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Livelihood Vulnerability of Agricultural Communities to Climate Change in Selected Barangays in Brooke's Point, Palawan, Philippines

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ABSTRACT

Although climate change is a global issue, its impacts vary between countries, regions, communities and sectors. Due to their limited capacity to adapt to the changing climate and access to other forms of production, agrarian communities in developing nations suffer the most. This study assessed the vulnerability of agriculture-based households in three Barangays situated within the Mambalot-Filantropia Watershed in Brooke's Point, Palawan, Philippines. Through a comprehensive evaluation of socioeconomic and biophysical aspects, the study determined vulnerability levels and identified key influencing factors. A survey encompassing of 300 households and secondary data collection from relevant government sources formed the basis of the analysis. Analysis of the data following the Livelihood Vulnerability Index indicated moderate vulnerability across all three barangays, with Mambalot showing the highest LVI score (0.311), followed by Ipilan (0.276) and Maasin (0.260). Conversely, in the LVI-PCC assessment of which examines the interaction among exposure, sensitivity, and adaptive capacity, Ipilan showed the highest overall vulnerability (0.004), followed by Mambalot (-0.004) and Maasin (-0.008). Food vulnerability, social networks, and exposure to climate variability were identified as primary concerns, underscoring the need to prioritize climate change mitigation efforts in these areas. Study findings suggest the need for urgent interventions in such as crop and livelihood diversification, microfinance, community-government partnerships, and disaster risk reduction.

Key words: *climate change, vulnerability, livelihoods, agriculture, Philippines*

John Vincent Colili[1*]
Rico C. Ancog[2]
Eduardo C. Calzeta[2]
Evaristo Niño T. Cando III[3]

[1] Palawan State University, University Road, Puerto Princesa City, 5300 Palawan, Philippines
[2] School of Environmental Science and Management, University of the Philippines Los Baños, College, Laguna, Philippines 4031
[3] College of Human Ecology, University of the Philippines Los Baños, College, Laguna, Philippines 4031

*corresponding author: jcolili@psu.palawan.edu.ph

INTRODUCTION

Climate change poses a significant challenge to global socioeconomic development and environmental sustainability. Over the years, human activities have contributed to changes in climate patterns, leading to severe consequences for both natural and human systems (*IPCC 2022*). Research indicates that human health, ecosystems, and key socioeconomic sectors, which are crucial for sustainable development, are highly sensitive to these changes (*Rocha et al. 2022*). Despite global efforts to mitigate the effects of climate change, its impacts are expected to persist for decades (*IPCC 2023*).

Palawan, a province in the southwestern Philippines, is renowned for its rich biodiversity and ecological significance. However, its fragile landscape, characterized by a narrow mainland, small islands, steep topography, and highly erodible soils, makes it particularly vulnerable to the impacts ofclimate change. Nonetheless, despite its ecological importance, the province faces significant challenges due to climate change. A warming trend of 0.16°C per decade from 1951 to 2005 has been observed in Palawan (*UNESCO 2014, as cited in PCSDS 2015*). Moreover, approximately 56% of families in Palawan are estimated to be vulnerable to the consequences of climate change, particularly those involved in agriculture, fishing, and forestry (*Perez et al. 2013*). This convergence of warming trends, drought risks, and flooding vulnerabilities underscores the urgent need for vulnerability assessments to support the development of comprehensive climate change adaptation strategies in Palawan.

Assessing the components contributing to the vulnerability of systems is crucial for developing effective adaptation strategies and informing policies to mitigate climate change risks (*Ford and Smit 2004; Fussel and Klein 2006; Huong et al. 2018*). In the Philippines, although numerous vulnerability assessment tools have been developed and applied, most focus primarily on hazard identification (*Abalus et al. 2019*). Thus, gaps in information and technical support—particularly in localized, community-based assessments that integrate both socioeconomic and biophysical dimensions of vulnerability- in some respect, have contributed to the weak implementation of cost-effective climate adaptation strategies (*Lasco et al. 2009*). This study aims to address these informational gaps by examining the socioeconomic and biophysical factors influencing the vulnerability of agrarian households in southern Palawan and to aid in identifying adaptation needs and developing targeted interventions to enhance the resilience of these households.

MATERIALS AND METHODS

Study Area

The municipality of Brooke's Point is situated at the southeastern tip of Palawan, Philippines (**Figure 1**). Classified as a first-class municipality, it had a population of 73,994 as of 2020. The area is predominantly forested and mountainous in its upstream regions, while its lowland plains are covered with built-up areas and extensive plantations of both perennial and annual crops. Portions of the vast Mt. Mantalingahan Protected Landscape fall within the territorial control of the municipality. The presence of these mountainous and forested regions enabled the formation of two relatively large watersheds within the municipality, the Tigaplan and Mambalot-Filantropia watersheds (*Amigo et al. 2017*).

