained from Global Forest Watch, an initiative of the World Resources Institute, while agricultural land use was collected from PAGASA and the Department of Agriculture (DA).

A. Composite Index

The variables for economic resilience and vulnerability were all converted into a dimensional index with the intention of normalizing the values of each variable [16]. Afterward, the composite index was created out of the normalized values. Equation 1 shows the dimensional index:

$$X_t^n = X_t - min(X_t) \,/\, max(X_t) - min(X_t) \quad (1)$$

Where:

- X_t^n - factor's normalized value for a given region in Visayas/Mindanao (n) at a specified time (t)
- X_t - factor's value at a specified time (t)
- $min(X_t)$ - factor's lowest/minimum value for a given region in Visayas/Mindanao (n) at a specified time (t)
- $max(X_t)$ - factor's highest/maximum value for a given region in Visayas/Mindanao (n) at a specified time (t)

To determine the overall economic resilience and vulnerability for both Visayas and Mindanao, the composite indices using equal weights, namely: economic resilience index (Eq. 2) and vulnerability index (Eq. 3) were formed [9]:

$$ERI = \Sigma X_t^n \,/p \quad (2)$$

$$VI = \Sigma X_t^n \,/p \quad (3)$$

Where:

- ERI - yields the value of the composite index for economic resilience
- VI - yields the value of the composite index for vulnerability
- ΣX_t^n - summation of economic resilience and vulnerability variables' normalized values
- p - total no. of variables for economic resilience or vulnerability

The results of the economic resilience and vulnerability indices were used for trend, matrix, and mapping analyses.

1) Matrix Analysis

The matrix that was used for the analysis was a modified matrix based on different circumstances, as shown in Figure 2 [9], [41]. It was divided into four quadrants: the average economic resilience index (AERI), shown by the horizontal blue line, and the average vulnerability index (AVI), shown by the vertical red line.

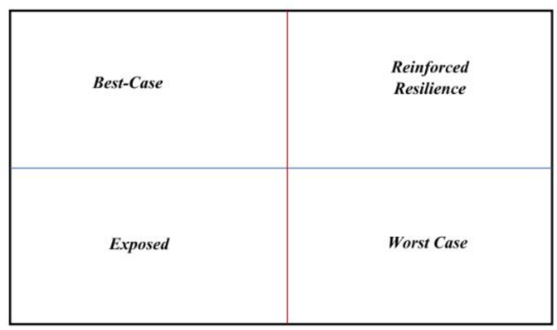


Fig. 2. Economic resilience and vulnerability index matrix

The first quadrant is labeled the "reinforced resilience quadrant" and describes an area that has both high economic resilience and vulnerability. This means that the region's ability to handle the effects of disasters is reinforced by its economic resilience, despite existing vulnerability factors. The second quadrant is called the "best case quadrant" and refers to an area that has high economic resilience and low vulnerability. This quadrant suggests that the region's economic resilience is sufficient to mitigate the effects of disasters and vulnerability. The third quadrant is known as the "exposed quadrant" and indicates a region with low vulnerability and economic resilience. This means that despite having a low level of vulnerability, the region is unable to improve its economic resilience. The fourth quadrant is called the "worst-case quadrant," which identifies an area with high vulnerability and low economic resilience. Regions in this quadrant are expected to suffer greatly from natural disasters due to their high vulnerability and limited ability to cope with disaster impacts based on their low economic resilience index.

2) Trend Analysis

In assessing the various trends that were exhibited throughout the period of 2000–2022, the economic resilience and vulnerability index results for each region of the two groups of islands: Visayas and Mindanao, were analyzed, and trend lines were generated by utilizing the Microsoft Excel software. The generated trend lines were assessed as to whether or not the economic resilience and vulnerability variables contributed to diminishing or increasing the impact of hydrometeorological disasters in the aforementioned portions of the Philippines.

3) Economic Resilience, Vulnerability, and Net Economic Resilience Mapping

A density analysis was carried out in order to produce heat maps. This was conducted by the researchers, wherein the index values of the economic resilience and vulnerability factors by region at a time were used to produce spatial heat maps. Each cell corresponded to an area within a particular region, which had an equivalent density value, and the wholeness of each region's layer was visualized with the use of the temperature gradient feature, which was derived from several fixed intervals of the index values that the researchers programmed in QGIS 3. More intense colors represent larger values of a particular vulnerability variable of that area or region, while less intense colors signify smaller values of the vulnerability variable of the area or region. Lastly, the spatial heat maps generated were in 5-year intervals, which showed how the ERI and VI changed gradually, increasing or decreasing the effects of disasters in the process. Three outputs were produced here, namely: a vulnerability index map, economic resilience map, and net-economic resilience map.

4) Econometric Analysis

To conduct the panel data analysis, the composite index variables were disaggregated. The Disability Adjusted Life Year (DALY) for disaster was used as the dependent variable in the panel data analysis. This variable was taken from the WHO's Disability Adjusted Life Year lost due to diseases and injuries and was adapted to measure the impact of disasters in a non-monetary measure [39]. This tool considers various factors caused by disasters, such as mortality, injuries, and property damage. It converts them into an index representing the number of years of life lost in a country due to a disaster. The Life Years Index (Equation (4)) was created to address differences in the value of money across countries, and it measures life years lost in a disaster, considered a significant and equal measure in modern society.

$$Lifeyears = L[M \; x \; (A^{exp} - A^{med})] + I(N) + DAM\,(Y/P) \quad (4)$$

Whereas:

- $L(M, A^{death}, A^{exp})$ is the number of years lost due to event mortality, calculated as: $M \; x \; (A^{exp} - A^{death})$
    - L – a function derived from mortality (M)
    - A^{death} – the age of those who died
    - A^{exp} – the age expectancy (92 yrs. Old for all countries, according to the United Nations)

However, it is possible to utilize the nation's median age because it is challenging to obtain the age of people who died [39]. By doing so, the previous formula for the L function became: $M \; x \; (A^{exp} - A^{med})$

- I(N) is the no. of people injured or affected persons
- DAM(Y,P) is the number of human years lost as a result of the damage to capital assets and infrastructure, including residential and commercial buildings, public buildings, and other types of infrastructure such as roads and water systems, calculated as: $DAM = Y/P$
- **Y –** monetary damages (value of the destroyed or damaged capital)
- **P –** per capita annual income or annual wage rate

For the purpose of identifying the relationship of the dependent variable (impact of disasters) with the two independent variables (economic resilience and vulnerability), this study used Panel Data Analysis in dealing with data gathered from multiple years and regions of Visayas and Mindanao.

