Research article

Vulnerability Assessment of Communities to Climate Variabilities and Extremes: The Case of Cangaranan Watershed, Antique, Philippines

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Abstract This study assessed the vulnerability of households in the Cangaranan Watershed to climate variability and extremes and examined their adaptive strategies. Using a mixed-methods approach, data were collected through face-to-face interviews and focus group discussions across two municipalities in Antique Province, Philippines: Bugasong and Valderrama. The study involved 192 randomly selected respondents, complemented by socio-demographic data and development plans from municipal and provincial sources. A community-based vulnerability index was developed to identify the key factors contributing to this vulnerability. The findings revealed that the average respondent age was over 55 years, with a balanced gender distribution (54% women). Most respondents were married, had diverse educational backgrounds, and had an average monthly household income of PhP 12,434.00. Agriculture, particularly rice farming, is the primary livelihood in this area. The watershed has faced severe climate-related challenges over the past two decades, including numerous typhoons (e.g., Frank, Ondoy, Yolanda, Paeng, and Odette), prolonged droughts (notably during the 2009-2015 period), and recent El Niño events (2023-2024). These events have resulted in food shortages, water scarcity, and disruption of domestic water supply. Farmers employ various coping mechanisms, such as reducing consumption, taking out loans, and seeking assistance from social networks, NGOs, and government agencies. This study underscores the urgent need for effective and inclusive climate resilience strategies, emphasizing the importance of development planning that prioritizes the most vulnerable populations. Future research should focus on evaluating the long-term impact of adaptation measures and addressing socioeconomic barriers in marginalized communities.

Keywords climate variability, climate extremes, vulnerability assessment, climate change, adaptation practices

INTRODUCTION

Climate change is expected to create various weather patterns with significant and adverse effects. This causes intraseasonal and interannual variability in climate, extreme weather events such as typhoons, greater rainfall variability characterized by increased rainfall frequency and intensity, and prolonged dry spells. There have been many recent examples of floods and droughts in tropical Asia. According to the 2001 report of the Intergovernmental Panel on Climate Change (IPCC), the anticipated impacts of climate change, including global warming, may lead to an increased occurrence and intensity of extreme weather events in Asia. Significant changes in climate patterns have been documented in the Philippines, including an increase in the frequency of extreme weather events. These include an increase of 0.14°C in the mean, maximum, and minimum annual temperatures from 1971 to 2000, and an increase in the annual mean rainfall since the 1980s (Cruz et al., 2007). Since the 1990s, there has been a noticeable trend in the number of rainy days and shifts in the onset of rainfall in the Philippines. The frequency of tropical cyclones entering the Philippine Area of Responsibility (PAR) has increased (Cruz et al., 2007), along with the occurrence of stronger ones. In 2024, the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) released updated climate projections based on the Coupled Model Intercomparison Project Phase 6 (CMIP6). These projections indicate that the Philippines is expected to experience a significant increase in mean annual temperatures, ranging from 1.8°C to 2.2°C by 2050, affecting all regions of the country. An increase in rainfall is likely during the southwest monsoon in many areas of Luzon and Visayas. However, Mindanao is projected to experience a decreasing rainfall trend, particularly by 2050. Yusuf and Francisco (2009) stated that all regions of the Philippines are vulnerable to climate change. Maplecroft (2012) ranked the Philippines 10th among countries with an extreme climate change risk owing to the country's increasing exposure to extreme weather disturbances, growing population, and low adaptive capacity to combat the adverse impacts of climate change.

The watershed areas in the Philippines are believed to be adversely affected by climate change (CC). Watersheds are critical to a country's economic development and environmental protection and are therefore key to the pursuit of sustainable development. More than 70% of the total land area of the Philippines is located within watersheds. It is estimated that no less than 1.5 million hectares of agricultural land currently derives irrigation water from these watersheds (Pulhin et al., 2006). Moreover, approximately 20 to 24 million people, one-third of the country's total population, inhabit the uplands of many watersheds and are significantly dependent on them for resources and survival (Pulhin et al., 2006).