The Mambalot-Filantropia watershed (MFW), situated in the barangays of Mambalot, Ipilan and Maasin, is the focal area of this study. It has a total land area of 11,910.93 ha and accounts for approximately 17.45% of the municipality's land area. The watershed is a composite of two major river systems, the Mambalot River and the Filantropia River. The shallow and winding water channels of the watershed serve as one of the primary sources of water for domestic and agricultural use in the municipality.

Primary Data Collection

A total of 300 households were sampled for this study, with the sample size determined based on farmer population data from each barangay, as listed in the Registry System for Basic Sectors in Agriculture (RSBSA). This total was then proportionally allocated based on farmer population across the three barangays(**Table 1**). Quantitative data were collected using a structured questionnaire, which was developed through a review of relevant literature and consultation with experts. The questionnaire covered topics such as climate change impacts, land use practices, access to resources, socioeconomic status, and institutional support. The survey was conducted from September to December 2023 and administered exclusively to agrarian households within communities in the MFW, with respondents selected randomly.

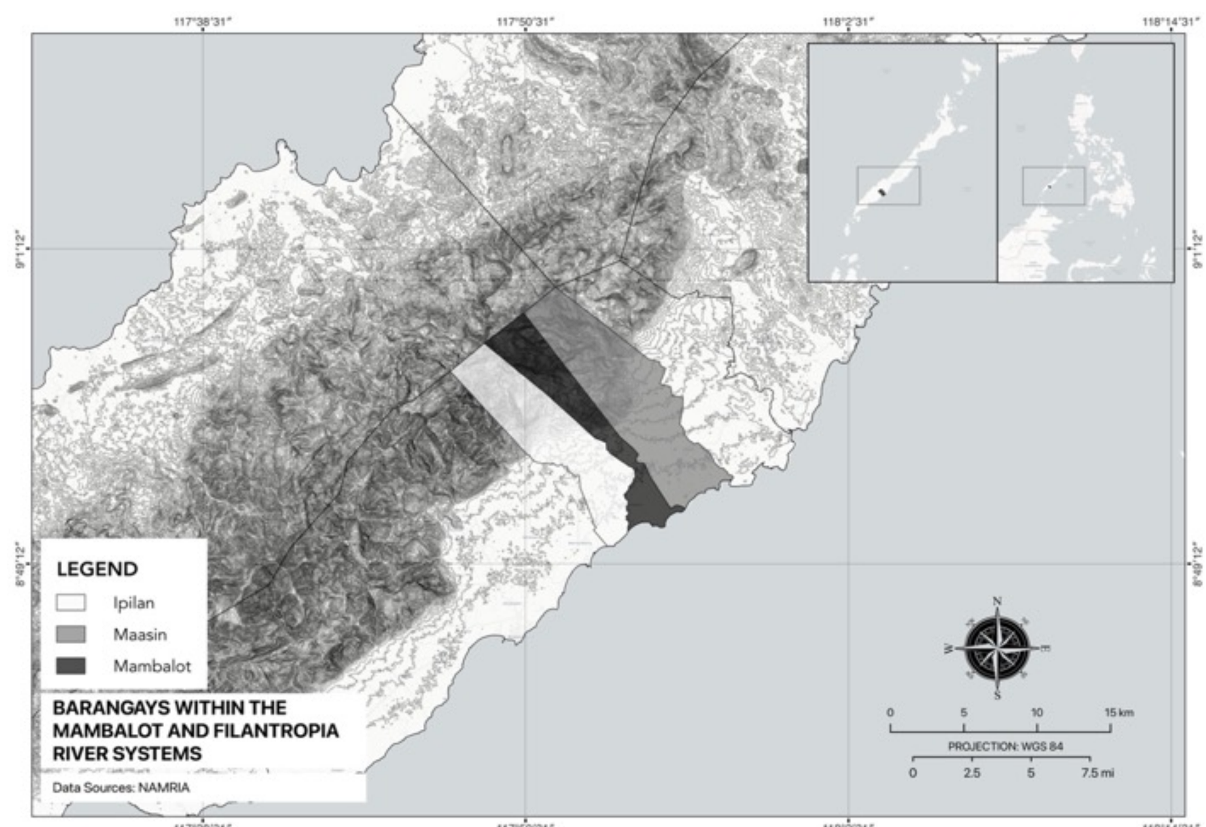

Figure 1. Location of the study area.

Table 1. Total number of respondents for each barangay within Mambalot-Filantropia Watershed.

