Journal of Environmental Science and Management SI-2: 42-59 (2020) ISSN 0119-1144

Climate Variability, Change and the Impacts on Livelihood Vulnerability of Farming Households in Koronadal, South Cotabato, Philippines

ABSTRACT

This study examined the changes and variability in temperature and rainfall patterns in the past 31 years (1981-2012) and assessed their impacts on livelihood vulnerability of farming households in the City of Koronadal, South Cotabato, a less studied area in Mindanao located in Southern Philippines. Using the Intergovernmental Panel on Climate Change (IPCC) framework, household vulnerability was assessed using survey data from 265 respondents, complemented with focus group discussion, and field observations from 2013 to 2015. Results showed significant changes in monthly mean minimum (increased by 0.74 C, $p < 0.01$) and mean maximum (decreased by 0.65C, $p < 0.01$) temperature. Rainfall patterns showed a decreasing trend and revealed significant changes in June ($p<0.01$), August, and December ($p<0.05$), signifying that climate change and variability took place as manifested by floods, landslides, and drought experienced by farming households. The study confirmed that majority of the farming households had "moderate to high vulnerability" to climate variability and change. As climate change brings new forms of risks, appropriate adaptation strategies are needed to address both current and future vulnerability and require robust vulnerability assessment founded on recent scientific advancement and innovative strategies congruent to this study.

Lorena L. Sabino[1*]
Juan M. Pulhin[1]
Josefina T. Dizon[2]
Ma.Victoria O. Espaldon[3]
Rex Victor O. Cruz[4]

[1] Department of Social Forestry and Forest Governance, College of Forestry and Natural Resources University of the Philippines Los Baños (CFNR-UPLB), College, Laguna, Philippines
[2] College of Public Affairs and Development, UPLB
[3] School of Environmental Science and Management, UPLB
[4] Institute of Renewable Natural Resources, CFNR-UPLB

*Corresponding author: llsabino@up.edu.ph

Keywords: *climate change, climate variability, livelihood vulnerability*

INTRODUCTION

The Germanwatch global climate risk index of 2020 has shown that in 2018, the Philippines ranked second among the world's most vulnerable countries to strong extreme weather events and ranked fourth in a span of 20 years from 1999-2018 (*Eckstein et al. 2019*). The report of the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) revealed an increase of 0.68˚C in annual mean temperature with an increasing trend in annual and seasonal rainfall for the past 65 years (1951-2015) in the country. Climate projections showed a continuous warming in the future and a projected rainfall reduction over central sections of Mindanao (*PAGASA 2018*). In March 2016, the City of Koronadal was placed under the state of calamity due to severe drought (*CNN Philippines 2016*). This phenomenon severely affected the food supply and livelihood of local communities where livelihood sources were mainly dependent on weather conditions.

The rising temperature, increasing erratic rainfall, more frequent and severe floods, strong cyclones, severe droughts, changes in hydrological cycles, and sea-level rise are the manifestations of climate change (*Asian Development Bank 2009; CARE International 2009; Department for International Development 2004*). Climate change is defined as a change in the state of a climate, which is identifiable by changes in the mean and/or the variability of its properties persisting for an extended period, typically, decades or longer. On the other hand, climate variability is the variation in the mean state and other statistics such as standard deviations, the occurrence of extremes of the climate on all spatial and temporal scales beyond that of individual weather event (IPCC 2013, p.1450 & 1451, Annex III – Glossary). The *IPCC* (*2013*) is now 95% certain that human activities are the main causes of current global warming, which influenced climate patterns to change. Moreover, IPCC confirms that warming of the climate system is unequivocal and portends irreversible and dangerous impacts.

Climate variability and change impact negatively climate-dependent sectors such as agriculture (*Amuzu et al. 2018*) with the livelihood of small holder famers being more precarious (*Harvey et al. 2014*). This is due to experience resulting from climate extreme events and crop loss or damage caused by disease outbreaks and pest infestation. As livelihood is affected, income is lost, which in turn exacerbates poverty and food insecurity (*Herrera et al. 2018*). Poor population in developing countries like the Philippines is more vulnerable to climate change impacts since they are less capable of resisting hazards (*Barbier and Hochard 2018*). Livelihood and agricultural productivity are basically affected by multiple shocks including climate change impacts that increase household vulnerability (*Ziervogel and Calder 2003*). Livelihood vulnerability, on the other hand, is influenced by many factors, which include low capacity to prepare, to cope and to recover from shocks and stresses (*Department for International Development 2004*). Sometimes, vulnerability is shaped by the lack of households' adaptive capacity (*Qaisrani et al. 2018*). Weak social networks and lack of financial resources also make the livelihood vulnerable to climate change (*Zacarias 2019*). Overall, the interrelated range of social, economic, political, and environmental changes threaten livelihood sustainability resulting to vulnerability (*Fraser et al. 2011*).

Small holder farmers would also be affected due to their limited information regarding vulnerability and adaptation needs to climate change (*Harvey et al. 2014*). This highlights the fact that understanding the current vulnerability is indispensable in adapting to present and future climate changes (*Bohle et al. 1994*). Robust vulnerability assessment at the grassroots level is crucial to enhance adaptation. A large number of adaptation programs and projects have failed simply because they were not able to properly identify the major aspects and magnitude of vulnerability in the community (*USAID 2007*). Individual vulnerability assessment at the grassroots is valuable in understanding the characteristics of households and gives opportunity to design better risk management strategies (*Celidoni 2013*).

Currently, the most widely adopted definition of vulnerability to climate change is based on *IPCC* (*2007*), which defined vulnerability as the degree to which a system is susceptible to and unable to cope with the adverse effects of climate change, including climate variability and extremes. It is a function of the character, magnitude, and rate of climate variation to which a system is exposed to, its sensitivity and adaptive capacity.

On the Island of Mindanao, particularly in the study area, few studies have been conducted on the changing climate patterns and their impacts on livelihood vulnerability at the grassroots level. This lack of information often leads to inappropriate action in dealing with climate change impacts. This study therefore examined the changes and variability in temperature and rainfall for the past 31 years (1981-2012) and assessed their impacts on the livelihood vulnerability of the farming households using equal and unequal weighting methods. Specifically, it aimed to: determine the temperature trends, rainfall patterns and changes in three decadal periods (1981-2010); analyze the climate variability (rainfall and temperature) for the period of 1981-2012; and generate a vulnerability map based on exposure, sensitivity and adaptive capacity.

MATERIALS AND METHODS

Location of the Study

This study was conducted from April 2013 to July 2015 involving 265 local household respondents in farming communities at the Roxas Mountain Range in the City of Koronadal covering five barangays, namely, Assumption, Saravia, Carpenter Hill, Paraiso, and San Isidro (**Figure 1**). The study area was chosen based on the 2010 report of the Mines and Geosciences Bureau (MGB) in Region XII, which indicated that out of eight barangays within the Roxas mountain range, two barangays namely, Assumption and Saravia are highly susceptible to landslides, while three barangays are moderately susceptible, namely, Carpenter Hill, Paraiso, and Sta. Cruz. As a result, when climate extreme events occurred, the livelihood sources, mainly agriculture, were largely affected.

The Roxas Mountain Range has a land area of 1,137 ha and was proclaimed as a watershed area under Proclamation No. 607 on June 23, 1995. The area provides important natural resources such as water, food, forest and non-forest products to the communities as well as home and ancestral shelter to some of the B'laan indigenous people. Majority of these households cultivate areas ranging from 0.5 to 4.0 ha for their livelihood sources.

Research Design

A courtesy visit to the local government unit (LGU) of the City of Koronadal along with a letter of request for permission was done prior to conducting the study in the area. A structured household survey questionnaire was prepared, which included questions on respondents'