The researchers utilized the generic panel data model (Eq. 5) to arrive later on with their regression model involving the variables they've chosen for the study:

$$Y_{it} = \beta_o + \beta_1 X_{1t} + \beta_2 X_{2t} + \ldots + \beta_i X_{it} + \varepsilon_{it} \quad (5)$$

Whereas:

- Y_{it} is the DALY for disaster
- X_{it} are the variables affecting Y
- ε_{it} is the error term

Equation 1 was converted to its natural logarithmic to interpret the coefficients as approximate proportional differences, although variables measured in ratio form were not converted to natural log. Equation 6 shows the natural log model:

$$lnY_{it} = \beta_o + \beta_1 lnX_{1t} + \beta_2 lnX_{2t} + \ldots + \beta_i lnX_{it} + \varepsilon_{it} \quad (6)$$

Finally, the regression models used for this study is shown in Equation 7, with the vulnerability variables, and in Equation 8, with the economic resilience variables:

$$lnDALYD_{rt} = \beta_0 + \beta_1 lnFreq_{rt} + \beta_2 lnRain_{rt} + \beta_3 lnIntensity_{rt} + \beta_4 PopuDen_{rt} + \beta_5 ForLoss_{rt} + \beta_6 Agri_{rt} + \varepsilon_{rt} \quad (7)$$

$$lnDALYD_{rt} = \beta_0 + \beta_1 lnAveFamInc_{rt} + \beta_2 lnAveFamSav_{rt} + \beta_3 Educ_{rt} + \beta_4 lnHealth_{rt} + \beta_5 Beds_{rt} + \beta_6 lnGovRev_{rt} + \beta_7 HouseMat_{rt} + \beta_8 lnOwn_{rt} + \beta_9 Elec_{rt} + \beta_{10} Water_{rt} + \beta_{11} lnGRDPrt + \beta_{12} Employ_{rt} + \varepsilon_{rt} \quad (8)$$

Where:

- $DALYD_{rt}$ – the value of Disability Adjusted Life Year for Disaster in region r at time t measured in years
- $Freq_{rt}$ – the annual number of hydrological disasters or water-related disasters in region r at time t

- $Rain_{rt}$ – the annual level of average Rainfall Volume experienced annually by region r at time t measured in millimeters (mm).
- $Intensity_{rt}$ – the maximum wind speed per tropical cyclone by region r at time t measured in kilometers per hour (km/h)
- $PopuDen_{rt}$ – the no. of people per sq. km. of land area by region r at time t
- $ForLoss_{rt}$ – the ratio of the number of hectares loss of Forest Cover in region r at time t
- $Agri_{rt}$ – the percentage of land used for agriculture by region r at time t
- $AveFamInc_{rt}$ – the annual Average Family Income in region r at time t measured in Philippine pesos
- $AveFamSav_{rt}$ – the annual Average Family Savings in region r at time t measured in Philippine pesos
- $Educ_{rt}$ – the Average Cohort Survival Rate for Education in region r at time t
- $Health_{rt}$ – the number of Health Professionals per 1,000 people by region r at time t
- $Beds_{rt}$ – the number of beds in health institutions per 1,000 people by region r at time t
- $GovRev_{rt}$ – the annual Government Revenue in region r at time t measured in Philippine pesos
- $HouseMat_{rt}$ – the ratio of the presence of Sturdy House Material in region r at time t
- Own_{rt} – the ratio of Living Place Ownership in region r at time t
- $Elec_{rt}$ – the ratio of number of households with Electricity Connectivity in region r at time t
- $Water_{rt}$ – the ratio of number of households with Access to Drinking Water in region r at time t
- $GRDP_{rt}$ – the annual Gross Regional Domestic Product per capita by region r at time t
- $Employ_{rt}$ – the annual employment rate by region r at time t
- ε_{rt} – the error term
- B_0 – the constant
- β_1, β_2, β_3, β_4, β_5, β_6, β_7, β_8, β_9, β_{10}, β_{11}, β_{12} – the parameters for the variables under the econometric model

The Gnu Regression, Econometrics, and Time-Series Library (GRETL) software was employed as a means to run the regression model. The researchers provided the interpretations and corresponding analyses for the results in the succeeding chapters. Alongside this, regression errors such as multicollinearity and heteroskedasticity were assessed through the results of the Variance Inflation Factor (VIF) and White's Test for Heteroskedasticity. Autocorrelation was also assessed using the Durbin-Watson's Test given that the researchers are using panel data. The model that was used for the panel data analysis was the pooled Ordinary Least Squares (OLS).