Barangays	Number of Registered Farmers	Sampling Size
Ipilan	486	107
Maasin	371	82
Mambalot	500	111
TOTAL	1,357	300

Data Analysis

The household survey data were analyzed following the livelihood vulnerability index (LVI) approach developed by *Hahn et al.* (*2009*) to determine the vulnerability of agriculture-dependent households in the MFW. The LVI uses a balanced weighted average technique (*Sullivan et al. 2002*), where each subcomponent (**Table 2**) contributes equally to the overall index, despite the fact that each major component has a unique number of subcomponents. By using the simple method of assigning equal weights to each essential component, the LVI formula produces an assessment tool that may be used by a variety of users in environments with minimal resources. The selection of indicators for this study was guided by the Sustainable Livelihoods Framework (SLF), which considers five core asset categories—human, social, natural, physical, and financial—as essential for livelihood security and resilience. This framework has been widely applied in vulnerability assessments to capture the multifaceted nature of household wellbeing in the face of climate change (*Chambers and Conway, 1992*). In line with empirical studies (*Pandey and Jha 2011; Ancog et al. 2016; Tran et al. 2022*) the chosen indicators reflect both exposure to climate-related shocks and household adaptive capacity and sensitivity across these five capitals. The study also used the LVI-IPCC framework, which reformulates the index based on the IPCC's definition of vulnerability as a function of exposure, sensitivity, and adaptive capacity. This ensures that the methodology is not only context-specific but also theoretically grounded and consistent with established vulnerability assessment approaches in the literature.

Standardizing each subcomponent as an indicator is important because they are all measured on various scales. The following is a description of equation 1 used for this conversion:

$$index_{sb} = \frac{s_b - s_{min}}{s_{max} - S_{min}} \qquad (1)$$

where s_b is the original subcomponent for barangays b and s_{min} and s_{max} are the minimum and maximum values, respectively, for each subcomponent determined using data from all the research areas.

After all the subcomponents were standardized, the subcomponents were averaged using Equation 2 to calculate the value of each major component:

$$M_b = \frac{\sum_{i=1}^{n} = index_{s_b i}}{n} \qquad (2)$$

where M_b = one of the seven major components for barangay b [socio-demographic profile (SDP), livelihood strategies (LS), social networks (SN), health (H), food (F), water (W), or natural disasters and climate variability (NDCV)], $index_{Sb}i$ represents the subcomponents, indexed by *i*, that make up each major component, and n is the number of subcomponents in each major component.

When the values for each of the seven major components of a barangay were calculated, they were averaged using equation 3 below to obtain the barangay-level LVI:

$$LVI_b = \frac{\sum_{i}^{7} = w_{Mi\,M_{bi}}}{\sum_{i}^{7} = W_{Mi}} \qquad (3)$$

The weighted average of the seven main components is the Livelihood Vulnerability Index, or LVI_b. In order to guarantee that every subcomponent contributes equally to the total LVI, the weights of each major component, or WMi, are established by the number of subcomponents that comprise each major component. In this study, the LVI is scaled as follows: 0.0 indicates the least vulnerability, 0.21-0.40 indicates moderate vulnerability, and 0.41-0.5 indicates the highest level of vulnerability similar to the work of *Gravitiani et al.* (*2018*).

After the values under the exposure, sensitivity, and adaptive capacity components have been calculated, the three contributing factors are merged using the following equation:

$$CF_b = \frac{\sum_{i=1}^{n} w_{Bi} B_{di}}{\sum_{i=1}^{n} W_{Bi}} \qquad (4)$$

where CF_b is an IPCC-defined contributing factor for barangay (exposure, sensitivity, or adaptive capacity), B_{di} is the major component for barangays indexed by i, w_{Bi} is the weight of each major component, and n is the number of major components in each contributing factor. After calculating the exposure, sensitivity, and adaptive capacity, the three contributing elements were merged

Table 2. Major components and subcomponents analyzed in this study.

Major component	Subcomponent	Source
Socio-demographic Profile	Dependency ratio	*Hahn et al. (2009)*
	Proportion of households led by women	*Hahn et al. (2009)*
	Mean age of female household heads	
	Percentage of households where the head has never attended school	*Hahn et al. (2009)*
	Proportion of households with orphaned children	*Ancog et al. (2016)*
Livelihood Strategies	Rate of illiteracy	*Hahn et al. (2009)*
	Percentage of households with a family member working in another community	*Hahn et al. (2009)*
	Proportion of households relying exclusively on agriculture for income	*Tran et al. (2022)*
	Mean Agricultural Livelihood Diversification Index (range: 0.20–1)	*Tran et al. (2022)*
	Percentage of households reporting no government support for agricultural mechanization	*Tran et al. (2022)*
Social Network	Proportion of farmers lacking formal training in crop production and climate adaptation	*Hahn et al. (2009)*
	Mean Receive: Give ratio (range: 0–15)	*Hahn et al. (2009)*
	Mean Borrow: Lend Money ratio (range: 0.5–2)	*Hahn et al. (2009)*
Health	Percentage of households that have not sought assistance from local government in the past year	*Hahn et al. (2009)*
	Average travel time to the nearest healthcare facility (minutes)	
	Proportion of households with a family member suffering from a chronic illness	*Hahn et al. (2009)*
	Percentage of households where a family member missed work or school in the past two weeks due to illness	*Hahn et al. (2009)*
	Mean Malaria Exposure*Prevention Index (range: 0–12)	*Hahn et al. (2009)*
Food	Proportion of households relying on family farms for food supply	*Hahn et al. (2009)*
	Mean number of months households experience food shortages (range: 0–12)	*Hahn et al. (2009)*
	Mean Crop Diversity Index (range: >0–1)	*Hahn et al. (2009)*
Water	Percentage of households reporting conflicts over water	*Hahn et al. (2009)*
	Proportion of households using natural water sources	*Hahn et al. (2009)*
	Percentage of households with inconsistent water supply	*Hahn et al. (2009)*
	Average travel time to the nearest water source	*Hahn et al. (2009)*
	Inverse of the mean amount of water stored per household (range: >0–1)	*Hahn et al. (2009)*
Natural Disasters and Climate Variability	Mean number of flood, drought, and cyclone events in the past six years (range: 0–7)	*Hahn et al. (2009)*
	Percentage of households that did not receive warnings before natural disasters	*Hahn et al. (2009)*
	Proportion of households experiencing injury or loss of life due to the most severe disaster in the past six years	*Hahn et al. (2009)*
	Mean monthly variability of daily maximum temperature	*Hahn et al. (2009)*
	Mean monthly variability of daily minimum temperature	*Hahn et al. (2009)*
	Mean monthly variability of average precipitation	*Hahn et al. (2009)*