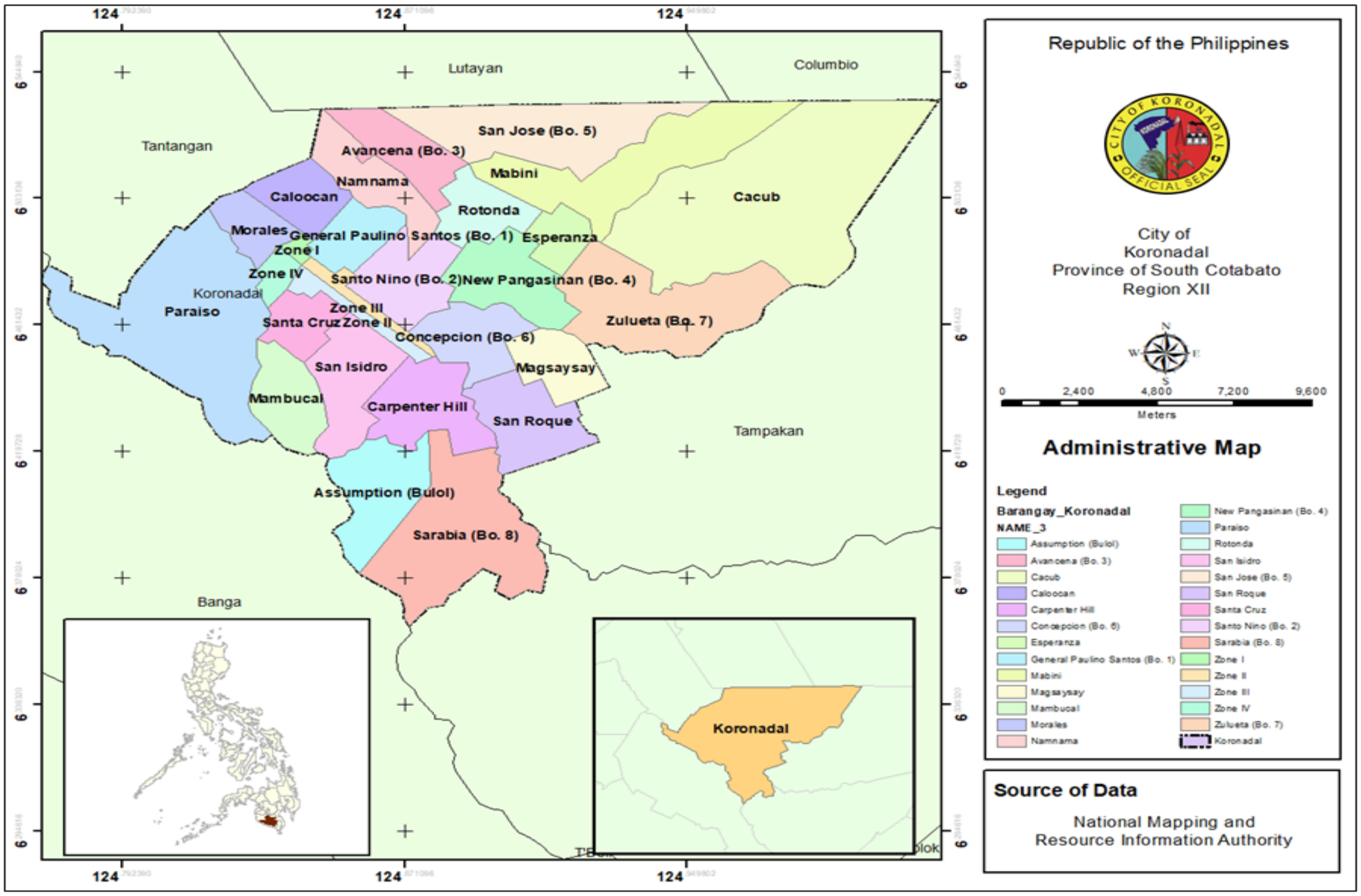

Figure 1. Study sites in Roxas Mountain Range, City of Koronadal.

socio-demographic profiles and information on vulnerability based on exposure, sensitivity and adaptive capacity of the randomly selected 265 respondents. The number of respondents was determined by using the formula of *Sukhatme* (*1953*) as shown in Equation 1. The stratified random sampling using lottery technique and proportional allocation to determine the sample size per barangay was applied (**Table 1**).

$$n = \frac{N * P}{P * CV^2 (N-1) + Q} = \frac{5{,}830 * 0.05}{0.50 * 0.06^2 (5{,}830 - 1) + 0.50} \quad (1)$$

Where:
n= sample size
N= household population (5,830)
CV= coefficient of variation (set to 0.06)
P= proportion of households who are vulnerable (set to 0.5)
Q= 1-P
n= 265 households (sample size)

In addition, focus group discussion (FGD) and key informant interviews (KIIs) were also used in gathering information. There were 11 key informants and in July 2015, FGD was conducted with nine attendees composed of farmer-leaders and representatives from the local government. Secondary data collection such as climate data in terms of daily temperature (maximum, minimum, mean) and rainfall pattern from 1981 to 2012 were obtained from Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA). Historical climate data in the study area were not available, hence, data from the General Santos station, the nearest station, were used.

Table 1. Proportionate distribution of the household-respondents within the study area.

Barangay	No. of Households*	Sample Size
1. Assumption	382	17
2. Saravia	1,414	64
3. Carpenter Hill	1,268	58
4. Paraiso	1, 149	52
5. San Isidro	1,617	74
Total sample size		265

*Source: City Planning Office, 2009

In assessing and mapping livelihood vulnerability, the geographic location of the surveyed households was determined using a Geographic Positioning System (GPS)-Garmin Rino 655t model and the geographic information system (GIS) was used to visualize on a map the vulnerability of households. Then, analytical hierarchy process (AHP) which is a pair-wise comparison method was used to validate the weights or priority factors of vulnerability index such as exposure, sensitivity and adaptive capacity.

Conceptual Framework and Vulnerability Index/ Indicators

Vulnerability index was based on the *IPCC* (*2001*) guidelines. Indicators of exposure, sensitivity, and adaptive capacity were assessed to estimate the vulnerability of livelihood programs (**Figure 2 and Table 2**).

Measurement of vulnerability indices/indicators

In this study, exposure was interpreted in terms of the frequency and magnitude of heavy rainfall, intense temperature, and occurrence of climate extreme events (e.g., flashflood/flooding, landslides and drought). The more exposed the households are to these climate-related events, the more vulnerable they are to climate change and variability. *Arias et al.* (*2014*) also did vulnerability assessments using IPCC determinants and this study was used as reference material. The analyses were based on the constructed indicators for exposure, sensitivity and adaptive capacity indices. *Piya* (*2012*) also noted that climate change in rural communities where livelihoods are weather-dependent would be more vulnerable as the weather and extreme events become more unpredictable.

Sensitivity was measured in terms of the respondent's experience of crop damages and occurrences of pests and diseases due to climate events in their barangays. The higher the percentage of crop damage and occurrence of pests and diseases, the more sensitive would be the household's livelihood to climate-related events. *Piya* (*2012*) reported that occurrences of drought phenomenon would result to high crop damage. Finally, adaptive capacity was based on the ability of the household to adjust to climate-related impacts. This was assessed based on the five dimensions of livelihood assets framework of *Chambers and Conway* (*1992*), namely, human, financial, social, physical, and natural capital that enable the farming households to respond and cope with climate change and extreme events.

Human capital indicators were assessed based on the number of dependents such as children (below 18 years old) and elderly (60 years old and above) and number of household members with secondary education. The greater the number of dependent members, the lower is the adaptive capacity of the household to climate change impacts and aggravated when the dependents are children and elderly who are more prone to illnesses. On the other hand, respondents have higher adaptive capacity when more household members have secondary or tertiary education. Social capital was assessed based on the number of household members belonging to a community organization either individually or in groups,

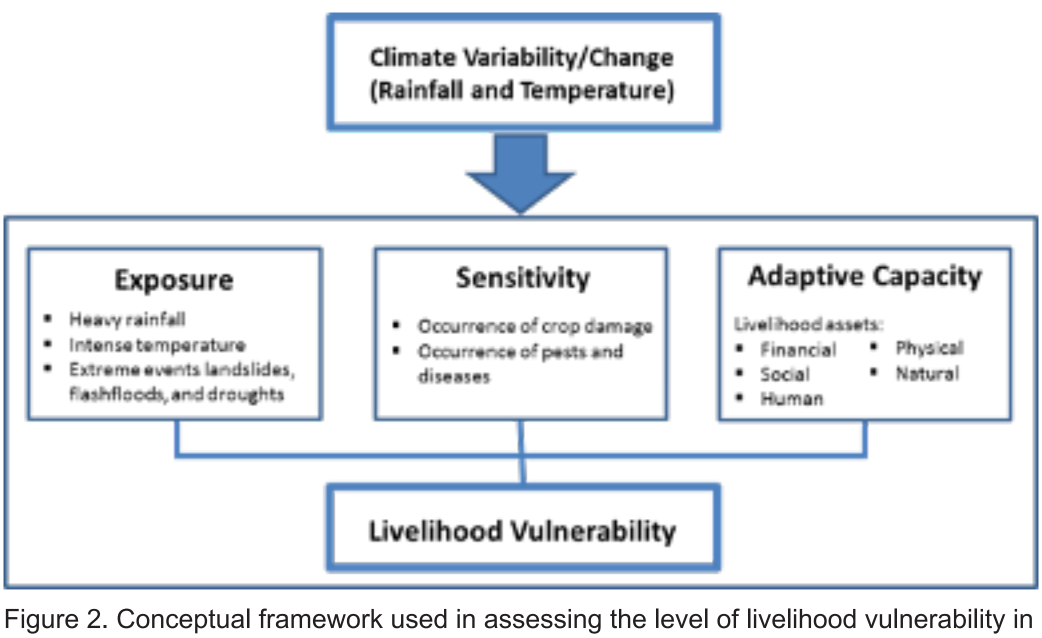

Figure 2. Conceptual framework used in assessing the level of livelihood vulnerability in Roxas Mountain Range, City of Koronadal.

Table 2. Vulnerability Index and indicators.

Vulnerability Index	Indicators	Measurement
Exposure	• Rainfall • Temperature • Drought • Flashfloods • Landslides	• Frequency (Recurrence time) • Magnitude (Intensity)
Sensitivity	• Crop damage • Pests and diseases	• Percent of damaged to crops per ha • Percent of pest infestations and disease occurrences
Adaptive capacity	• Human capital	• Number of dependents: children 18 and below and elderly above 60 • Number of HH members with secondary education
	• Social capital	• Number of HH having membership to organization • Presence of LGU
	• Financial capital	• Number of income sources • Membership to financial institutions
	• Natural capital	Water, Land and Forest • Access to and source of drinking water • Distance to sources of drinking water • Access to irrigation • Ownership of agricultural lands/areas • Distance of farm from the house • Existence of remaining forest in the area
	• Physical capital	Infrastructure • Ownership of the house • Type of the house • Location of the house • Distance to main concrete roads • Distance to school • Distance to health center • Distance to barangay hall • Distance to market center Transportation • Means of public transportation • Accessibility of public transportation • Distance to public transportation • Affordability of public transportation Communication • Number of televisions • Number of radios • Number of mobile phones

and the presence of service providers such as local government units (LGUs) and non-government organizations (NGOs) whom they can turn to for help. When more household members have community organization or group membership, the higher will be their linkages and networks, thus, increasing their adaptive capacity. The presence of service providers in the communities also increases social linkages and adaptive capacity to climate-related events.

The assessment of financial capital was based on the number of income sources and membership to any financial institutions. The greater the number of income sources, and the higher the number of membership or access to any financial institutions such as banks, cooperatives and other credits groups, the higher will be their adaptive capacity. Natural capital was estimated based on water, land, and forest resources. Water resource was measured based on access to sources of drinking water and irrigation for farming, while land resource considered ownership of agricultural land with its home proximity. Forest resource was based on the existence of forest in the area. Water resource accessibility is very important; the nearer the distance to more reliable sources of water for drinking and irrigation, and the livelihood as sustainable, the higher will be an adaptive capacity to climate change. The shorter the distance from the farm to their home which means more time allocated to farming activities will make them easily adapt to climate changes. In addition, available forests in their respective communities serve as additional livelihood and food sources for their survival from climate shocks.