4. Results and Discussion

A. Results

1) Matrix Analysis

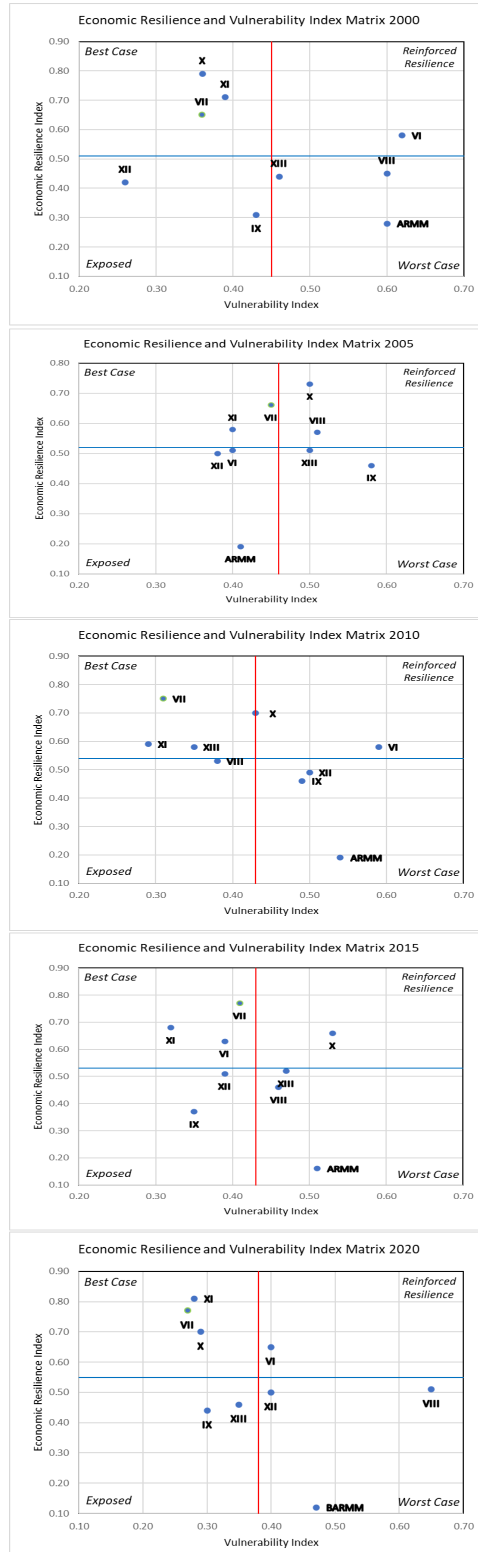


Fig. 3. Economic resilience and vulnerability index matrices

The economic resilience and vulnerability indexes for 2000, 2005, 2010, 2015, and 2020 are displayed in five matrices in

Figure 3. From 2000 to 2020, Regions VII, Central Visayas, and Region XI, or Davao Region, were consistently situated in the "best case quadrant," suggesting a high level of economic resilience and low vulnerability. Both regions contain the main economic hubs of each of the main island groups, the province of Cebu for Visayas and Davao City for Mindanao. Region VII and Region XI are also not frequented by natural disasters, which is vital since it increases the region's ability to meet its urgent demands before and after a disaster.

On the other hand, ARMM or, BARMM, and Region VIII, or Eastern Samar, were primarily found in the "worst case quadrant," which denotes high vulnerability and low economic resilience. ARMM/BARMM has the lowest economic resilience elements of all the regions hit by disasters. Its economic resilience score is likewise far lower than the AERI, making it severely vulnerable to disasters. In the event of a major disaster, the region might require external help to lessen the disaster's immediate effects. In 2005, it was situated in the "exposed quadrant," indicating a lower vulnerability index than the AVI of the country. Due to its eastern location facing the Pacific Ocean and within the Pacific Ring of Fire, Region VIII is one of the most disaster-prone places in the nation. Because of the frequent destruction caused by hydrometeorological disasters, its provinces, particularly the Samar provinces, are among the poorest in the country, demonstrating their slow recovery from natural disasters. However, Region VIII was susceptible in 2005 and was located in the "reinforced resilience quadrant," where it had a higher economic resilience index than the AERI in the Philippines. The notable 4.7% growth in employment and the rise in the average family income may be the possible cause.

Region VI, Western Visayas, and Region X, or Northern Mindanao, were the most frequently found in the "reinforced resilience quadrant," showing that they have a high economic resilience index despite having a high vulnerability index. Among the wealthiest provinces in the Philippines in terms of assets are the provinces of Iloilo and Negros Occidental in Region VI and the province of Bukidnon in Region X. The regions' economic resilience allows them to withstand the impact of disasters. For instance, when Typhoon Bopha, locally known as Super Typhoon Pablo, hit Region X, primarily Bukidnon, in 2012, their economic resilience index increased the following year. In 2000 and 2020, Region X was situated in the "best case quadrant." This can be attributed to having a low frequency of disasters and rainfall. In 2015, Region VI was located in the "best case quadrant." The gross regional domestic product (GRDP) growth of Region VI was higher than that of the other Visayan regions from 2013 to 2015, which could be a sign of recovery as they had recently been severely damaged by Typhoon Haiyan, also known locally as Super Typhoon Yolanda.

Region IX, Zamboanga Peninsula, and Region XII, or Soccsksargen, were typically found in the "exposed quadrant," indicating that the economic resilience and vulnerability indexes are lower than the AERI and AVI. The provinces of Zamboanga del Norte in Region IX and Sarangani in Region XII are among the poorest provinces in the country. This is concerning as being in the exposed quadrant means that a region cannot build up its economic resilience even if it has a low level of vulnerability, making it vulnerable to unpredictable rain or typhoon landfalls due to climate change. For instance, in October 2022, Tropical Storm Nalgae, locally known as Paeng, devastated these regions, shocking officials because it was forecasted to hit the Visayas and then move towards Luzon.

2) Trend Lines

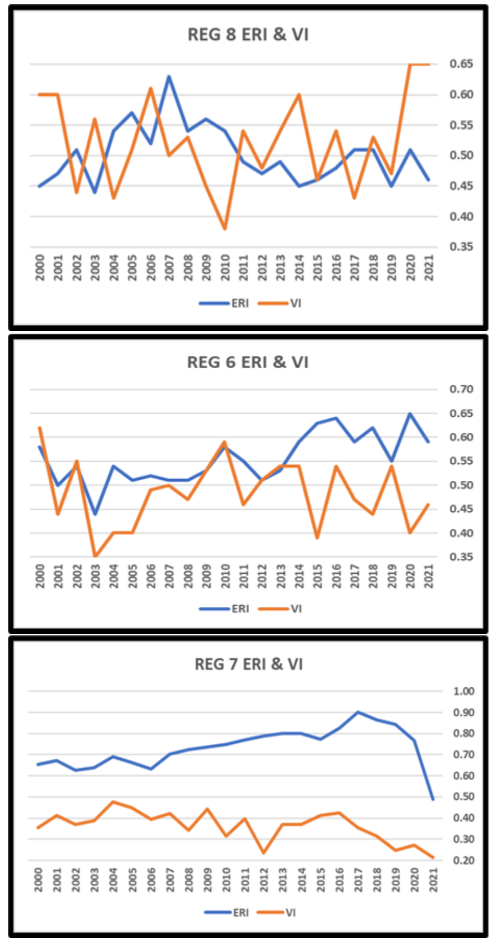


Fig. 4. Visayas regions economic resilience index & vulnerability index trend lines

Figure 4 shows that the Visayas Regions' ERI differs in their levels across the period of 2000-2022. Specifically, Region VI and VIII's ERI stayed below 0.40, where the former gradually increased from 2012, while the latter started from 2014. Consequently, both VI remained remarkably higher than their ERI throughout the period. Region VI's VI is continually decreasing while Region VIII's VI continues to worsen up to the date. On the other hand, Region VII's ERI has been very high since 2000, with all indices above the 0.60 level. However, a sharp decline was recorded during 2021, breaching its sustained high ERI across the years. Region VII's VI exhibited the same declining behavior as its ERI, with its VI almost breaking through the 0.20 level.