using the following equation:

$$LVI - IPCC_b = (e_b - a_b) * s_b \quad (5)$$

The IPCC vulnerability framework is then used to express the LVI–IPCC$_b$ using equation 5, where an is the calculated adaptive capacity score for barangays (b), which is the weighted average of the socio-demographic, livelihood strategies, and social networks major components, and e is the calculated exposure score for barangays (b), which is equivalent to the natural disaster and climate variability major component. Furthermore, the weighted average of the main food, water, and health components is the sensitivity score (s) that has been computed for barangays (b). The LVI–IPCC is scaled from -1 being the least vulnerable to 1 being the most vulnerable.

RESULTS AND DISCUSSION

Livelihood Vulnerability Across the Mambalot-Filantropia Watershed

Data analysis indicated consistent trends in the Livelihood Vulnerability Index (LVI) across the three barangays (**Table 3**). Access to water resources ranks as the least pressing concern for households engaged in agriculture within the MFW area (**Figure 2**). Ipilan, Maasin, and Mambalot exhibited relatively low indices of 0.081, 0.056, and 0.115, respectively, underscoring the consistent access to water supply and comparative abundance or adequacy of water resources for domestic use in these areas. The survey indicates that water conflicts are rare across the surveyed areas. In Maasin,

Table 3. LVI subcomponent values for Ipilan, Maasin, and Mambalot, Brooke's Point, Palawan, Philippines.

Major Components	Subcomponent	Units	Barangays		
			Ipilan	Maasin	Mambalot
Socio-Demographic Profile	Dependency ratio	Ratio	48.257	46.694	53.594
	Proportion of households led by women	Percent	10.377	29.630	31.395
	Mean age of female household heads	1/years	54.182	51.875	45.741
	Percentage of households where the head has never attended school	Percent	6.604	1.220	2.326
	Proportion of households with orphaned children	Percent	0.094	8.046	3.448
	Rate of illiteracy	Percent	1.278	1.132	8.846
Livelihood Strategies	Percentage of households with a family member working in another community	Percent	19.802	26.829	45.238
	Proportion of households relying exclusively on agriculture for income	Percent	12.791	3.659	9.302
	Mean Agricultural Livelihood Diversification Index (range: 0.20–1)	1/no. of livelihoods	0.357	0.369	0.395
Social Networks	Percentage of households reporting no government support for agricultural mechanization	Percent	64.486	60.366	72.093
	Proportion of farmers lacking formal training in crop production and climate adaptation	Percent	35.714	15.385	54.762
	Mean Receive: Give ratio (range: 0–15)	Ratio	0.843	0.938	1.159
	Mean Borrow: Lend Money ratio (range: 0.5–2)	Ratio	1.196	1.189	1.238
	Percentage of households that have not sought assistance from local government in the past year	Percent	77.143	71.951	61.628
Health	Average travel time to the nearest healthcare facility (minutes)	Minutes	33.925	42.07	23.837
	Proportion of households with a family member suffering from a chronic illness	Percent	21.698	35.37	27.907
	Percentage of households where a family member missed work or school in the past two weeks due to illness	Percent	21.495	4.88	12.791
	Mean Malaria Exposure*Prevention Index (range: 0–12)	Months* Bednet Indicator	0.276	0.09	0.459
Food	Proportion of households relying on family farms for food supply	Percent	45.794	45.122	45.349
	Mean number of months households experience food shortages (range: 0–12)	Months	1.280	0.256	1.488
	Mean Crop Diversity Index (range: >0–1)	1/no. of crops	0.336	0.359	0.359
Water	Percentage of households reporting conflicts over water	Percent	9.346	1.220	12.791
	Proportion of households using natural water sources	Percent	11.215	2.439	2.804
	Percentage of households with inconsistent water supply	Percent	3.774	1.266	0.000
	Average travel time to the nearest water source	Percent	7.832	1.179	1.599
	Inverse of the mean amount of water stored per household (range: >0–1)	1/Liters	0.065 1.764	0.166 2.220	0.275 2.570
Natural Disasters and Climate Variability	Mean number of flood, drought, and cyclone events in the past six years (range: 0–7)	Count	 45.794	 17.742	 31.395
	Percentage of households that did not receive warnings before natural disasters	Percent	 0.467	 0.000	 4.070
	Proportion of households experiencing injury or loss of life due to the most severe disaster in the past six years	Percent	 0.759	 0.759	 0.759
	Mean monthly variability of daily maximum temperature	Celsius			
	Mean monthly variability of daily minimum temperature	Celsius	0.584	0.584	0.584
	Mean monthly variability of average precipitation	mm	103.03	103.03	103.03