Physical capital was assessed based on infrastructure, transportation, and communication services. Infrastructures include ownership of the house, type of housing materials, location of the house, and distance to main services such as concrete roads, schools, health centers, barangay center, and market. If the respondents own and live in permanent structures (e.g., concrete house), which are located in broad plain areas and near the public services (e.g., main concrete roads, schools, market, etc.), the higher will be their adaptive capacity. Transportation sub-indicators, on the other hand, are availability, accessibility, and affordability of public transportation. The study assumed that with more available, accessible, and affordable modes of public transport, the household can easily market their produce and increase their income sources, hence, their adaptive capacity will be higher. Communication was assessed based on the availability of means of communication such as television, number of radios and number of mobile phones. These communication gadgets enable the households to be more informed and receive more early warnings as well as share information and updates with government officials and service providers when climate-related events happen in their communities.

Data Analysis

Climate Trends, Changes, and Climate Variability

The time series data (1981-2010) were divided into three decadal periods (Period 1: 1981-1990; Period 2: 1991-2000 and Period 3: 2001- 2010) to detect the trends and changes in temperature and rainfall patterns. Changes in climatic patterns were analyzed using monthly decadal analysis using F-test and analysis of variance and yearly analysis using t- test and analysis of variance (ANOVA). Decadal changes were derived by getting the difference in each period.

Moreover, climate variability in cases of extreme events was determined through computed coefficient of variation (CV) of climate parameters (temperature and rainfall). CV is simply the standard deviation, divided by the average of climate variables. Variability is a test of disparity of distance from each observation from the mean. In addition, the Bartlett's test was employed to determine the homogeneity and to test the equality of variances across the 31 years from period 1981 to 2012. This hypothesized that variances are equal across the years for the minimum and maximum temperature as well as rainfall. Community observations related to climate change and variability/extreme events were also examined and analyzed using descriptive analysis such as frequency and percentage.

Vulnerability Analysis of Farming Livelihood

The indicators of household vulnerability were a combination of discrete, ordinal, and nominal measurement scales. These scaled indicators were normalized by applying min-max method which transformed all values ranging from 0 to 1 to come up with standardized values, and for comparability and aggregation purposes. In normalizing variables that have positive influence or impact on vulnerability, Equation 2 was used while Equation 3 was used for variables hypothesized to have negative effect on vulnerability.

$$y = \frac{X_1 - \text{Min}\,(X_1)}{\text{Max}\,(X_1) - \text{Min}\,(X_1)} \quad (2)$$

$$y = \frac{\text{Max}\,(X_i) - X_i}{\text{Max}\,(X_i) - \text{Min}\,(X_i)} \quad (3)$$

Where:
y= normalized value within the range of 0 to 1
Xi= represents the individual value of indicator to be transformed
Min (Xi)= minimum value for that indicator
Max (Xi)= maximum value for that indicator

Once the various indicators were normalized, average weights for each index (exposure, sensitivity and adaptive capacity) were computed using equal and unequal weighting for aggregation and comparison purposes.

Vulnerability rating using equal weights

The overall vulnerability rating using equal weights was determined following the formula of *Heltberg and Osmolovsky* (*2010*) as shown in Equation 4 where overall vulnerability rating was the average of three factors since equal weights were assigned for every indicator. Prior to averaging of the normalized values of the three factors, a deduction of the value of one was employed in the adaptive capacity indicators.

$$V = {}^{1}/_{3}\ [(E) + (S) + (1 - AC)] \quad (4)$$

Where:
V = level of vulnerability

E = average exposure normalized values
S = average sensitivity normalized values
AC = average adaptive capacity normalized values

The level of vulnerability and corresponding normalized scale should fall within the range of 0.00 to 1.00. The closer the computed value to the upper limit, the higher is the degree of vulnerability of the households' livelihood to climate change and variability. Vulnerability rating ranging from 0.00 to 0.33 was classified as low, 0.34 to 0.66 as moderate, and 0.67 to 1.00 as high.

Vulnerability rating using unequal weights

The overall vulnerability rating using unequal weighting method was done with the aid of the analytical hierarchy process (AHP). The AHP is a pair-wise comparison method to validate the weights or priority factors of vulnerability index by scoring based on the preferred scale values ranging from 1 to 9 (**Table 3**) in accordance with the intensity experienced by communities. Each index was given a score against each other through Focus Group Discussion (FGD) where the participants rated the indices (exposure, sensitivity and adaptive capacity) against each other based on their experiences. The paired comparison matrix with eigenvector values/scores was normalized in dividing each score by the sum total for each column. The average values of the three factors considered for vulnerability index were computed which were then used as weights for calculating the vulnerability index.

Consistency ratio (CR) was also determined to verify the likelihood of the matrix judgments. CR values greater than 0.10 are indicative of irrelevant judgment. On the other hand, values lower than 0.1 are considered acceptable (*Saaty 2006*). Prior to computation of consistency ratio (CR), consistency index (CI) was first computed by using Equation 5. CR was obtained by dividing the CI with the random index (RI), (Equation 6). There is standard set of values for RI in accordance with the number of samples. In this study, the RI value used was 0.58 since three parameters were considered.

Table 3. Analytical hierarchy process (AHP) preference standard rating.

Intensity	Description Rating	Explanation
1	Equally preferred	Two factors contribute equally
3	Moderately preferred	Experience and judgment moderately favor one over the other
5	Strongly preferred	Experience and judgment strongly favor one over the other
7	Very strongly preferred	Experience and judgment very strongly favor one over the other
9	Extremely preferred	Experience and judgment are absolutely extreme
2, 4, 6, 8	Intermediate values	When compromise is needed

Source: *Saaty R.W. (1987)*; *Saaty, T.L (2006)*

$$\mathrm{CI} = \frac{(\lambda - n)}{(\mathrm{n} - 1)} \tag{5}$$

Where:
λ = largest or principal eigenvalue of the matrix
n = is the order of the matrix

$$\mathrm{CR} = \frac{CI}{\mathrm{RI}} \tag{6}$$

Where:
CI= Consistency Index
RI= Random Index

The obtained weights for exposure, sensitivity and adaptive capacity index based on community perception were then used to compute the overall vulnerability (Equation 7). Vulnerability is high if the values of exposure and sensitivity are equal to 1 with adaptive capacity value of 0 and vice versa.

$$V = (W_e * E) + (W_s * S) + [W_{ac} * (1 - AC)] \tag{7}$$

Where:
V = level of vulnerability
We = computed weights of exposure
E = average exposure normalized values
Ws = computed weights of exposure
S = average sensitivity normalized values
Wac = computed weights of adaptive capacity
AC = average adaptive capacity normalized values

RESULTS AND DISCUSSION

Observed Climate Trends and Changes

Minimum Temperature Trends and Changes. In general, the monthly mean minimum temperature (tmin) data showed an increasing trend (**Figure 3**). For three decades (1981-2010), there was an average increase of 0.74°C on the monthly mean minimum temperature (**Table 4**) which implied that significant changes in minimum temperature occurred in three decades. Analysis of mean tmin indicated statistically significant changes (p<0.01) from January to December and the t-test result also showed significant changes in all decadal periods.

Maximum Temperature Trends and Changes. Decreasing trends were observed in monthly mean maximum temperature (tmax) for three decadal periods (**Figure 4**). There was an average decrease of 0.65°C for three time periods (**Table 5**). The monthly mean analysis for tmax also revealed statistically significant changes (p<0.01) from January to December except for June and September. The t-test result also showed highly significant changes (p<0.01) for Period 1 and 2 and Period 1 and 3 and significant changes (p<0.05) for Period 2 and 3.

Mean Temperature Trends and Changes. A monthly analysis of mean temperatures showed a slightly increasing trend (**Figure 5**) and revealed statistically significant changes (p<0.01) for the months of January, April, June to September and December as well as significant changes (p<0.05) for May and November. For the entire three periods, there was an observed increase of 0.04 °C in monthly mean temperature (**Table 6**). The T-test results of observed changes in mean annual temperature only showed significant changes (p<0.01) in Periods 1 and 2 and Periods 2 and 3 but not in Periods 1 and 3.

Rainfall patterns and changes. Generally, the monthly average rainfall showed a decreasing trend although the trend in Period 1, particularly in the month of June, exhibited a drastic increase of 89.21 mm (**Figure 6**). The average monthly rainfall only showed statistically

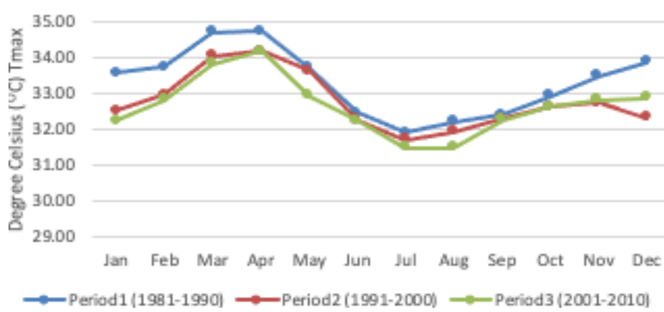

Figure 4. Monthly mean maximum temperature (tmax) for three time periods.

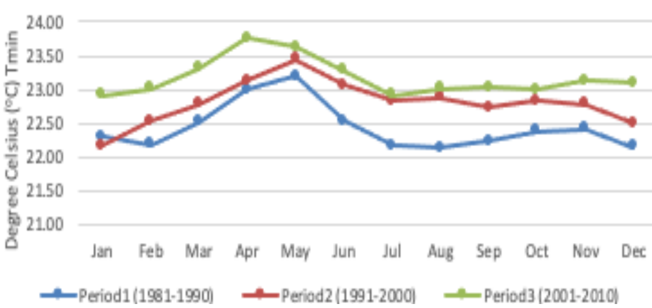

Figure 3. Monthly mean minimum temperature (tmin) in three time periods.