The Cangaranan River Basin in Antique Province is located west of Panay Island. The Department of Environment and Natural Resources (DENR) River Basin Control Office (RBCO) identified the Cangaranan Watershed as one of 421 river basins in the Philippines, with a drainage area of 294 km^2 and an estimated 374 million cubic meters of annual runoff. It is also one of the seven major river basins in Antique Province. The main stem of the basin, the Cangaranan River, passes through the Municipalities of Valderrama and Bugasong.

Previous studies on climate change in watershed areas have focused on biophysical aspects (Jose et al., 1996). Studies focusing on the human dimensions of climate change are lacking. Specific to the Cangaranan Watershed, there is minimal information on climate change and its impact on local communities. Of greater concern is the limited knowledge of the vulnerability of these communities to climate variability and extremes and their coping mechanisms to minimize the adverse impacts of these phenomena.

Most socioeconomic studies on climate variability and extremes have focused on a single event, such as El Niño, including those by David et al. (2007). Few studies have examined the impacts of other climate stressors, such as typhoons, La Niña, and early or late onset of the rainy season. Studies from other Southeast Asian contexts, such as Cambodia, also highlight the limited adaptive capacity of rural communities to face climate change, emphasizing the role of localized assessments in understanding vulnerability (Chun, 2016; Chhinh and Poch, 2012). Vulnerability assessments of communities have been conducted in various watersheds in Antique, such as the Sibalom Watershed (Saldajeno et al., 2012). However, the available literature and sources addressing the impact of climate variability and extremes on local communities within the Cangaranan Watershed remain limited. This pioneering study attempts to fill this gap.

OBJECTIVE

This study aimed to assess the communities in the Cangaranan Watershed, their vulnerability to climate variability and extremes, including related hazards, and their ability to respond to stress. Specifically, the study sought to answer multiple objectives, including **a.** identifying the socioeconomic profile of various communities within the watershed; **b.** identifying the climate variability and extremes experienced by the local communities over the last 20 years, including the socioeconomic impacts; **c.** identifying which socioeconomic groups in the watershed experienced the most negative impacts; **d.** assessing the extent and nature of their vulnerability to climate variability and extremes; and **e.** identifying the adaptation practices of the local communities.

METHODOLOGY

Study Location

The Cangaranan Watershed is located in the Antique Province of the Philippines. It spans a considerable area, with the majority of the floodplain situated within the Bugasong and Valderrama municipalities, comprising four (4) barangays: Pandanan and Ubos in the Municipality of Valderrama and Igbalangao and Ilaures in the Municipality of Bugasong. Study site recommendations were gathered from the Office of the Municipal Agrarian and Municipal Environment and Natural Resources Office (MENRO). As cited by Paringit et al. (2017), the most devastating flooding event in the province occurred after Typhoon Frank landfall in 2008. The local population and officials claimed that the floodwater reached a height of 2 m in their communities.

Research Design and Instrumentation

This study used a mixed-methods approach that integrated qualitative and quantitative techniques. Qualitative analyses have focused on understanding the vulnerabilities of different socioeconomic groups. Quantitative analyses were employed to analyze household-level data using a vulnerability index developed based on household survey data, incorporating four key indicators: food, water, livelihood, and health. Drawing from Peras et al. (2008), this study relied solely on community-assigned weights for the indicators to ensure that local perspectives shaped the results. These indicators were further subdivided into relevant variables reflecting household sensitivity and coping capacity, following the framework of Moss et al. (2001). Focus group discussions (FGDs) in four barangays in Bugasong and Valderrama gathered community inputs to assign weights to the index components. The participants reached a consensus on these weights, ensuring that the index aligned with their experiences and priorities. This collaborative process highlighted variations in community perspectives and emphasized the importance of localized input in assessing vulnerability.

Sampling

Using Slovin's formula, a sample size of 192 respondents was computed. This sample size ensured a high level of accuracy, with a permissible error of 0.10 and a confidence interval of 90%. Respondents were selected through random sampling using barangay data.