only 1.2% of households reported water conflicts, while Mambalot and Ipilan had slightly higher rates, at 12% and 9.3%, respectively. The water supply is generally consistent, with only 3.8% of the Ipilan and 1.3% of the Maasin households experiencing issues and none experiencing issues in Mambalot. The travel times to water sources are short: 1.2 minutes in Maasin, 1.6 minutes in Mambalot, and 7.8 minutes in Ipilan.

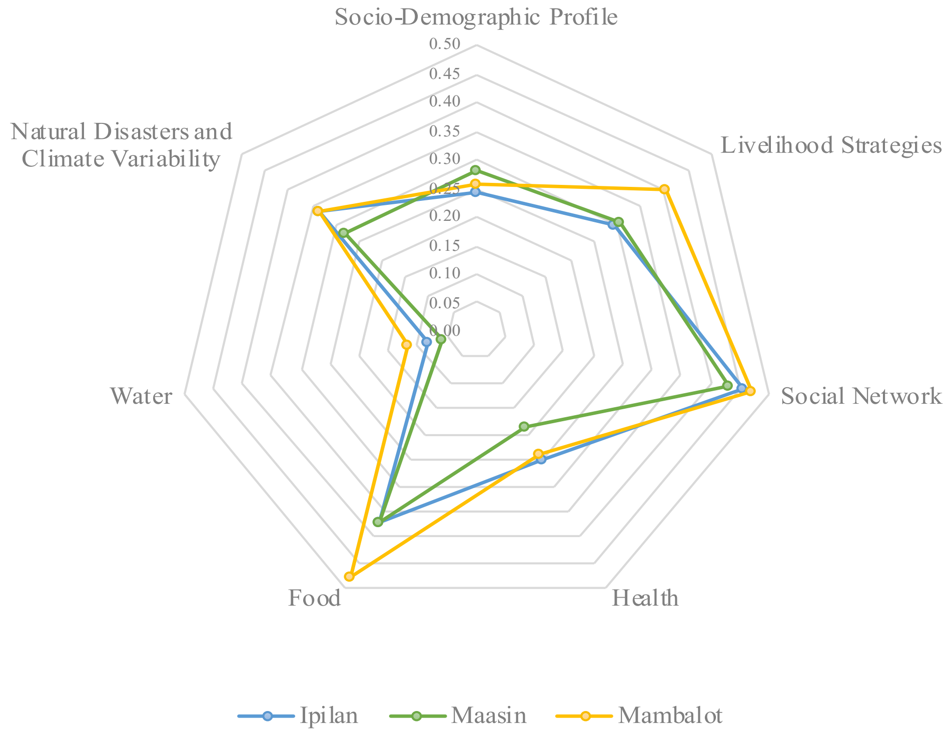

Figure 2. Vulnerability spider diagram of the major components of the livelihood vulnerability index (LVI) for the Barangays of Ipilan, Maasin, and Mambalot, Brooke's Point, Palawan, Philippines.

These results may be attributed to decentralized water access through household-operated jetmatic pumps (Maasin: 83.0%, Ipilan: 88.8%, Mambalot: 95%), which might have helped in minimizing competition and disputes and improving water access. However, due to this relative proximity and access, surveyed households tend to store less water. In Maasin and Mambalot, households store less water (23 liters and 10.7 liters, respectively) than in Ipilan (55.7 liters), affecting their index scores. This is consistent with the findings that Ipilan has the highest percentage of households relying on natural water sources, at 11.2%, compared to that of Maasin and Mambalot, at 2.4% and 3.5%, respectively.

Health-related vulnerability scores are moderate across Ipilan (0.252), Maasin (0.188), and Mambalot (0.240), suggesting a relatively healthy population and greater access to health facilities in the study area (**Table 4**). The household survey revealed key insights into healthcare accessibility across the MFW. Ipilan recorded the highest index score for travel time to the nearest health facility (0.299) despite being closer to a hospital, with an average travel time of 34 minutes, while Maasin had an average of 42 minutes and Mambalot had an average of 24 minutes. This discrepancy may stem from poor road conditions, limited public transport, or a lack of household transportation in Ipilan. Maasin, the farthest from the town center, had the second-highest travel time index (0.258). Mambalot reported significantly shorter travel times (0.173), indicating better transportation accessibility (**Table 4**).