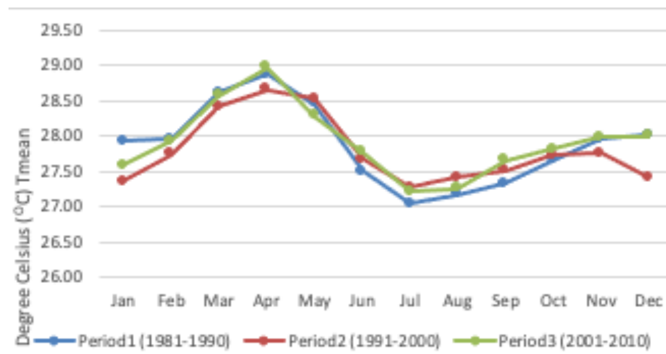

Figure 5. Monthly mean temperature (tmean) for three time periods.

Table 4. Changes in mean minimum temperature for three decadal periods.

	Average Minimum Temperature (°C)			Average	Detected Changes (°C)		
	Period 1 (1981-1990)	Period 2 (1991-2000)	Period 3 (2001-2010)		Periods 2 and 1	Periods 3 and 2	Periods 3 and 1
Jan	22.29	22.17	22.91	22.45	-0.12	0.74	0.61
Feb	22.18	22.52	23.00	22.57	0.34	0.48	0.82
Mar	22.52	22.78	23.30	22.87	0.26	0.52	0.79
Apr	22.99	23.13	23.76	23.29	0.13	0.63	0.76
May	23.20	23.44	23.62	23.42	0.24	0.18	0.43
Jun	22.53	23.06	23.28	22.96	0.53	0.22	0.75
Jul	22.17	22.82	22.92	22.64	0.65	0.10	0.75
Aug	22.12	22.88	23.01	22.67	0.76	0.13	0.89
Sep	22.24	22.73	23.02	22.67	0.50	0.29	0.79
Oct	22.38	22.83	22.99	22.74	0.45	0.16	0.61
Nov	22.42	22.78	23.12	22.77	0.36	0.34	0.71
Dec	22.14	22.50	23.10	22.58	0.36	0.59	0.95
Average	22.43	22.80	23.17	22.80	0.37	0.37	0.74

Table 5. Changes in maximum temperature for three decadal periods.

	Average Minimum Temperature (°C)			Average	Detected Changes (°C)		
	Period 1 (1981-1990)	Period 2 (1991-2000)	Period 3 (2001-2010)		Periods 2 and 1	Periods 3 and 2	Periods 3 and 1
Jan	33.56	32.53	32.25	32.78	-1.03	-0.28	-1.31
Feb	33.73	32.96	32.83	33.17	-0.77	-0.13	-0.90
Mar	34.70	34.05	33.83	34.19	-0.65	-0.22	-0.87
Apr	34.74	34.18	34.17	34.37	-0.56	-0.01	-0.57
May	33.72	33.62	32.93	33.42	-0.10	-0.68	-0.78
Jun	32.47	32.27	32.25	32.33	-0.20	-0.02	-0.22
Jul	31.90	31.71	31.49	31.70	-0.19	-0.22	-0.41
Aug	32.20	31.92	31.50	31.87	-0.28	-0.43	-0.71
Sep	32.42	32.29	32.27	32.33	-0.13	-0.02	-0.15
Oct	32.93	32.62	32.64	32.73	-0.32	0.02	-0.30
Nov	33.48	32.73	32.84	33.02	-0.75	0.10	-0.65
Dec	33.86	32.32	32.88	33.02	-1.55	0.56	-0.98
Average	33.31	32.77	32.66	32.91	-0.54	-0.11	-0.65

Table 6. Detected changes in mean temperature for three decadal periods.

	Average Minimum Temperature (°C)			Average	Detected Changes (°C)		
	Period 1 (1981-1990)	Period 2 (1991-2000)	Period 3 (2001-2010)		Periods 2 and 1	Periods 3 and 2	Periods 3 and 1
Jan	27.93	27.35	27.58	27.62	-0.58	0.23	-0.35
Feb	27.96	27.74	27.92	27.87	-0.22	0.18	-0.04
Mar	28.61	28.41	28.57	28.53	-0.19	0.15	-0.04
Apr	28.87	28.65	28.96	28.83	-0.21	0.31	0.10
May	28.46	28.53	28.28	28.42	0.07	-0.25	-0.18
Jun	27.50	27.67	27.77	27.65	0.16	0.10	0.27
Jul	27.04	27.27	27.20	27.17	0.23	-0.06	0.17
Aug	27.16	27.40	27.26	27.27	0.24	-0.15	0.09
Sep	27.33	27.51	27.65	27.50	0.18	0.14	0.32
Oct	27.66	27.72	27.82	27.73	0.07	0.09	0.16
Nov	27.95	27.76	27.98	27.89	-0.19	0.22	0.03
Dec	28.00	27.41	27.99	27.80	-0.59	0.58	-0.01
Average	27.87	27.79	27.91	27.86	-0.09	0.13	0.04

significant changes for the months of June (α=0.01), August and December ($p<0.05$). No significant changes were observed for the other months and there was an observed decrease of 0.50 mm average monthly rainfall for the entire three decadal periods (**Table 7**).

In summary, yearly analysis by using one-way analysis of variance (ANOVA) and t-test in climate parameters (temperature and rainfall) for the three time periods revealed significant changes had occurred for the three periods for the maximum, minimum and mean annual temperatures, but without observed significant changes in rainfall parameter.

The foregoing findings through monthly and yearly analysis for three decadal periods revealed significant changes in climatic patterns suggesting that climate change occurred and is being experienced by the farming communities in the study area.

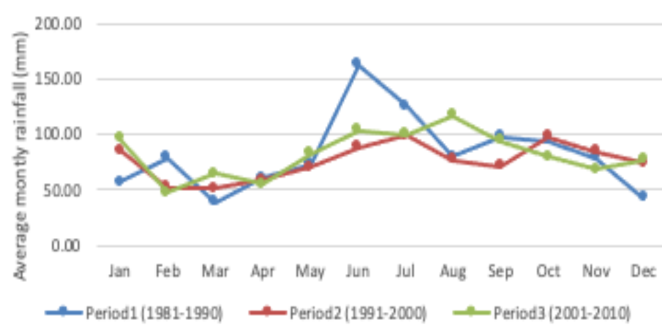

Figure 6. Monthly average rainfall for three time periods.

Community Perception on Climate Change. Results from household survey showed that almost all (99.6%) of the respondents believed that the climate in the study

Table 7. Detected changes in average monthly rainfall for three decadal periods.

	Average Minimum Temperature (°C)			Average	Detected Changes (°C)		
	Period 1 (1981-1990)	Period 2 (1991-2000)	Period 3 (2001-2010)		Periods 2 and 1	Periods 3 and 2	Periods 3 and 1
Jan	56.82	85.85	95.61	79.43	29.03	9.76	38.79
Feb	79.29	51.98	47.32	59.53	-27.31	-4.66	-31.97
Mar	38.70	50.85	64.52	51.36	12.15	13.67	25.82
Apr	60.97	58.44	55.50	58.30	-2.53	-2.94	-5.47
May	73.17	70.60	82.21	75.33	-2.57	11.61	9.04
Jun	162.38	88.12	103.78	118.09	-74.26	15.66	-58.60
Jul	125.62	98.81	99.28	107.90	-26.81	0.47	-26.34
Aug	80.13	77.06	116.79	91.33	-3.07	39.73	36.66
Sep	98.08	71.53	93.89	87.83	-26.55	22.36	-4.19
Oct	94.21	98.23	80.15	90.86	4.02	-18.08	-14.06
Nov	78.55	84.32	68.14	77.00	5.77	-16.18	-10.41
Dec	42.50	74.14	77.25	64.63	31.64	3.11	34.75
Average	82.53	75.83	82.04	80.13	-6.71	6.21	-0.50

area has changed over the past 30 years. Household respondents observed the abnormalities in rainfall and temperature patterns in the area. Local people used to have two seasons of cropping. The "panuig" or wet season (1st cropping) starts from March to June when they plant and expect abundant harvest within the months of July to October. On the other hand, the "panolilang or dry season for the 2nd cropping, starts on August until September and they expect to harvest from January to February. The respondents complained about the abnormalities of rainfall and temperature as a clear demarcation of the two cropping seasons no longer exists in the area due to unpredictable weather conditions. As observed, wet season was wetter bringing about floods and landslides while intense heat was experienced particularly during summer, such that there were cases when farmers no longer work beyond 9:00 in the morning. Farmers also experienced cases when the usually dry months became unusually wet.

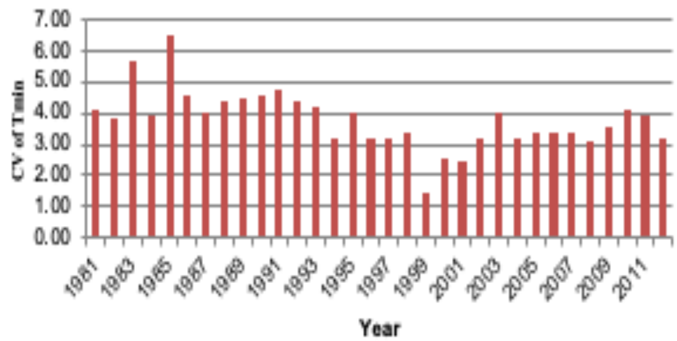

Figure 7. Coefficient of Variation of minimum temperature from 1981 to 2012.

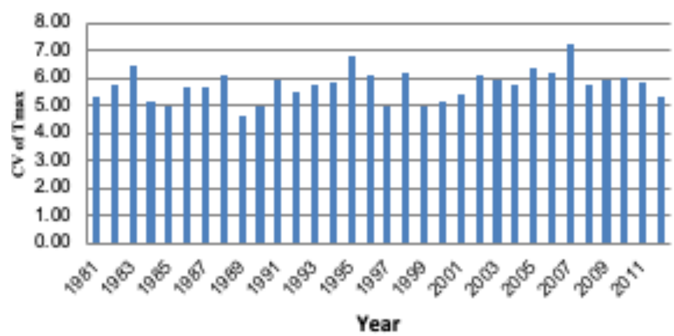

Figure 8. Coefficient of Variation of maximum temperature from 1981 to 2012.