Data Collection

This study used diverse methods to collect data effectively, addressing all research goals, including a household survey. A household survey was conducted through face-to-face interviews using structured questionnaires with 192 respondents across selected barangays within the Cangaranan Watershed from January to May of 2024. The structured questionnaires consisted of five distinct sections: Socio-Economic Profile of the Respondents, Perceived Impact and Benefits of Watershed Climate Variability and Extremes experienced over the last two decades and their impacts, and household vulnerability in terms of food availability, water supply, livelihood, health, and Adaptation Strategies. Enumerators were trained, and the tool was pretested to ensure clarity and appropriateness. Secondary data were collected from the following sources Secondary data were gathered from municipal and provincial development plans, sociodemographic statistics from the National Statistics Office (NSO), maps from different agencies, the Department of Environment and Natural Resources (DENR), the Department of Agriculture, and Local Government Units. Comprehensive climatic data were obtained from agencies such as the Philippine Atmospheric, Geophysical and Astronomical

Services Administration (PAGASA). Participatory rural appraisal techniques were used. FGDs were conducted. Participants were selected through purposive sampling in coordination with barangay officials, ensuring representation from key vulnerable groups, such as farmers, women, and elders, with knowledge of past climate events in the watershed area. These discussions utilized a combination of participatory techniques, including timeline analysis and participatory vulnerability assessments. A timeline analysis was employed to identify significant natural events experienced by local communities in the watershed, reflecting climate variability and extremes from 2004 to the present day. In addition to assessing past and current vulnerability, the FGDs explored the vulnerability of different socioeconomic groups in the watershed to potentially harsher conditions in the future. Consistent with the participatory approach of the research, the FGDs also involved gathering communities' perspectives to determine the relative importance of different variables in developing a vulnerability index.

Data Analysis

Survey data were summarized using measures of central tendency (means, medians, and modes) and variability (standard deviations and ranges) to outline the socioeconomic characteristics and vulnerability levels. Qualitative data from FGDs were systematically categorized and analyzed for recurring themes and patterns, offering insights into the participants' experiences, perspectives, and adaptation strategies. A composite vulnerability index was developed by integrating quantitative and qualitative findings with weights assigned during the FGDs. This index captures the multidimensional nature of vulnerability and reflects both the statistical trends and community input.

RESULTS AND DISCUSSION

Respondents Socio-Economic Characteristics

The respondents' average age was 55 years, ranging from 23 to 85 years, highlighting their wide-ranging life experiences and familiarity with climatic variability and extremes in the watershed. Gender representation was balanced, with females accounting for 54% of respondents. Most respondents were married, with 39% having a secondary education, 21% having a tertiary education, and 10% lacking a formal education. Notably, 91% of the respondents were residents, reflecting their deep-rooted connections and understanding of the area's ecological and sociocultural dynamics.

Table 1 Demographic characteristics of the respondents

Category	Frequency	Percent %
The average age is 55 years old		
Gender distribution N=192		
- Male	89	46.40
- Female	103	53.60
Educational level N=190		
- None	10	5.20
- Primary	1	0.50
- Elementary	65	33.90
- High School	74	38.50
- College	40	20.80
Ethnic affiliation N=191		
- Native	174	90.60
- Migrants	17	8.90

The data reveal that the average monthly household income of respondents is PHP 12,434.00, which is only 3.35% above the national poverty threshold set by the Philippine Statistical Authority, indicating minimal financial security. Most households (61%) rely on crop cultivation as their primary income source, whereas others engage in small-scale businesses, fishing, and institutional employment, emphasizing the watershed's critical role in sustaining diverse livelihood. Additionally, 67% of farmers are smallholders who manage less than one hectare of land. Among landowners, only 43% (82 192) hold formal land titles, limiting their ability to leverage land for financial gain. Furthermore, 37% of the respondents practiced monocropping, primarily by cultivating rice, highlighting the challenges of land tenure security and the need for agricultural diversification.