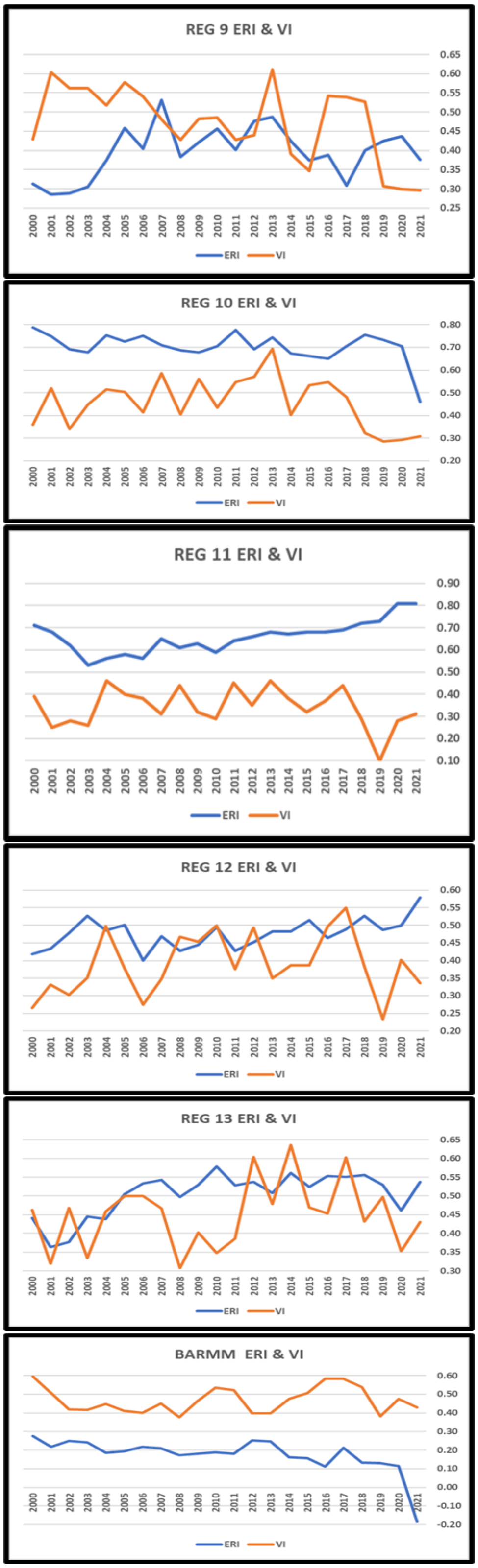


Fig. 5. Mindanao regions economic resilience index & vulnerability index trend lines

Figure 5 is indicative of ERI downtrends in the majority of Mindanao Regions. Regions IX and XIII deviated by a slight margin from their highest annual index. Regions X and BARMM, meanwhile, experienced a sharp drop from 2020-2021, with the latter passing through the zero threshold. In general, the VI of the Mindanao Region are all in a state of decline up to the latest period.

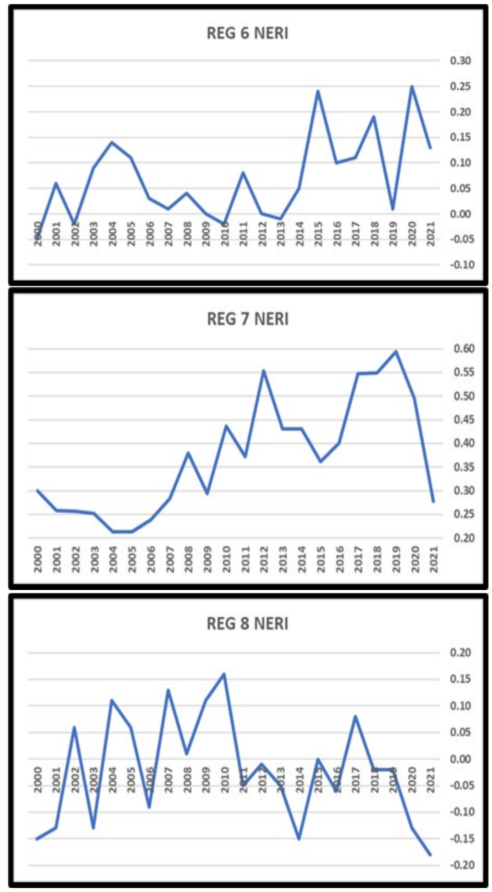
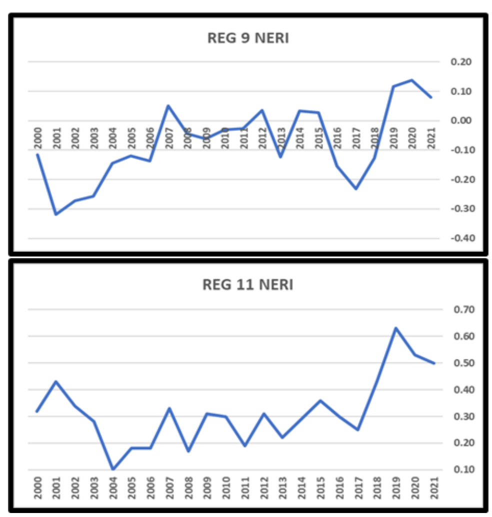


Fig. 6. Visayas regions net economic resilience index trend lines

Concurrently, as shown in Figure 6, the NERI of most of the Visayas Regions surged within the last decade. Still, it was notable that the NERI of Regions VI and VIII both stayed beneath the zero threshold while Region VII almost burst through the resistance level of 0.60 before eventually demonstrating a major drop from 0.50 to slightly below the 0.30 index level from 2020 to 2021.