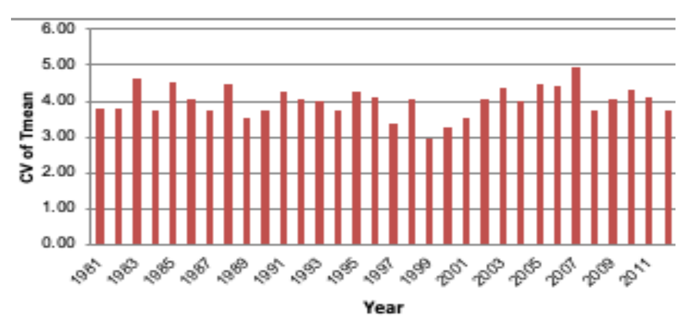

Figure 9. Coefficient of Variation of mean temperature from 1981 to 2012.

Observed Climate Variability

For three decades (1981-2012), the coefficient of variation and Bartlett's test of climate variables (temperature and rainfall) were not homogenous (**Figures 7-10**). Climate variables with high coefficient of variation (CV) entailed episodes of El Niño or dry spell while low CV implied La Niña events or heavy rainfall.

Looking at the computed CV for each climate parameter, high values were observed in 2007 for both maximum and mean temperatures. On the other hand, the lowest CV values for both maximum temperature and rainfall were observed in 1999. Both *Hilario et al.* (*2009*) and *Yumol* (*2010*) reported that an El Niño episode

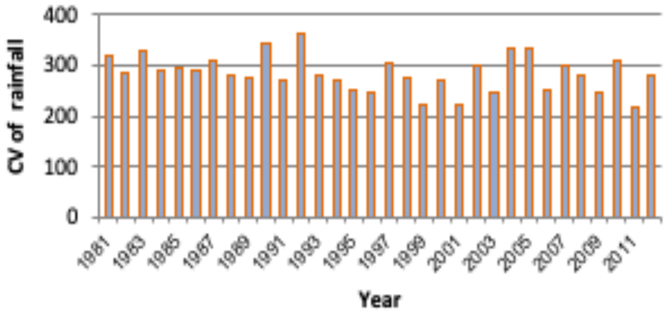

Figure 10. Coefficient of Variation of mean rainfall from 1981 to 2012.

occurred in the Philippines in 2007 from July to August which were normally rainy seasons. Similarly, the southern parts of Mindanao experienced moderate to severe drought which lasted for 13 months prior to a strong La Nina episode in 1999-2000. This was due to the non-migration of the inter-tropical convergence zone northward (*Hilario et al. 2009; Climate Prediction Center-National Oceanic and Atmospheric Administration 2016*). In support, participants of a focus group discussion held on July 28, 2015, relayed historical climate extreme events particularly, drought that they experienced from the 1970's until 2015 (**Table 8**).

Flores (*2005*) noted that an extreme event like flooding is one of the serious problems particularly in the urban center of the City of Koronadal which is located at the floodplains of the Buloc River watershed. During heavy rains, the Buloc River channel overflows and causes flooding. In addition, occurrences of localized landslides are common among communities in the study areas. Moreover, the communities experience other

Table 8. Extreme events experienced by the communities in Roxas Mountain Range, City of Koronadal from 1970 to 2015.

Decade	Year	Extreme Events	Impacts
1970s	1973	Drought	Crop failure
1980s	1982	Drought	Crop failure
	1986	Flashflood	Crop failure and water level up to waistline
	1988	Drought	No production
	1989	Flashflood	Three houses were washed and destroyed
1990s	1997-1998	Drought	Farmers have eaten kayos – wild yam
2000s	2007	Drought	Crop failure
	2012/2013	Flashflood	Four persons died
	2015	Landslide	
		Drought	No harvest
		Landslides	Seven houses were damaged

hazards that are either related to or caused by climate change such as drought, intense heat, and heavy rainfall. These phenomena largely affect the agricultural livelihood sources, processes and production such as growing and supplying corn, rice, root crops, vegetable and other high valued commodity crops which mainly constitute the local economy of Koronadal City.

Vulnerability of Farming Livelihoods

Mean Vulnerability Index. Based on the overall mean indices (**Table 9**), the exposure index rating ranged from 0.58 to 0.72. This implied that the households' livelihood was categorized as moderate to high exposure. In terms of sensitivity, the households' livelihood was from low to high with indices ranging from 0.28 to 0.75. Similarly, adaptive capacity index ranged also from low to high with index ratings from 0.29 to 0.68. Across the three indices of vulnerability, the households' livelihoods were categorized as either of medium or high vulnerability. Based on the overall mean rating, the respondents' livelihoods were categorized as moderately vulnerable to climate change.

Livelihood Exposure to Climate Variability and Change

More than half of the households' livelihoods or 54.3% (144 households) was moderately exposed, while 45.7 % (121 households) had high exposure to climate-related events (**Table 10**). Most of these households with moderate exposure were from Barangay Paraiso (90.4%), followed by Barangay San Isidro (64.9%). In the same way, households with high exposure were from Barangay Carpenter Hill (67.24%), followed by Saravia (64%), Assumption (58.8%), and San Isidro (35.9%).

All of the respondents in the survey relayed that they were exposed and have experienced climate related events such as intense rainfall, intense temperature, and extreme events. Majority of the respondents (66%) experienced landslides occurring every four to five years in their steeply sloping farms, particularly, in the case

Table 9. Mean vulnerability indices across levels.

Level	Numerical Rating	Mean Vulnerable Indices		
		Exposure	Sensitivity	Adaptive capacity
Low	0.00 - 0.33	0	0.28	0.29
Medium	0.34 - 0.66	0.58	0.53	0.44
High	0.67 - 1.00	0.72	0.75	0.68
Overall mean		**0.66**	**0.62**	**0.43**

Table 10. Level and percentage of exposed households to climate change and variability in Roxas Mountain Range, City of Koronadal.

Barangay/ No. of samples (N 265)	Level* and Percentage		
	Low	Moderate	High
Assumption (n= 17)	0	41.2	58.8
Carpenter Hill (n=58)	0	32.8	67.2
Paraiso (n=52)	0	90.4	9.6
San Isidro (n=74)	0	64.9	35.1
Saravia (n=64)	0	35.9	64.1
Overall Percentage	**0**	**54.3**	**45.7**

*Low level - 0.00-0.33; Moderate level - 0.34-0.66; and High level - 0.67-1.00

of Barangays Assumption, Saravia, and Paraiso. More than half of the respondents (52%) from Barangays Carpenter Hill, San Isidro, and Saravia relayed that they have also experienced floods/flashfloods in their community. Prolonged droughts usually from seven to nine months were rarely experienced beyond five years by the communities. One to three months of intense heat were often experienced by the respondents. Most of these communities with high exposure ratings often experienced floods as in the case of Barangay Carpenter Hill and landslides in their respective farms due to high terrain, particularly, Barangays Assumption and Saravia (**Figure 11**).

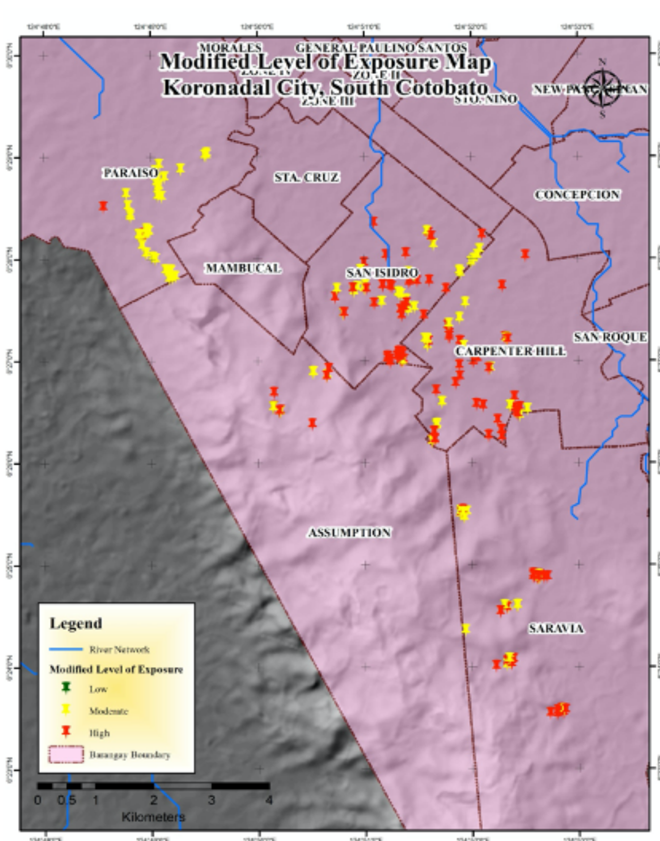

Figure 11. Level of exposure to climate change and variability of farming livelihood in Roxas Mountain Range, City of Koronadal.

Livelihood Sensitivity to Climate Variability and Change

Sensitivity index was observed from the low to high category. Majority of the households' livelihoods (49.8 % or 132 households) were highly sensitive to crop damage and occurrence of pests and diseases due to climate change impacts (**Table 11**). Most of these households were from Barangay Saravia (64%), followed by Barangay Carpenter Hill (55%) (**Figure 12**). During heavy rains, waters caused lodging of crops impacting

Table 11. Level and percentage of households' livelihood sensitivity to climate change and variability in Roxas Mountain Range, City of Koronadal.