Table 2 Economic profile of the respondents

Category	Frequency	Percent %
Major sources of income (N= 186)		
Farming	138	71.80
Small enterprises (e.g., sari-sari store)	7	3.60
Employment	7	3.60
Fishing	8	4.20
Others (hired labor, driver, forest products gathering, etc.)	26	13.50
Average monthly income= PHP 12,434.00		
Farm sizes of cultivated land (N=166)		
<1 ha	129	67.20
1.1 – 2 ha	22	11.50
2.1 – 3 ha	9	4.70
3 ha and above	5	2.60
Tenure types of cultivated lands (N=164)		
Title	83	43.20
CSC/CLOA/NIA Agreement	3	1.60
Tax declaration	19	9.90
Others (agreement, right, amortization)	57	29.70
Agricultural/farm practices of farmers (N=159)		
Mono-cropping	71	37.00
Crop rotation	63	32.80
Agroforestry or mixed cropping	21	10.90
Crop diversification	4	2.10

Past Climate Variability and Extremes in the Cangaranan Watershed

Climate change significantly drives water scarcity, affecting communities that depend on limited drinking, sanitation, and agricultural resources (Gizaw, 2023). Household surveys and FGDs noted severe droughts in 2009 and 2015, coinciding with strong El Niño events recorded by the Oceanic Niño Index. Notably, the 2010 El Niño caused extensive drought across 977 ha and 208 ha in the Philippines, incurring $580M in agricultural damage (Pulhin and Tapia, 2016). According to David et al. (2007), Panay, along with areas in Luzon and Mindanao, is highly vulnerable to El Niño. While respondents were unable to pinpoint the exact timing of past El Niño events, they vividly remembered an extreme El Niño episode that started in April 2023 and was expected to end by the end of May 2024, which brought an unusually prolonged and severe drought, far exceeding the typical three-month dry spells they had previously experienced. This recent event has significantly impacted their lives and livelihoods. Data from the PAG-ASA and Municipal Disaster Risk Reduction and Management Office (MDRRMO) from the Municipalities of Bugasong and Valderrama show that 67 typhoons hit the area from 2004 to 2024, with notable events including Typhoons Frank (2008), Ondoy (2009), Yolanda (2013), Paeng (2021), and Odette (2022), which caused profound and lasting impacts within the watershed community.

Communities' Perceived Benefits and Impacts from the Watershed

Watersheds are vital for water resource management and disaster risk reduction, particularly in countries vulnerable to typhoons (Pulhin et al., 2010). However, the interview results in Bugasong revealed that households perceived the watershed as a medium of destruction, citing massive flooding and sedimentation during heavy rains and typhoons, exacerbated by quarrying and insufficient stone wall construction. In contrast, respondents in Valderrama recognized the watershed as critical for water supply for agriculture and domestic use. Pulhin et al. (2008) emphasized the importance of watersheds in sustaining agriculture, particularly by ensuring irrigation during dry seasons, which helps prevent water scarcity and supports rice production in the Philippines. Despite this, nearly half of the respondents did not recognize the value of watersheds, highlighting the need for educational campaigns and extension programs to promote conservation and maintain watershed ecological benefits.

Table 3 Benefits and impact of watershed

Benefits and impact of watershed	Bugasong		Valderrama		Total
	frequency*	%	frequency*	%	frequency
Destruction due to floods and sedimentation	82	88.17	61	61.61	143
Agricultural (for farming and livestock) use	32	34.40	59	59.60	91
Domestic use	19	20.43	67	67.67	86
Source of freshwater fishes	13	14.00	22	22.22	35
Sand and gravel for house construction	8	8.60	0	0.00	8

*Note: *Multiple responses*

Socio-economic Groups within the Watershed

Based on the FGDs, societal stratification in the Cangaranan Watershed revealed distinct vulnerability levels. Small farmers are the most vulnerable, facing hardships due to their low education, lack of land ownership, and limited capital, which makes them highly susceptible to climate variability. Findings from this study are comparable to the results of the study of Chhinh and Poch (2012), where small-scale farmers often face the greatest climate risks due to land tenure insecurity, low education, and poor access to financial resources. Those with moderate vulnerability include small-scale farmers with modest landholdings ranging from 0.5 to 2 hectares and local entrepreneurs who have slightly better access to resources but still face challenges in accessing them. Employees from different sectors and households with access to capital and technology are the least vulnerable, benefiting from higher education, substantial land, agricultural machinery, and diverse resources, which enable them to better adapt to climate impacts. These differences highlight the need for tailored climate-adaptation strategies that address the unique needs of each socioeconomic group.