The survey also revealed a high prevalence of chronic illnesses among agriculture-practicing households, with Maasin reporting the highest percentage (35.4%), followed by Mambalot (22.4%) and Ipilan (21.7%). Ipilan had the highest percentage of households reporting missing work or school due to illness (21.5%), compared to Maasin (4.8%) and Mambalot (10%). This study further examined the impacts of climate change on vector-borne malaria (*Hanna and Oliva 2016*). Mambalot had the highest Malaria Exposure Prevention Index score (0.459), indicating greater vulnerability than Ipilan (0.276) and Maasin (0.091). However, these results should be interpreted cautiously due to the high number of missing responses from Maasin and Ipilan.

In contrast to the previous two components, food vulnerability scores highlighted considerable vulnerability across the barangays (FoodIpilan 0.370; FoodMaasin 0.371; FoodMambalot 0.477), emphasizing severe susceptibility to primary food sources and challenges accessing food in the study areas. Nearly half of the agrarian households in MFW rely heavily on family farms for subsistence, either through direct consumption or commercialization. Ipilan has the highest reliance at 46.3%, followed by Mambalot at 45.3% and Maasin at 45.1%. This dependence makes these barangays

Table 4. Resulting indexes for each subcomponent and major component.

Subcomponent	Livelihood Vulnerability Index per barangay			Major component	Livelihood Vulnerability Index per barangay		
	Ipilan	Maasin	Mambalot		Ipilan	Maasin	Mambalot
Dependency ratio	0.684	0.756	0.664	Socio-demographic Profile	0.245	0.281	0.257
Proportion of households led by women	0.104	0.293	0.314				
Mean age of female household heads	0.605	0.535	0.416				
Percentage of households where the head has never attended school	0.066	0.012	0.023				
Proportion of households with orphaned children	0.001	0.080	0.034				
Rate of illiteracy	0.013	0.011	0.088				
Percentage of households with a family member working in another community	0.198	0.268	0.452	Livelihood Strategies	0.294	0.308	0.401
Proportion of households relying exclusively on agriculture for income	0.128	0.037	0.093				
Mean Agricultural Livelihood Diversification Index (range: 0.20–1)	0.143	0.476	0.193				
Percentage of households reporting no government support for agricultural mechanization	0.645	0.604	0.721				
Proportion of farmers lacking formal training in crop production and climate adaptation	0.357	0.154	0.548				
Mean Receive:Give ratio (range: 0–15)	0.126	0.110	0.200	Social Network	0.454	0.430	0.472
Mean Borrow:Lend Money ratio (range: 0.5–2)	0.464	0.459	0.601				
Percentage of households that have not sought assistance from local government in the past year	0.771	0.720	0.616				
Average travel time to the nearest healthcare facility (minutes)	0.299	0.258	0.173	Health	0.252	0.188	0.240
Proportion of households with a family member suffering from a chronic illness	0.217	0.354	0.224				
Percentage of households where a family member missed work or school in the past two weeks due to illness	0.215	0.049	0.103				
Mean Malaria Exposure*Prevention Index (range: 0–12)	0.276	0.091	0.459				
Proportion of households relying on family farms for food supply	0.463	0.451	0.453	Food	0.370	0.371	0.477
Mean number of months households experience food shortages (range: 0–12)	0.140	0.085	0.244				
Mean Crop Diversity Index (range: >0–1)	0.508	0.577	0.734				
Percentage of households reporting conflicts over water	0.093	0.012	0.128	Water	0.081	0.056	0.115
Proportion of households using natural water sources	0.093	0.012	0.128				
Percentage of households with inconsistent water supply	0.112	0.024	0.035				
Average travel time to the nearest water source	0.019	0.013	0.000				
Inverse of the mean amount of water stored per household (range: >0–1)	0.116	0.072	0.160				
Mean number of flood, drought, and cyclone events in the past six years (range: 0–7)	0.252	0.185	0.367	Natural Disasters and Climate Variability	0.336	0.277	0.337
Percentage of households that did not receive warnings before natural disasters	0.458	0.177	0.314				
Proportion of households experiencing injury or loss of life due to the most severe disaster in the past six years	0.005	0.000	0.041				
Mean monthly variability of daily maximum temperature	0.481	0.481	0.481				
Mean monthly variability of daily minimum temperature	0.431	0.431	0.431				
Mean monthly variability of average precipitation	0.390	0.390	0.390				
Overall LVI	0.276	0.260	0.311				

particularly vulnerable to climate change impacts such as droughts and floods, which could significantly affect their food security and livelihoods (*Dumenu and Obeng 2016*). On the other hand, households in Mambalot and Ipilan face the highest average food insecurity, with surveyed households reporting that they struggle to find food for approximately 1.5 and 1.3 months per year, respectively. At that time, the Maasin had a relatively lower annual incidence of 0.26 months. These periods often coincide with dry months and seasonal activities, such as school enrollments, which place additional financial strain on farmers, limiting their ability to purchase food (*Blackmore et al. 2021*). Crop diversification across the study area is also low, which limits resilience to climate change. Mambalot has the lowest crop diversity index (0.734), indicating that farmers in the area typically plant only 1 to 3 types of crops. Similarly, Maasin (0.577) and Ipilan (0.508) also exhibited low diversification rates, highlighting a significant area of concern.