Barangay/ No. of samples (N 265)	Level* and Percentage		
	Low	Moderate	High
Assumption (n= 17)	0	70.6	29.4
Carpenter Hill (n=58)	19.0	25.9	55.2
Paraiso (n=52)	11.5	51.9	36.5
San Isidro (n=74)	10.8	41.9	47.3
Saravia (n=64)	4.7	31.3	64.1
Overall Percentage	**10.6**	**39.6**	**49.8**

*Low level - 0.00-0.33; Moderate level - 0.34-0.66; and High level - 0.67-1.00

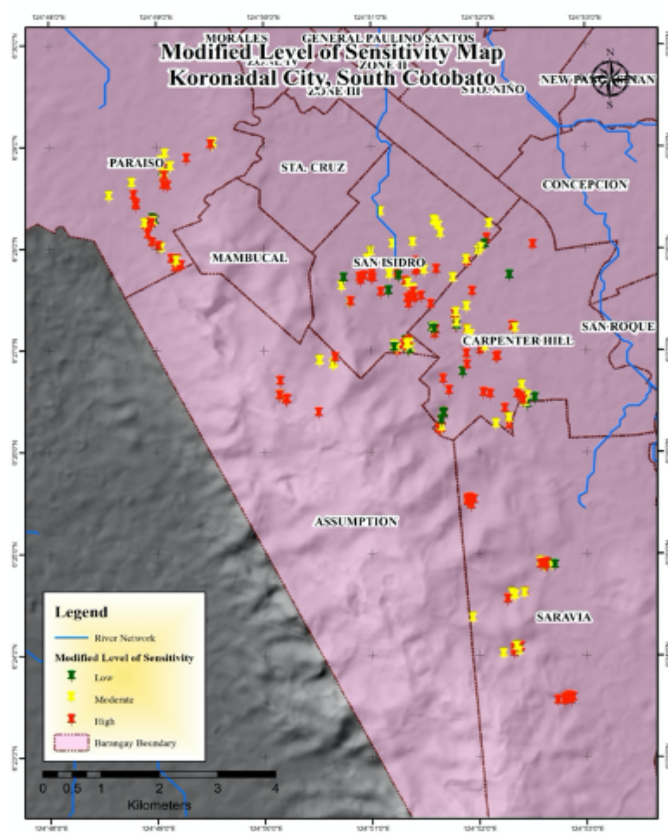

Figure 12. Level of farming livelihood sensitivity to crop damage and pests and disease occurrence as influence by climate change and variability in Roxas Mountain Range, City of Koronadal.

livelihood sources and waters accumulated on the road would cause infrastructure and property damages.

The Provincial Agriculture Office in South Cotabato from 2011 to 2012 reported that about 120 farmers within the study area experienced crop damage mostly caused by flashfloods and lodging of corn and rice crops due to heavy rainfall. Of approximately 179 ha, 40.34 % (72 ha) were damaged with about 329 mt in production losses with an estimated monetary value of PhP 3,962,947 (US$ 92,376.39). The local government units provided cash assistance to affected families amounting to PhP 272,550.00 (US$ 6,353.1469) which means that an individual farmer received an estimated average cash assistance of PhP 2, 271.25 (US$ 52.94).

The participants of the focus group discussion (FGD) confirmed the increasing incidence and sudden spread of pests and diseases on agricultural crops (e.g., rice, corn, coconut, banana, and vegetables) in the study area. Pests such as corn borer, army borer, rice stem borer, rice bug, leaf hopper, leaf folder and fruit borer as well as cut worms for vegetables attack during rainy season. In the same way, black bug, coconut leaf beetle, banana bunchy top virus, aphids, and rats usually attack during the hot days.

The Food and Agriculture Organization (*FAO 2008*) noted that the distribution, incidence and intensity of animal and plant pests and diseases are altered by climate change (*FAO 2008*). Climate change may have also contributed to crop damages through effects on pests and disease (*Gornall et al. 2010*). *Gregory et al.* (*2009*) indicated that the impacts of pests and diseases on yield in current conditions are well known. *Quarles* (*2007*) stated that global warming caused agricultural and forest insect pests to increase as a result of warmer temperatures while an increased rainfall would alleviate fungi causing diseases.

During the FGD, the respondents realized that they need to use disease-resistant crop varieties and short-duration crops to decrease insect pest infestation. Alternative livelihoods, such as off- or non-farm opportunities and skills enhancement may be able to reduce their dependence on cash crops livelihood sources, thus making them more resilient. This will reduce their sensitivity to climate variability (extreme) and change. *Petzoldt* (*n.d.*) advised that the best strategy for farmers to follow is to use integrated pest management (IPM) practices like monitoring the occurrence of pests and keep records of the severity, frequency, and cost of managing pests over time as basis in making decisions as to whether it is economical to continue growing a particular crop or use a certain pest management technique. It is also important for them to have an awareness of crop pest trends by keeping in mind that climate change is a gradual process to adapt.

Households' Adaptive Capacity to Climate Change and Climate Variability

Households in the study area have differential adaptive capacity index (**Table 12**). About 1% of the households found to have high adaptive capacity were from Barangay San Isidro, where respondents have higher educational attainment (**Figure 13**). Those with low adaptive capacity came from Barangays Assumption (29.4%) and Saravia (12.5%). In general, majority (90.6%) of the households fell into moderate adaptive capacity in terms of human, social, financial, natural capitals and high physical capital.

About 73.21% of the respondents had moderate human capital and many of them came from Barangay Paraiso (80.7%) and Carpenter Hill (79.3%). About 19.25% with high human capital mostly came from Barangay Saravia (32.8%) and about 7.55% had low human capital mostly (17.2%) came from Barangay Carpenter Hill (17.2%). More than half of the respondents (53.8%) had low social capital and majority of them came from Barangay Saravia (81.25%). Only 32.83% were categorized as moderate while 13.58% had high social capital in which majority came from Barangays Assumption and San Isidro, respectively.

In addition, about half of the respondents (50.19%) were of moderate financial capital which mostly came from Barangay San Isidro. Only 38.87% of the respondents were rated as having high financial capital while 10.94% had low financial capital, and majority of these household-respondents came from Barangays Assumption and Carpenter Hill, respectively. Then, about half of the respondents (50.19%) were of moderate

Table 12. Level and percentage of households' adaptive capacity to climate change and variability in Roxas Mountain Range, City of Koronadal.

Barangay/ No. of samples (N 265)	Level* and Percentage		
	Low	Moderate	High
Assumption (n= 17)	29.4	70.6	0
Carpenter Hill (n=58)	5.2	94.8	0
Paraiso (n=52)	5.8	94.2	0
San Isidro (n=74)	4.1	91.9	4.1
Saravia (n=64)	12.5	87.5	0
Overall Percentage	**8.3**	**90.6**	**1.1**

*Low level - 0.00-0.33; Moderate level - 0.34-0.66; and High level - 0.67-1.00

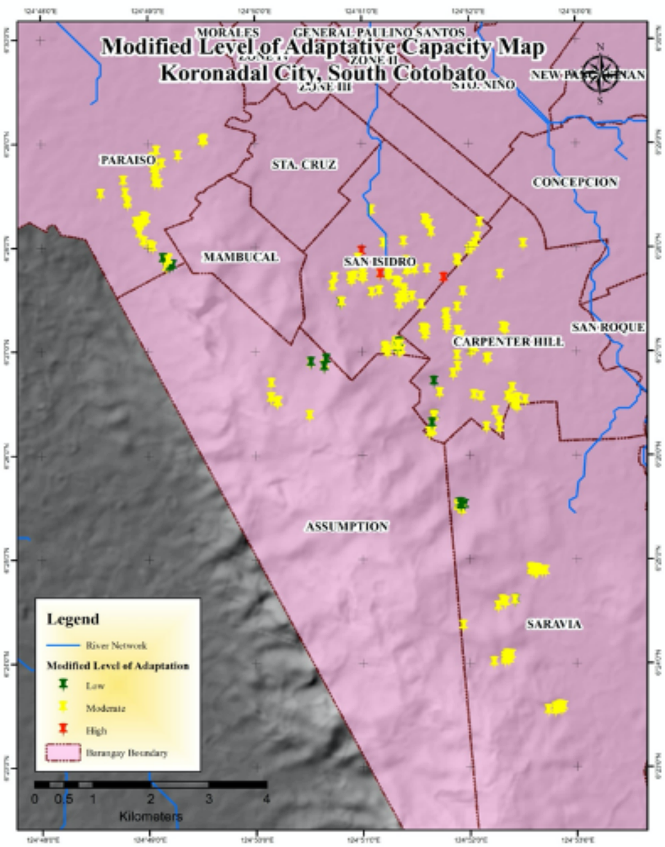

Figure 13. Level of household adaptive capacity to climate change and variability in Roxas Mountain Range, City of Koronadal.

financial capital who mostly came from Barangay San Isidro. Only 38.87% of the respondents were rated as having high financial capital, while 10.94% had low financial capital and majority of these household-respondents came from Barangays Assumption and Carpenter hill, respectively.

In terms of natural capital, about 66% have moderate natural capital who came mostly from Barangays Assumption and Saravia. Only about 34% of the respondents have low natural capital, most of whom are from Barangays San Isidro and Carpenter Hill. Finally, majority of the respondents (52.8%) with high physical capital came from Barangays Assumption and Saravia. Meanwhile, 47.17% were categorized as moderate and only 0.75% with low physical capital. Most of them came from Barangay San Isidro. All of the findings imply that there are programs related to increasing adaptive capacity, particularly, for those household communities. These households with low adaptive capacities, especially in terms livelihood capitals clustered in certain communities can be prioritized in program development initiatives focused on enhancing their resiliency to climate variability and change.

Abaje (*2015*) highlighted that the capacity of individuals or households to adapt to the impacts of climate change is a function of their access to resources. Results of the study showed that households responded to climate variability and change according to their capacity—indicated in their standing livelihood assets. However, appropriate adaptation strategies are still needed to improve their adaptive capacity. Farmers with low adaptive capacity respond only to the risk that affects them most and/or employ the cheapest adaptation measure. On the other hand, farmers with high adaptive capacity responded to climate risks by shifting from one adaptation strategy to another (*Defiesta and Rapera 2014*). Better adaptive capacity therefore translates to more adaptation strategies.