Impact of Climate Variability and Extremes

This study assessed the impact of climate variability and extremes on communities in the Cangaranan Watershed, focusing on food, water, livelihoods, and health. The results highlighted several key issues: food shortages and rising costs due to extreme weather, with limited crop cultivation, affecting community sustainability. Water challenges are significant, particularly in Barangay Ilaures and Igbalangao, where outdated irrigation systems were damaged by Typhoon Undang in 1984. After the irrigation canal was destroyed, there was no further assistance from the government or other agencies that initiated the construction of an irrigation system in the study area. Consequently, most farmers in these areas are compelled to depend solely on rainwater to irrigate and cultivate their lands, highlighting their vulnerability to climatic irregularities and the need for resilient agricultural practices. Thus, the availability of domestic water in the barangays of Ilaures and Igbalangao is generally secure, as most households possess water pumps.

The study also noted the vulnerability of lowland communities, such as Ilaures and Igbalangao, to intense flooding during the typhoons. Farmers face challenges in terms of crop yield, with early rains benefiting crops, delayed rains, prolonged wet periods, and El Niño events causing significant damage to crops. Climate extremes, particularly typhoons, droughts, and floods, significantly disrupt farming, leading to crop loss and reduced income. Smallholder farmers, especially those without land, experience greater vulnerability and debt accumulation during extreme conditions, whereas wealthier farmers with better resources have greater resilience to climate change.

This study revealed that health issues are closely associated with extreme climate. Respondents reported an increase in heat-related illnesses, such as hypertension, stroke, and migraines, during periods of extreme heat, whereas prolonged rainy seasons were linked to an increase in waterborne diseases, such as diarrhea and dengue. These findings are consistent with those of previous studies [insert references]. For instance, the World Weather Attribution (2024) reported that the April 2024 heatwave in the Philippines, with temperatures exceeding 40°C, would have been "virtually impossible" without human-induced climate change, leading to a spike in heat-related illnesses in the country. The World Health Organization (WHO) lists heat stress, cardiovascular strain, and worsening of pre-existing conditions (including hypertension and stroke) as health risks associated with extreme heat. Similarly, the Department of Health (as cited in Philippine Tribune, 2024) noted a significant increase in dengue cases during the same period, attributing this to warmer temperatures and heavy rainfall, which create ideal conditions for breeding mosquitoes.

Table 4 Impact of climate variability and extremes on food, water, livelihood, and health in Cangaranan watershed

Climate variability and extremes	Impacts	Frequency	Percent %
El Nino	• Shortage of food/ water (domestic/irrigation) supply	129	67.19
	• Misunderstanding among individuals stemming from water scarcity.	69	35.94
	• Zero/ decrease in income due to drought	152	79.17
	• A lesser number of crops	143	74.48
	• Rise in health issues (such as Hypertension, migraine, overfatigue, mild stroke, irritability	85	44.27
Typhoon	• Destruction of homes	58	30.21
	• Overflowing/ Flooding of the watershed	81	42.19
	• Deposits of sediments in rice paddies result in damage to crops	74	38.54
	• Losses in crop production	124	64.58

Extent and Nature of People's Vulnerability to Climate Variability and Extremes

This study assessed community vulnerability to climate variability using a locally developed index that reflects residents' perceptions and experiences. The index, created through participatory FGDs, prioritizes four categories: food, water, livelihood, and health issues. Water scarcity was identified as the most critical issue, with the highest weight (40%), followed by food (25%), livelihood (20%), and health (15%).

Food vulnerability is linked to crop yield, which is heavily affected by climate extremes, leading to food shortages and malnutrition, especially among smallholder farmers. Water scarcity, exacerbated by climate extremes, has been recognized as the main concern, with limited irrigation and damaged infrastructure increasing the vulnerability. Despite adaptation efforts, communities felt that strategies often led to additional costs and conflicts that reduced their effectiveness.