Ipilan had the lowest vulnerability in terms of the sociodemographic profile index while Mambalot and Maasin showed moderate vulnerability (SDPIpilan 0.245; SDPMambalot 0.270; SDPMaasin 0.257). The dependency ratio, indicating the proportion of dependents to the working-age population, is highest in Maasin (0.756) and Ipilan (0.684), suggesting a heavier burden on the workforce and potentially lower productivity and economic growth (*Mubiru et al. 2018*). Mambalot (0.664) has a lower dependency ratio, implying better economic dynamics. Higher dependency ratios are correlated with reduced adaptive capacity to climate change (**Table 4**). Compared with those in Ipilan, female-headed households in Maasin (29%) and Mambalot (31%) are more prevalent. Ipilan has the oldest average age for female household heads (58.2 years). Female-headed households face greater challenges, especially with climate change, due to limited access to resources (*Bradshaw et al. 2017*).

On the other hand, education levels are generally high, with Maasin having the fewest household heads who never attended school (1.22%) and the highest literacy rate (98%), while Ipilan has the highest percentage of household heads without schooling (6.6%). Higher education and literacy often correlate with better socioeconomic status and access to resources, aiding adaptation to environmental changes (*Feinstein and Mach 2019*). Finally, households with orphans are rare, with Maasin having the highest percentage (8%), followed by Mambalot (3.4%) and Ipilan (0.1%).

In terms of livelihood strategies, Mambalot (0.401) has a greater vulnerability score than does Ipilan (0.294) and Maasin (0.308). This is possibly due to the greater number of surveyed households in Mambalot with family members working in a different community (45.2%) and the greater percentage of rice farmers who depend on natural water sources such as small streams and springsfor irrigation (54.8%). This reliance on natural water sources restricts farmers' crop choices and limits the number of annual cropping cycles they can undertake annually (*Andersen et al. 2015*). Conversely, Ipilan had the highest dependence on agriculture (12.8% of households), indicating a greater vulnerability to yield fluctuations (*Morton 2007*). In contrast, Maasin (3.7%) and Mambalot (9.3%) are less dependent, suggesting a more diversified economic base. Ipilan also had the highest livelihood diversity index (0.143), followed by Mambalot (0.193), indicating broader agricultural activities and reduced vulnerability compared to Maasin, which had a lower diversity index (0.476) and greater vulnerability (*Altieri et al. 2015*). Furthermore, the study revealed that many agriculture-practicing households in the MFW lack government support for mechanization and training in crop production and climate change adaptation. Mambalot had the highest percentage of households reporting a lack of support (72%), followed by Ipilan (64.5%) and Maasin (60%).

Social network vulnerability is notably high across Ipilan (0.454), Mambalot (0.430), and Maasin (0.472), indicating that weaknesses within social networks impact overall resilience in the MFW. Specifically, in terms of social exchange, Ipilan has the lowest average Receive:Give ratio of 0.126, reflecting a tendency to provide more assistance than to receive. Conversely, Maasin and Mambalot exhibited slightly greater and more balanced exchange dynamics. Regarding the Borrow:Lend Money ratio, Mambalot has the highest value at 0.601, suggesting a greater inclination to borrow, potentially due to greater financial constraints. Ipilan and Maasin, with ratios of 0.464 and 0.459, respectively, may indicate a more stable financial landscape. Furthermore, few households in the studied localities sought local government assistance in the past 12 months. Ipilan had the highest percentage of households not seeking assistance (77%), followed by Maasin (72%) and Mambalot (61.6%). This low rate of seeking government help may reflect a reliance on community or self-help mechanisms and cultural norms that favor less dependence on government interventions.

Finally, Ipilan (0.336), Maasin (0.277), and Mambalot (0.337) exhibited moderate vulnerability to natural disasters and climate variability. This highlights the significant impact of environmental risks on livelihoods in these communities. Therefore, targeted efforts to build resilience are essential. Surveys reveal a trend in Mambalot, where households have faced floods, droughts, and cyclones an average of 2.6 times per year over the past six years. This value is considerably greater than those of Ipilan (1.8 times) and Maasin (2.2 times). Fortunately, despite this frequent exposure to extreme weather events, injuries or deaths are rare. Mambalot, the most exposed community, reported that only 4% of households experienced such cases. Ipilan and Maasin reported much lower percentages, 0.5% and 0%, respectively. While there have been recent improvements in connectivity and warning systems, significant gaps remain. A substantial proportion of households reported inadequate disaster warnings: 45.8% in Ipilan and 31.4% in Mambalot. In contrast, only 10.3% of the Maasin households felt that the warnings were insufficient. Furthermore, temperature and precipitation data for Palawan (1991-2021) indicate moderate variability. The daily maximum temperatures have a standard deviation of 0.76°C, and the minimum temperatures vary by 0.58°C. Precipitation shows significant variability, with a mean standard deviation of 103.03 mm monthly.