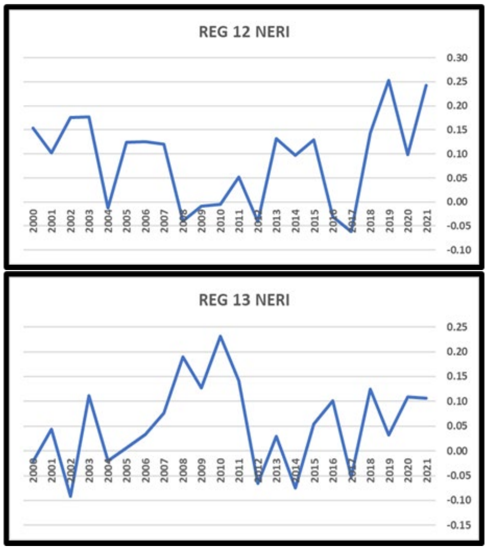
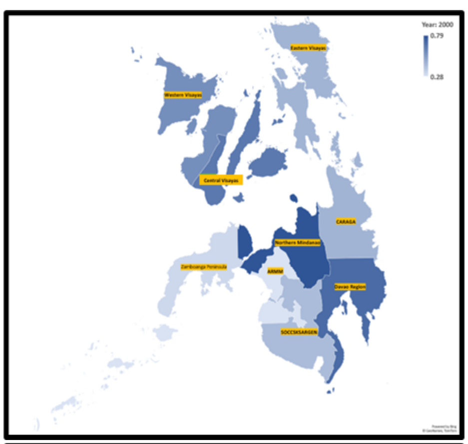
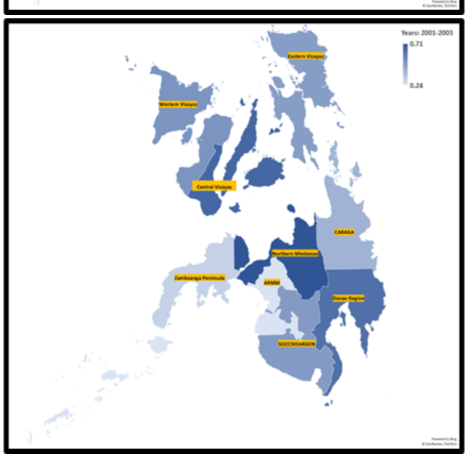


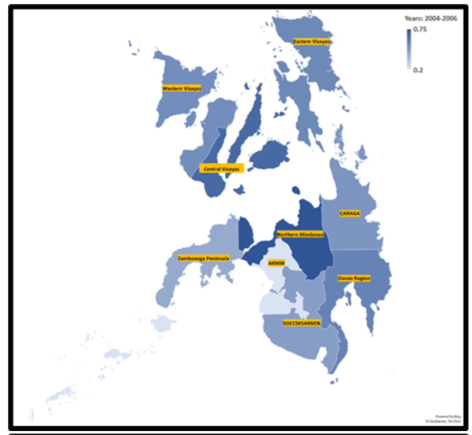
Fig. 7. Mindanao regions net economic resilience index trend lines

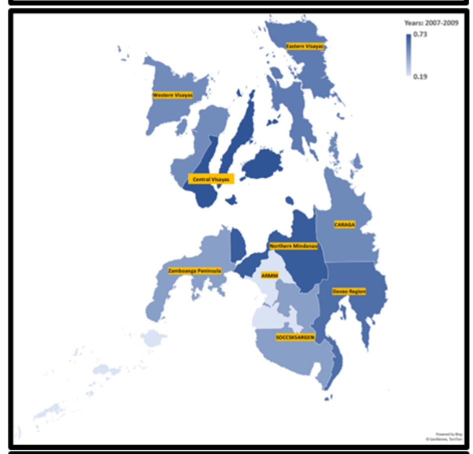
On the contrary, as shown in Figure 7, almost all of Mindanao Regions' NERI grew, except two regions that exhibited a continual record of diminishing NERI, namely, Regions XIII and BARMM. However, given that the latest years are the most crucial observations in the trends, Regions IX, X, and BARMM's NERI all portrayed declining rates of 42.86%, 63.41%, and 69.44%, respectively. On the contrary, Regions XI, XII, and XIII steadily improved starting from the years 2003, 2017, and 2002, respectively.