Livelihood diversification has emerged as a key strategy for reducing vulnerability, with households seeking alternative income sources demonstrating greater resilience. Health problems, particularly during extreme weather, also contribute to vulnerability, with those experiencing health issues or lacking access to medical services ranking higher on the vulnerability index.

Adaptation Strategies and Practices

Local communities in the Cangaranan Watershed have developed various adaptation strategies to mitigate the effects of extreme climate. Strategies categorized as food, water, livelihood, and health aim to reduce the vulnerability and enhance resilience. Key practices include reducing food and water consumption, improving storage, and shifting to alternative food sources such as sweet potatoes and bananas. Many also practice agroforestry and grow drought-resistant crops, such as root vegetables and legumes, to increase their resilience. Similar adaptive strategies have been documented in other rural areas of Southeast Asia, including improved food storage, shifting to drought-tolerant crops, and diversifying livelihoods. In Cambodia, households have adopted multiple coping mechanisms, including agroforestry and alternative income sources, to reduce climate-related risks (Chun, 2016; Chhinh and Poch, 2012).

Communities often rely on informal credit sources, such as family and neighbors, and turn to off-farm work, such as factory jobs or carpentry, during adverse conditions such as El Niño. Some seek support from local kinship networks and government or non-governmental organizations. Additionally, prayer is considered an adaptive strategy that offers comfort without any cost.

During calamities, asset disposal, such as selling livestock, is a common coping mechanism. Water security is addressed by channeling water from nearby streams, which is labor-intensive. Households also use herbal remedies to manage health issues. Despite these efforts, challenges persist in terms of long-term resilience, and research highlights the need for targeted interventions, such as improved access to climate information, financial support, and agricultural technologies to enhance adaptive capacity and sustainability.

Table 5 Adaptation practices employed by households in Cangaranan watershed during climate variability and extremes

Adaptation practices	Frequency N=192	Percent %
Reducing food and water consumption/ storage	154	80.21
Tree shade as relief from the intense temperature	136	70.83
Secure loans/ credit	94	48.96
Support from relatives/ family ties	68	35.42
Praying	52	27.08
Off-farm work/ alternative employment from farming	49	25.52
Rely on Assistance from the government/ NGOs	46	23.96
Asset disposal	32	16.67
Find other sources of water	13	6.77
Use herbal medicines	30	15.63
Affected but do nothing	21	10.94

CONCLUSION

Over the two-decade span from 2004 to 2024, the Cangaranan watershed was affected by numerous typhoons. Severe droughts occurred in 2009 and 2015, respectively. Between April 2023 and May 2024, the El Niño phenomenon compounded the difficulties of this year, presenting an extended period of intense drought and causing substantial disruptions. Watershed communities are deeply intertwined with agriculture, and vulnerability to climate variability and extremes varies significantly across socioeconomic groups.

The survey results revealed that a significant number of respondents, particularly in the Municipality of Bugasong, perceived the watershed as a source of destruction (e.g., flooding) rather than as a provider of ecosystem services. This indicates a gap in the understanding of watershed functions. To address this, there is a need for sustained extension of Information, Education, and Communication (IEC) initiatives to raise awareness of the importance of watershed management and how it contributes to reducing community vulnerability to climate extremes.

The prevailing droughts have presented new challenges for affected communities, emphasizing the escalating severity of climate-induced phenomena and the increasing need for effective coping and adaptive strategies to mitigate their impacts on the livelihoods of those dependent on agriculture in the region. Considering the adaptive strategies mentioned by the respondents, the development of water-harvesting systems, improved irrigation infrastructure, and efficient water-use practices are key adaptation measures that help mitigate the effects of climate extremes on agriculture and water supplies. Although communities adopt various coping strategies to address these challenges, an examination of community knowledge and perceptions of the watershed, as well as the effectiveness of coping strategies in dealing with climate variability and extremes, is necessary. This deeper understanding is crucial for developing effective and context-specific policies and programs that address unique challenges and opportunities within the watershed.

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