Overall, the findings revealed that all three barangays exhibited moderate levels of vulnerability according to the Livelihood Vulnerability Index (LVI). Among them, Barangay Mambalot was the most vulnerable, with an LVI of 0.311, followed by Ipilan (0.276) and Maasin (0.260). Moderate vulnerability indicates that while these communities face exposure to climate-related risks, they still possess some capacity to cope and adapt (*IPCC 2014*). It reflects partial resilience wherein support systems may exist but are not robust enough to endure prolonged or severe shocks. Though not in immediate crisis, these communities are at a tipping point where timely support could significantly enhance resilience or, conversely, its absence could push them into high vulnerability (*Birkmann 2006*).

LVI IPCC results

The LVI–IPCC analysis produced results that slightly differed from those of the standard LVI analysis. Ipilan and Mambalot appear to be more exposed to climate change impacts (with exposure scores of 0.336 and 0.337, respectively) compared to Maasin (0.277) (**Table 5**). In terms of sensitivity- considering health status, food, and water security- Mambalot registered the highest score (0.248), indicating greater sensitivity than both Ipilan (0.180) and Maasin (0.178). For adaptive capacity, based on demographic characteristics, livelihood options, and social networks, Ipilan had the lowest score (0.311), while Mambalot (0.355) and Maasin (0.323) showed relatively higher capacities to adapt.

Overall, the LVI–IPCC analysis identified agrarian households in Ipilan as the most vulnerable (0.004), followed by those in Mambalot (-0.004) and Maasin (-0.008). Ipilan's high exposure and only moderate adaptive capacity resulted in high exposure and only moderate adaptive capacity resulted in a net positive LVI–IPCC score, reflecting greater overall vulnerability. These findings highlight that vulnerability cannot be understood through individual indicators alone, but by the dynamic interaction among exposure, sensitivity, and

Table 5. Livelihood Vulnerability Index–IPCC contributing factor calculations for Ipilan, Maasin, and Mambalot, Brooke's Point, Palawan, Philippines.

Indicators	Ipilan	Maasin	Mambalot
Exposure	0.336	0.277	0.337
Adaptive Capacity	0.311	0.323	0.355
Sensitivity	0.180	0.178	0.248
LVI-IPCC	0.004	-0.008	-0.004

adaptive capacity (*Smit and Wandel 2006*), as articulated in the LVI–IPCC framework.

CONCLUSION AND RECOMMENDATIONS

The Livelihood Vulnerability Index analysis indicated that all three barangays exhibited moderate levels of vulnerability, with Mambalot emerging as the most vulnerable among the three, with an index of 0.311. This suggest that although not in immediate crisis, these communities require targeted support to prevent further decline. On the other hand, the LVI-IPCC analysis revealed that Barangay Ipilan, with its low adaptive capacity (0.311), was the most vulnerable among the three localities, registering an overall LVI-IPCC score of 0.004. In both indices, Maasin consistently exhibited the lowest vulnerability. This outcome is attributed to Maasin's relatively low exposure and stronger adaptive capacity to climate and livelihood stressors. At the subcomponent level, Maasin demonstrated high water security, with widespread access to jetmatic pumps, minimal water-related conflicts, and a consistent supply. Additionally, the barangay also reported low health and food vulnerability, reflected in shorter durations of food shortages and fewer illness-related disruptions.

After the key contributing factors to vulnerability in MFW were identified, social network vulnerability appeared to be the greatest contributor, followed by food and exposure to climate variability and natural disasters. In contrast, access to water resources ranks as the least pressing concern for households engaged in agriculture within the MFW area. Interestingly, these results are consistent across the three studied barangays, with only minor variations in index scores. This study successfully applied the LVI framework, originally developed by *Hahn et al.* (*2009*) for Mozambique, to the Philippine context within the Mambalot-Filantropia Watershed (MFW). While the core structure remained the same, subcomponents were adjusted to reflect local realities. However, researchers replicating this methodology elsewhere in the Philippines should consider cultural norms, local dynamics, and other contextual factors that may differ from those of the MFW region.

Based on the results of the analysis, it is recommended that local and national government units, along with other stakeholders, prioritize proactive adaptation measures to reduce vulnerability and bolster resilience among MFW communities, particularly in areas of food, social networks, and disaster risk. A closer examination of the individual subcomponents highlights the need for urgent interventions in areas such as crop and livelihood diversification, microfinance, strengthened community-government partnerships, and disaster risk reduction. Finally, further research into the biophysical components of watersheds should be conducted to obtain a more comprehensive picture of the impacts of climate change.

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