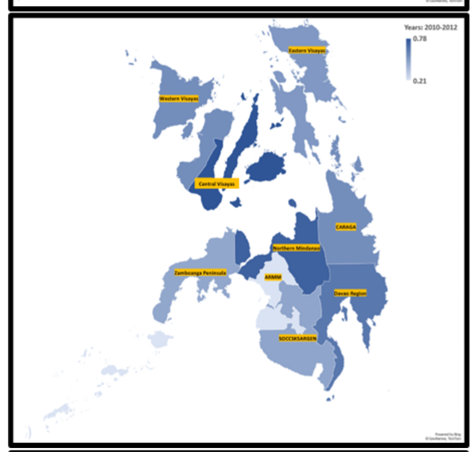
3) Mapping Analysis

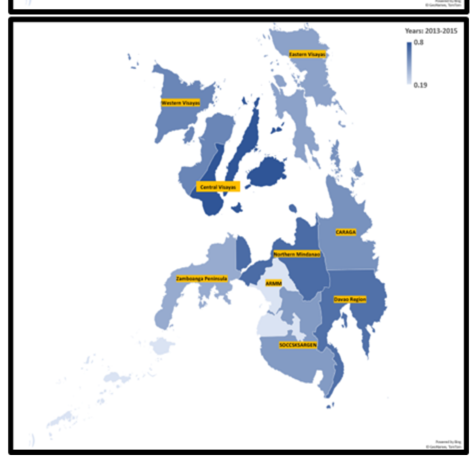












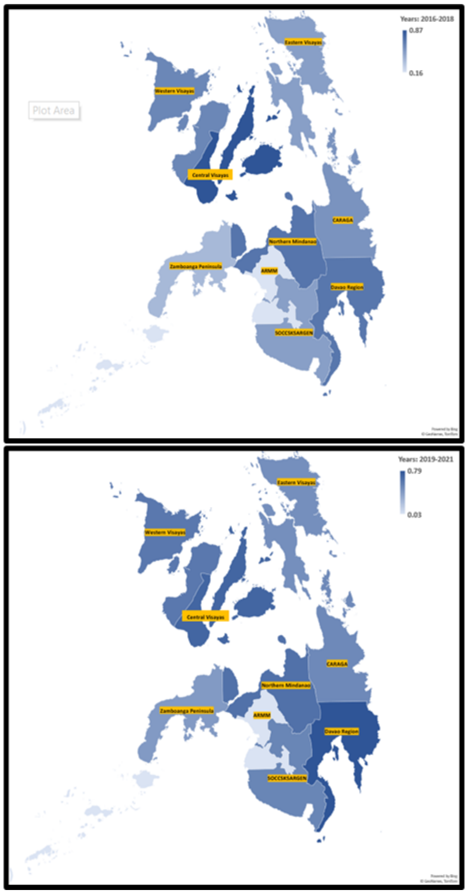
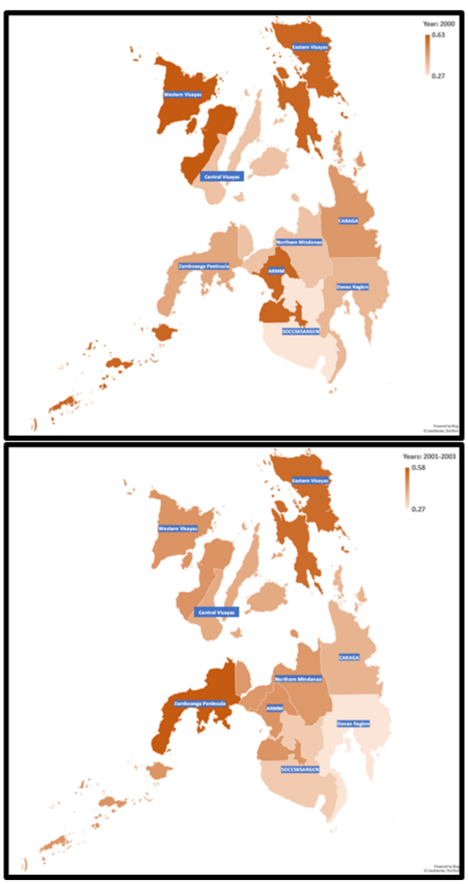
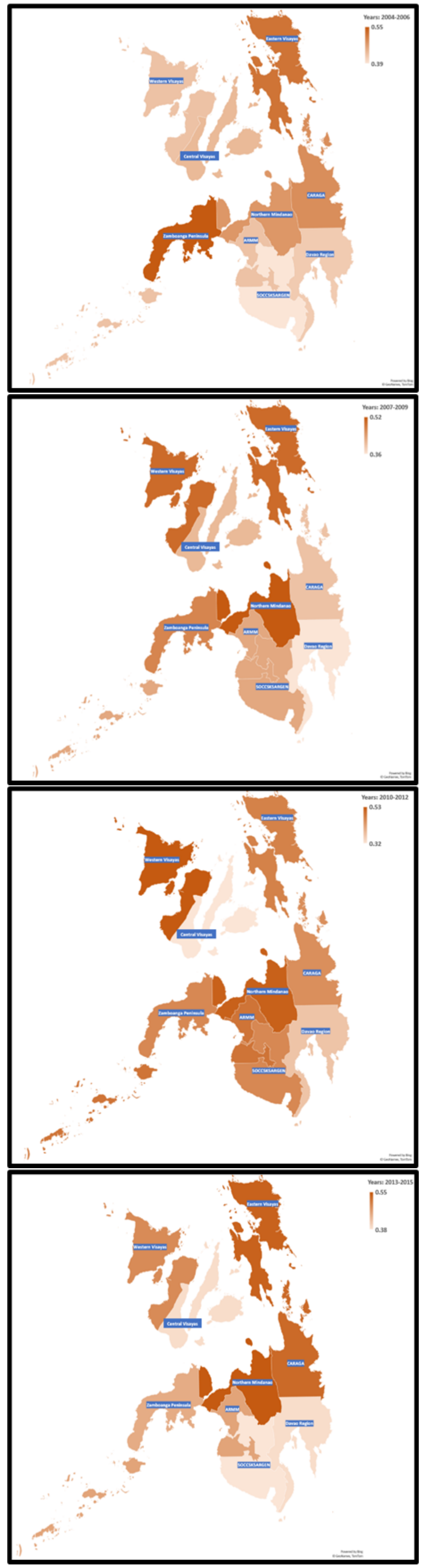


Fig. 8. Economic resilience maps





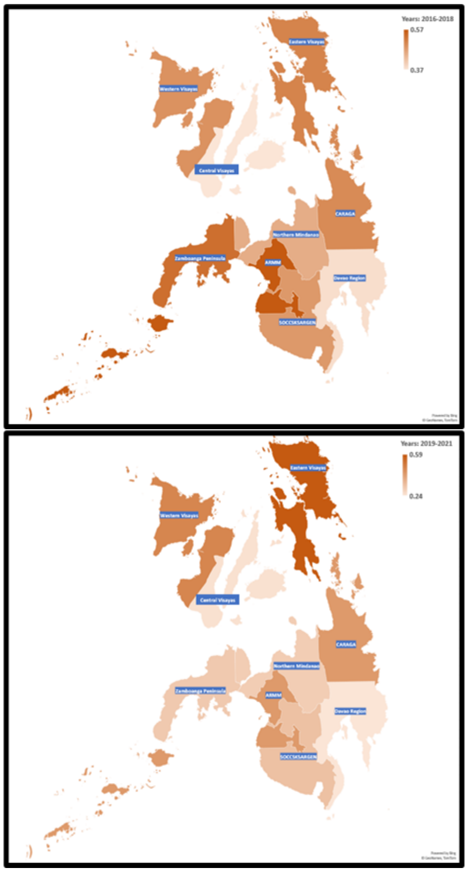
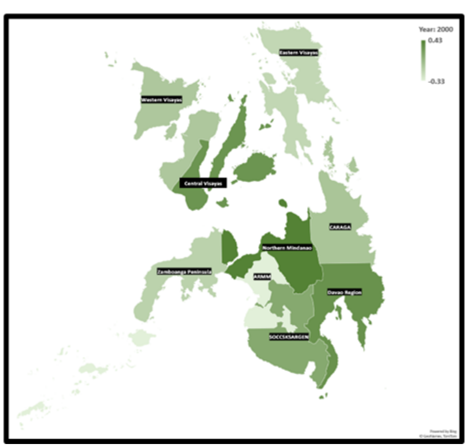


Fig. 9. Vulnerability maps

Figures 8 and 9 show that Central Visayas (VII), Northern Mindanao (X), and Davao Region (XI) demonstrated moderate to high economic resilience and moderate to low vulnerability levels across the years. However, Northern Mindanao (X) showed high vulnerability levels from 2007 to 2015 before receding to its previous levels. Conversely, the Western (VI) and Eastern (VII) Visayas, Zamboanga Peninsula (IX), and BARMM portrayed high vulnerability and low to moderate economic resilience levels throughout the aforementioned period. Lastly, Regions CARAGA (XIII) and Soccsksargen (XII) both exhibited low to moderate economic resilience and vulnerability levels.