Livelihood Vulnerability to Climate Change and Climate Variability

The overall vulnerability of households' livelihoods was assessed using equal and unequal weighting method. The mean indices based on equal weighting ranged from 0.56 to 0.69, which implied that the households' livelihoods vulnerability ranged from moderate to high. It is good to note, however, that no household was categorized with low vulnerability in terms of livelihood. On the other hand, with unequal weighting, the mean indices ranged from 0.33 to 0.72, which indicated low to high vulnerability (**Table 13**).

Households' Livelihood Vulnerability Based on Equal Weighting

Majority (93.6%) of the respondents were moderately vulnerable. Only 6.4% of the respondents were categorized as highly vulnerable to climate variability and change and majority of them came from Barangay Carpenter Hill. No household was categorized as having low vulnerability (**Table 14** and **Figure 14**).

Table 13. Mean vulnerability indices across levels based on equal and unequal weighting.

Level	Numerical Rating	Mean Vulnerable Indices	
		Equal Weights	Unequal Weights
Low	0.00 - 0.33		0.33
Medium	0.34 - 0.66	0.56	0.56
High	0.67 - 1.00	0.69	0.72
Overall mean		**0.57**	**0.62**

Table 14. Level and percentage of households' livelihood vulnerability to climate change and variability using equal weighting.

Barangay/ No. of samples (N 265)	Level* and Percentage		
	Low	Moderate	High
Assumption (n= 17)	0.00	100.0	0
Carpenter Hill (n=58)	0.00	82.8	17.2
Paraiso (n=52)	0.00	100.0	0
San Isidro (n=74)	0.00	94.6	5.4
Saravia (n=64)	0.00	95.3	4.7
Overall Percentage	**0.00**	**93.6**	**6.4**

*Low level - 0.00-0.33; Moderate level - 0.34-0.66; and High level - 0.67-1.00

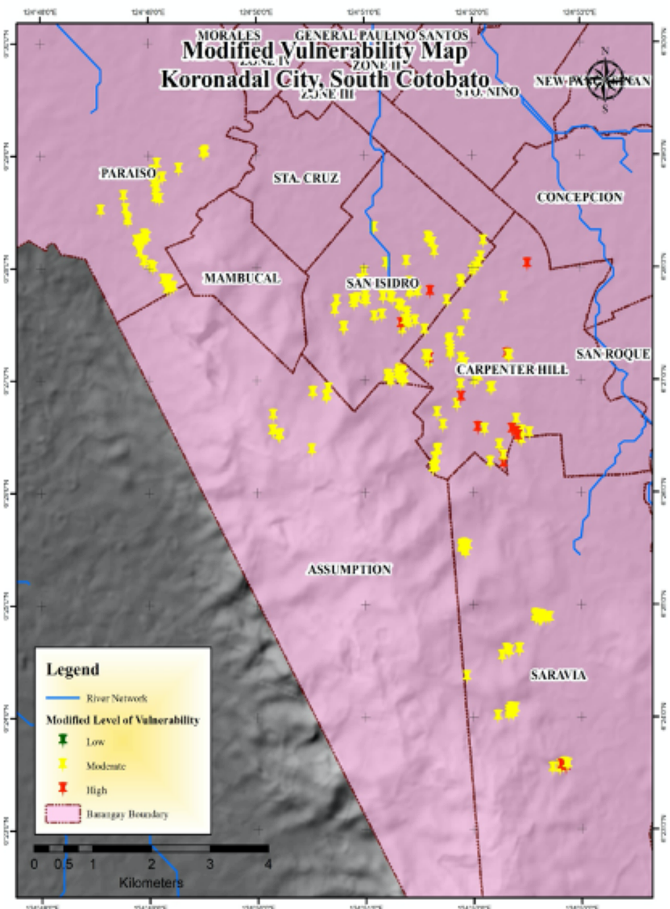

Figure 14. Level of households 'livelihood vulnerability to climate change and variability in Roxas Mountain Range, City of Koronadal.

Households' Livelihood Vulnerability Based on Unequal Weighting

The vulnerability of households' livelihood using unequal weighing through Analytical Hierarchy Process (AHP) also showed that majority (59.62%) of the respondents were moderately vulnerable, 40% were categorized as highly vulnerable, and only 0.38% (1 respondent) was categorized with low vulnerability to climate variability and change (**Table 15**).

Table 15. Level and percentage of overall households' livelihood vulnerability to climate change and variability in Roxas Mountain Range based on unequal weighting.

Barangay/ No. of samples (N 265)	Level* and Percentage		
	Low	Moderate	High
Assumption (n= 17)	0	52.94	47.06
Carpenter Hill (n=58)	1.72	53.45	44.83
Paraiso (n=52)	0	80.77	19.23
San Isidro (n=74)	0	58.11	41.89
Saravia (n=64)	0	53.12	46.88
Overall Percentage	**0.38**	**59.62**	**40**

*Low level - 0.00-0.33; Moderate level - 0.34-0.66; and High level - 0.67-1.00

Incidentally, the FGD participants said that majority of their livelihood sources were moderately vulnerable to climate variability and change. Farming households were still vulnerable although not in extreme conditions. This was due to their coping mechanism with the current impacts of climate-related events including intense rainfall, intense temperature and extreme events such as landslides, flashfloods, and droughts. The farmers' livelihood sources however, remained to be sensitive to crop damage and occurrences of pests and diseases. Being of moderate vulnerability, they still need appropriate adaptation strategies to increase their adaptive capacity.

The findings suggested that there was a need to reduce the vulnerability of households' livelihood by enhancing their adaptive capacity. This was possible by increasing their social capital networks through membership to farmer organizations or cooperatives as their technical and financial support mechanism. Strengthening the financial capital by creating non-farm alternative livelihood opportunities and improved access to market among the respondents was also important. Similarly, by improving the natural capital especially the forests cover is crucial in reducing the vulnerability of livelihood. Physical capital should also be given priority such as farm-to-market road, provision of public transportation and irrigation facilities. In addition, linkages with government and non-government agencies are critical in gaining access to other livelihood programs and capacity building opportunities as well as early warning communication system.

According to *Qaisrani et al.* (2018), reduced climate sensitivity and enhanced adaptive capacity among farmers can reduce livelihood vulnerability to climate change impacts. *Lyimo and Kangalawe* (*2010*) emphasized that livelihood diversification strategies, including integration of on-farm and non-farm activities, were essential in enhancing the adaptive capacity and ensured sustainable rural livelihood in a changing climate. *Sujakhu et al.* (*2018*) recommended that farmers should not solely rely on agriculture-based income but need to have a diversified livelihood system as well as improved human, natural and financial capitals.

CONCLUSIONS AND RECOMMENDATION

Climate-related events affect the agricultural crops and other high-valued crops grown by farming communities in Roxas Mountain Range, City of Koronadal, South Cotabato Province, which contribute to the households' livelihood vulnerability. The findings for both monthly and decadal analysis in three time periods (1981-2010) revealed significant changes in climatic patterns particularly the monthly mean minimum and maximum temperature. For three decadal periods, the monthly mean minimum temperature increased by 0.79 °C while the mean maximum temperature decreased by 0.65. The rainfall patterns also revealed significant changes in the months of June ($p<0.01$) August and December ($p<0.05$) suggesting that climate change occurred in Roxas Mountain Range, City of Koronadal over a three decades. Likewise, for the past 31 years (1981-2012), the coefficient of variation and Bartlett's test of climate variables (temperature and rainfall) were not homogenous, with high coefficient variation implied an El Niňo events while low coefficient variation entailed La Niňa episodes. The findings showed that the observed climate variability and change threatened the households' livelihoods considering that majority of them were rated to be "moderately to highly vulnerable" to the changing climate. The farming households were exposed to and experienced extreme events including intense heat, intense rainfall, floods, landslides and drought. These events had devastating impacts and brought havoc on the livelihood of farming communities in the study area. This means that the farming households' livelihood are generally sensitive with the adverse impacts of climate-related events despite their inherent tendencies to cope. The majority (90.6%) of the households fall into moderate adaptive capacity in terms of human, social, financial, natural capitals and high physical capital. They would need supplementary adaptation strategies and support to increase their adaptive capacity. Enhancing social capital and strengthening technical capability and capacity through exposure, trainings and seminars is an avenue to increase the households' adaptive capacity. Creating/developing of non-farm alternative livelihood sources and innovation of existing ones would lessen their dependence on farming and would make them less vulnerable to climate change impacts. It is therefore necessary for policy and decision makers to understand the current livelihood vulnerability of smallholder farmers in order to develop enabling policies and appropriate programs to minimize current and future adverse impacts and enhance the households' adaptation.

REFERENCES

Abaje, I.B., Sawa B.A, Iguisi E.O. and Ibrahim, A.A. 2015. "Assessment of Rural Communities' Adaptive Capacity to Climate Change in Kaduna State, Nigeria". J*ournal of Environment and Earth Science*5(20), pages? www.iiste.org ISSN 2224-3216 (Paper), ISSN 2225-0948 (Online) (Accessed on March 09, 2016).

Arias, J.K.B., Mendoza, M.E.T., Ballaran, V.G. Jr., and Dorado, R.A. 2014. "Household Vulnerability to Climate Change in Selected Municipalities in Laguna, Philippines," EEPSEA Research Report. Economy and Environment Program for Southeast Asia (EEPSEA).

Asian Development Bank. 2009. "The Economics of Climate Change in Southeast Asia: A Regional Review". http://www.adb.org/sites/default/files/publication/29657/economics-climate-change-se-asia.pdf (Accessed on August 30, 2015).

Barbier, E.B. and Hochard, J.P. 2018. "The Impacts of Climate Change on the Poor in Disadvantaged Regions". *Review of Environmental Economics and Policy* 12 (1), 26–47, https://doi.org/10.1093/reep/rex023

Bohle, H., Downing, T. and Watts, M. 1994. "Climate Change and Social Vulnerability: Toward a sociology and geography of food insecurity". *Global Environmental Change* 4 (1): 37 – 48. http://www.sciencedirect. com/science/article/pii/0959 378094900205. (Accessed on December 4, 2016).