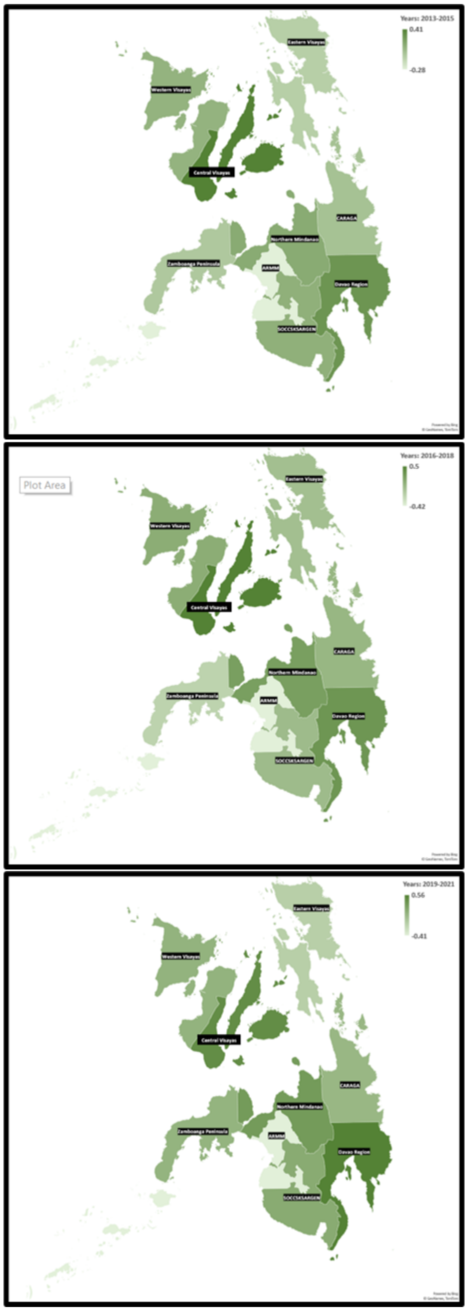


Fig. 10. Net economic resilience maps

The Net Economic Resilience maps for all periods included in this study were shown with the intention of showing the residuals of economic resilience left after being diminished by the vulnerability levels per region. Figure 10 shows maintained moderate to high levels of Net Economic Resilience of the Central Visayas (VII), Soccsksargen (XII), and Davao (XI) Regions. However, the remaining regions not mentioned demonstrated weak Net Economic Resilience across the period.

4) Econometric Analysis

a) Vulnerability

From the pooled data regression results from Table 1, the p-values of the constant, frequency of disaster, average rainfall volume, wind intensity, and population density show a positive significant relationship to the DALY for disaster. Interpreting the coefficient means that as the frequency of disaster, average rainfall volume, wind intensity, and population density increase by 1 unit, the DALY for disaster or the impact of hydrometeorological disaster increases by 0.239, 0.282, 0.247, and 0.184, respectively. Meanwhile, agricultural land use shows a significant negative relationship to the DALY for disaster. Interpreting the coefficient means that as the agricultural land use increases by 1 unit, the DALY for disaster or the impact of hydrometeorological disaster decreases by 0.134.

Table 1
Pooled data regression results of vulnerability variables

Panel Data Regression Result	Pooled Data Regression
Constant	0.624795***
Frequency of Disaster	0.239328***
Average Rainfall Volume	0.281788***
Wind Intensity	0.247001***
Population Density	0.183562**
Forest Cover Loss	−0.0252265
Agricultural Land Use	−0.133688*

Note: ***significant at 1% level, **significant at 5% level, *significant at 10% level

b) Economic Resilience

Table 2
Pooled data regression results of economic resilience variables

Panel Data Regression Result	Pooled Data Regression
Constant	0.566683**
Average Family Income	2.32496
Average Family Savings	−1.19918
Education Cohort Survival	−1.27500**
Number of Health Professionals	0.585395
Number of Beds in Health Institutions	−4.51824**
Local Government Revenue	2.09284***
Quality/Sturdy House Material	2.36418
Ownership of Living Place	−1.46160*
Electricity Connectivity	1.26613
Access to Drinking Water	1.73245
Gross Regional Domestic Product (GRDP)	−0.594133
Employment	−0.0728176

Note: ***significant at 1% level, **significant at 5% level, *significant at 10% level

From the pooled data regression results from Table 2, the p-values of the constant, education cohort survival, number of beds in health institutions, local government revenue, and ownership of living places are significant to the DALY for disaster. Interpreting the coefficient means that as the local government revenue increases by 1 unit, the DALY for disaster increases by 2.093. On the other hand, the education cohort survival, number of beds in health institutions, and ownership of living places have a negative relationship with DALY for disaster. Interpreting the coefficient means that as the education cohort survival, number of beds in health institutions, and ownership of living place increase by 1 unit, the DALY for disaster by 1.275, 4.518, and 1.462, respectively.

B. Discussion

The significant vulnerability and economic resilience variables from econometric analysis will be discussed:

1) Vulnerability

a) Frequency of Disaster, Average Rainfall Volume, and Wind Intensity

The frequency of disaster, average rainfall volume, and wind intensity show a significant positive relationship with DALY for disaster. Studies have shown that an increase in the frequency of disasters, and higher rainfall volume and wind intensity, can lead to greater vulnerability and more severe impacts on lives, livelihoods, and infrastructure. For instance, livelihood disruptions [35], [75], a higher likelihood of disaster-related factors flooding, rising economic damages [60], and temporary poverty were intensified by the frequency of hydrometeorological disasters. The average rainfall volume also showed that it increases the impact of hydrometeorological disasters. The result showed the same outcome as other studies that the average rainfall volume will likewise increase the number of fatalities due to the landslides and floods it can induce [16], [73]. This increased vulnerability to floods and landslides could also devastate properties, infrastructures, and agricultural crops [17], [18], [24]. In addition, as was stated in the studies of [29], [33], [72], wind intensity is a critical factor in estimating typhoon-related losses, with asset damage, such as houses and crops, being sensitive to maximum sustained wind speed, as well as significantly contributing to affected people. A study also mentioned that areas with poor resilience levels could increase the frailty against intense winds of hydrometeorological disasters [58].

Thus, the reason why it is more difficult for the afflicted area to recover from hydrometeorological disasters is likely related to the frequency of disasters, average rainfall, and wind intensity. This can also support the idea that hydrometeorological disasters have a prolonged impact and exacerbate localized damage. With the effects of climate change, it is expected that warmer bodies of water, such as oceans, will induce extra energy for the formation of hurricanes, leading to an increase in their frequency, making this a huge concern for the country.

2) Population Density

The population density shows a significant positive relationship with DALY for disaster. Previous studies showed results similar to this study, revealing that high population density significantly contributes to vulnerability, increasing the likelihood of a hazard turning into a disaster [5], [26], [65]. High concentrations of people, as well as infrastructures within an area, hinder evacuation, which increases injuries and fatalities, especially in impoverished areas. Moreover, a study has shown that densely populated areas near the coast are more vulnerable to the impact of disasters [34]. Most of the provinces in Visayas and Mindanao are coastal because of the 15 landlocked provinces, 12 are on the island of Luzon, while three are in Mindanao. This may be why, when a hydrometeorological disaster occurs in these regions, many are affected as they experience intensified winds, rains, and storm surges. Also, households with many individuals residing in them are highly vulnerable since they have little to no funds for emergencies. With the growing population of each region, and consequently its population density, more people would be at risk when a disaster occurs as more exposed individuals are prone to hazards.

a) Agricultural Land Use

As was stated, agricultural land use has a negative relationship with the impact of the disaster as agricultural land use has a significant influence on sensitivity since it helps to conserve water and soil, as barren areas with weak root systems are more likely to experience landslides, which are a secondary typhoon disaster [51]. Moreover, it can lessen wind speed and improve the soil's ability to hold water. Since the agricultural lands may help lessen the vulnerability of the regions to the impact of the disaster, it would be a concern for the Visayas and Mindanao regions as their agricultural land use has been decreasing over the years.

3) Economic Resilience

a) Education Cohort Survival

The education cohort survival shows a significant negative relationship with DALY for disaster. As was stated, education cohort survival is an indicator of the quality of education and the ability of the workforce to adapt to changing circumstances [49]. It can serve as a crucial adaptation strategy in areas affected by natural disasters as it influences how well coping mechanisms are adjusted during stress. It can also directly affect risk perception, skills, and knowledge, as well as indirectly affect poverty, health, and access to information [33], [42], [59]. Furthermore, a previous study has a similar result and emphasizes the importance of education cohort survival in preventing casualties during disasters, especially in typhoon-prone areas [77]. The study indicates that higher illiteracy rates in communities vulnerable to typhoons correlate with increased potential casualties and reduced awareness of adaptive measures during crises. In the case of the Philippines, the education cohort survival decreased during the COVID-19 pandemic as there were school closures and distance learning was inaccessible for others, affecting their economic resilience. With this, education can increase the coping abilities of local economies, which could decrease the impact of the disaster. It can be a positive externality that reduces vulnerability and strengthens resilience amidst climate change.

4) Number of Beds in Health Institutions

The number of beds in health institutions is a critical factor in disaster resilience as it determines the ability of a community to respond to health emergencies [33]. Adequate hospital bed capacity is crucial for effective disaster response, reducing the impact of disasters and improving medical care for casualties, both during and after the event, as they are better equipped to handle the medical needs of disaster victims [19], [59]. In the Philippines, the COVID-19 pandemic helped significantly increase the number of beds in health institutions. This can help accommodate a larger population needing assistance during disasters.

5) Local Government Revenue

The local government revenue shows a significant positive relationship with DALY for disaster. Since local government revenue can be seen as an indicator of economic well-being, a disaster may inflict more damage on a region with a larger budget. This result supports the previous study's finding, which shows a correlation between economic growth and more severe disaster-related damages [16]. Furthermore, since most of the landfalls of typhoons occur in Luzon, the regions in Visayas and Mindanao may not prioritize their regions' disaster risk preparedness and climate change adaptation programs. They may focus more on other things that can boost their economy, such as food security and infrastructure, which can cause more damage when a disaster hits. Therefore, a local government that can generate high revenue can have projects for their economic prosperity, which increases the possibility that disasters will cause higher disruptions and damages.

6) Ownership of Living Place

For the ownership of living places, the previous studies state that owning a living place is crucial for enhancing population resilience and coping with floods [13], [30]. A study also reinforces this, showing that households who own their living place are less vulnerable to flood risk, a significant factor in poverty determination [63]. Furthermore, being a homeowner provides a notable advantage by contributing to "peace of mind," especially if the owner is involved in overseeing the house's construction [66]. With this, the absence of homeownership reduces resilience to hydrometeorological disasters.

5. Conclusion

Examining the Economic Resilience Index and Vulnerability Index through trend analysis, matrix analysis, and mapping revealed substantial regional variations in economic resilience and vulnerability. From the results, the findings challenge the notion that high economic resilience implies low vulnerability. Certain regions, exemplified by Region VI and Region X, demonstrated high economic resilience alongside significant vulnerability. Conversely, regions with low economic resilience, such as Region VIII and BARMM, can experience high vulnerability. Moreover, regions like Regions VII and XI were identified as having favorable conditions to mitigate the potential impact of hydrometeorological disasters, boasting high economic resilience coupled with low vulnerability. This distinction between economic resilience and vulnerability underscores that an economy's ability to recover from a disaster hinge on its existing socioeconomic structure, which enhances economic resilience.

Additionally, the research aligns with prior studies, indicating that vulnerability variables, frequency of disaster, average rainfall volume, wind intensity, population density, and agricultural land use were identified as significant. The study also corroborated findings from previous research, indicating that economic resilience variables, education cohort survival, the number of beds in health institutions, local government revenue, and ownership of living places may influence the impacts of hydrometeorological disasters, particularly in the short term. However, the long-term scenario might deviate from this pattern. Moreover, the research highlighted that regions with high economic resilience may have inherent vulnerability and be susceptible to natural disasters or external triggers. Also, areas highly vulnerable to natural disasters may still incur escalated damages, even with increased economic resilience factors, due to additional infrastructure development and rising population density. Nevertheless, high economic resilience factors enhance the likelihood of an economy recovering from such disasters.

Therefore, the researchers recommend that local government budget programs of Regions VIII and BARMM should start prioritizing building up their overall community resilience against hydrometeorological disasters given that this is the only way to face a potential multitude of storms that would cripple them through monetary and infrastructural damages, cause the sudden displacement of their people, and endanger their regional populace as a whole in the form of number of deaths and injuries incurred throughout the occurrence of disasters. They can do this by building a comprehensive approach that involves both pre-disaster planning and post-disaster recovery strategies.

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