CARE International. 2009. "Climate Vulnerability and Capacity Analysis Handbook". www.careclimatechange (Accessed on December 4, 2015).

Celidoni, M. 2013".Vulnerability to poverty: an empirical comparison of alternative measures". *Applied Economics* 45 (12):1493-1506.

Chambers, R. and Conway, G. 1992. "Sustainable Rural Livelihoods: Practical Concepts for the 21st Century". Discussion paper 296, Institute of Development Studies, Brighton, UK; 1992. 178.

City Planning Development Office. 2009. Ecological Profile City of Koronadal.

Climate Change Prediction Center-National Oceanic and Atmospheric Administration. 2016. "Drought Related Information".http://www.cpc.ncep.noaa.gov/

CNN Philippines. 2016. Koronadal City under State of Calamity. http://cnnphilippines.com/regional/2016/03/12/state-of-calamity-el-ni%C3%B1o.html.

Department for International Development. 2004. The Impact of Climate Change on the Vulnerability of the Poor. http://www.unpei.org/sites/default/files/PDF/ resourceefficiency/KM-resource-DFID-impact-climatechange-vulnerability.pdf

Defiesta, G. and Rapera, C.L. 2014. "Measuring Adaptive Capacity of Farmers to Climate Change and Variability: Application of a Composite Index to an Agricultural Community in the Philippines". *Journal of Environmental Science and Management* 17(2):48-62 ISSN 0119-1144

Eckstein, D., Kunzel V., Schafer, L., and Winges, M. 2019. Global Climate Risk Index 2020. Briefing Paper. Who Suffers Most from Extreme Weather Events? Weather-Related Loss Events in 2018 and 1999 to 2018. https://germanwatch.org/sites/germanwatch.org/files/20-2-01e%20Global%20Climate%20Risk%20Index%202020_10.pdf. Date accessed?

FAO. 2008. Climate-Related Transboundary Pests and Diseases. Technical Background Document from the Expert Consultation Held On 25 To 27 February 2008 Food and Agriculture Organization, Rome. pp 1-59. http://www.fao.org/3/a-ai785e.pdf

Fraser, E. D. G., Dougill, A. J., Hubacek, K., Quinn, C. H., Sendzimir, J., and Termansen, M. 2011. "Assessing vulnerability to climate change in dryland livelihood systems: conceptual challenges and interdisciplinary solutions". *Ecology and Society* 16(3) pp1-13. http://dx.doi.org/10.5751/ES-03402-160303

Flores, J.G. 2005. "Runoff Estimates of Buloc River Watershed, Koronadal City, South Cotabato". Unpublished Master's Thesis. Presented to the Faculty of the School of Government and Management University of Southeastern Philippines, Obrero, Davao City.

Gornall, J., Betts, R., Burke, E., Clark, R., Camp, J., Willett, K., and Wiltshire, A. 2010. "Implications of Climate Change for Agricultural Productivity in the Early Twenty-First Century". Philosophical Transactions of the Royal Society. Phil. Trans. R. Soc. B (2010) 365, 2973–2989 doi:10.1098/rstb.2010.0158. https://royalsocietypublishing.org/doi/pdf/10.1098/rstb.2010.0158

Gregory, P.J., Johnson, S.N., Newton, A.C., and Ingram, J.S. 2009. "Integrating Pests and Pathogens into the Climate Change/Food Security Debate". Journal of Experimental Botany, 60 (10):2827–2838. Https://Doi.Org/10.1093/Jxb/Erp080

Harvey, C.A., Rakotobe, Z.L., Rao, N.S., Dave, R., Razafimahatrata, H., Rabarijohn, RH., Rajaofara, H., and Mackinnon, J.L. 2014. Extreme Vulnerability of Smallholder Farmers to Agricultural Risks and Climate Change in Madagascar. http://rstb.royalsociety publishing.org/content/369/1639/20130089

Heltberg, R., and Osmolovskiy, M. 2010. Mapping Vulnerability to Climate Change. http://siteresources.worldbank.org/INTTAJIKISTAN/Resources/A_climate_vulnerability_index_TJK.pdf.

Herrera, C., Ruben, R., and Dijkstra, G. 2018. "Climate Variability and Vulnerability to Poverty in Nicaragua." *Journal of Environmental Economics and Policy* 7 (3):324-344, DOI: 10.1080/21606544.2018.1433070

Hilario, F., de Guzman, R., Ortega, D., Hayman, P. and Alexander, B. 2009. "El Niño Southern Oscillation in the Philippines: Impacts, Forecasts, and Risk Management". https://dirp3.pids.gov.ph/ris/pjd/pidspjd09-1enso.pdf

Intergovernmental Panel on Climate Change. 2001. Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. pp 1-1042 https://library.harvard.edu/sites/default/files/static/collections/ipcc/docs/27_WGIITAR_FINAL.pdf

Intergovernmental Panel on Climate Change. 2007. Summary for Policymakers. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 7-22.

International Panel on Climate Change (IPCC). 2013. Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Intergovernmental Panel on Climate Change (IPCC). (2013). Annex III: Glossary [Planton, S. (ed.)]. In: Climate Change 2013: The physical science basis. Contribution of working group I to the fifth assessment report of the Intergovernmental Panel on Climate Change. [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Intergovernmental Panel on Climate Change (IPCC). (2013). Annex II: Glossary. [Agard, J. Lisa, E., Schipper F., (ed.)]. In: Climate change 2014. Impacts, adaptation and vulnerability. [Birkmann, J. Campos, M., Dubeux, C., Nojiri, Yukihiro, Olsson, L., Osman-Elasha, B., Pelling, M. Prather, M.J., Rivera-Ferre, M.G., Ruppel, O.C., Sallenger, A., Smith, K.R., St. Clair, A., Mach, K.J., Mastrandrea, M.D., & Bilir, T.E. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Lyimo, J.G. and Kangalawe, R.Y. M. 2010. "Vulnerability and Adaptive Strategies to the Impact of Climate Change and Variability. The Case of Rural Households in Semi-arid Tanzania." *Environmental Economics*, Volume 1, Issue 2, 2010. Pp 2-10. https://businessperspectives.org/pdfproxy.php?item_id:3695

PAGASA, 2018. Observed and Projected Climate Change in the Philippines. Philippine Atmospheric Geophysical and Astronomical Services Administration, Quezon City, Philippines, 36 pp. https://icsc.ngo/wp-content/uploads/2019/07/PAGASA_Observed_Climate_Trends_Projected_Climate_Change_PH_2018.pdf

Petzoldt, S. undated. Climate Change Effects on Insects and Pathogens. http://www.panna.org/sites/default/files/CC%20insects&pests.pdf (Accessed on March 9, 2016)

Piya, L. 2012. Vulnerability of Rural Households to Climate Change and Extremes: Analysis of Chepang households in the Mid-Hills of Nepal. https://pdfs.semanticscholar.org/48fe/7f29bde550a72adb380f2289ad0d7568ab58.pdf

Qaisrani, A., Umar, M.A., Siyal, G.E.A., Salik, K.M. 2018. "What Defines Livelihood Vulnerability in Rural Semi Arid Areas? Evidence from Pakistan". *Earth Systems and Environment* 2:455–475 https://doi.org/10.1007/s41748-018-0059-5

Quarles, W. 2007. Global Warming Means More Pests. 2007. The IPM Practitioner Monitoring the Field of Pest Management. Volume XXIX, Number 9/10, http://www.birc.org/SepOct2007.pdf

Saaty, R.W. 1987. The Analytic Hierarchy Process: What It Is and How It Is Used. Mat/d Modelling, Vol. 9, No. 3-5, pp. 161-176, 1987. https://www.sciencedirect.com/science/article/pii/0270025587904738

Saaty, T.L. 2006. The Analytic Network Process. In Book: Saaty, T.L. and Vargas, L. 2006. Making with the Analytical Process. Economic, Political, Social and Technological Applications with Benefits, Opportunities, Costs and Risks. Pages 1-26. DOI: 10.1007/0-387-33987-6_1

Sukhatme, P.V. 1953. "Sampling theory of Surveys, with Applications". Indian Society of Agricultural Statistics, New Delhi, and Iowa State College Press, Ames, Iowa, U.S.A. pp 1-519. http://www.ru.ac.bd/wp-content/uploads/sites/25/2019/03/407_05_00_Sukhatme_Sampling-Theory-of-Surveys-with-Applications-.pdf

Sujakhu, N.M., Ranjitkar, S., Niraula, R.R., Salim, M.A., Nizami, A., Schmidt-Vogt, D., and Xu, J. 2018. "Determinants of Livelihood Vulnerability in Farming Communities in Two Sites in the Asian Highlands". *Water International* DOI: 10.1080/02508060.2017.1416445

USAID. 2007. Adapting to Climate Variability and Changes: A Guidance Manual for Development Planning. United States Agency for International Development, Washington D.C. USAID. https://pdf.usaid.gov/pdf_docs/PNADJ990.pdf

Yumul, G.P., Cruz, N.A., Dimalanta C.B., Servando N.T., and Hilario F.D. 2010. "The 2007 Dry Spell in Luzon (Philippines): Its Cause, Impacts and Corresponding Response Measures". Springer 100 (3-4). *Climatic Change* 100:633–644 DOI 10.1007/s10584-009-9677-0. https://link.springer.com/article/10.1007/s10584-009-9677-0

Zacarias, D.A. 2019. "Understanding Community Vulnerability to Climate Change and Variability at a Coastal Municipality in Southern Mozambique". *International Journal of Climate Change Strategies and Management* 11 (1):154-176 https://doi.org/10.1108/ IJCCSM-07-2017-0145

Ziervogel, G. and Rebecca, C. 2003. Climate Variability and Rural Livelihoods: Assessing the Impact of Seasonal Climate Forecasts in Lesotho. Royal Geographical Society. Volume35, Issue4. Pages 403-417. December 2003. https://doi.org/10.1111/j.0004-0894.2003.00190.x