



Climate Change, Impacts and Adaptation Strategies of Farmers in Roxas Mountain Range, City of Koronadal, Philippines

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Abstract

Farmers in the Roxas mountain range, City of Koronadal used to have bountiful harvests during the time when the city was still free from climate-related hazards. However, this situation has recently changed due to the increasing climate-related risk events. Moreover, localized baseline scientific climate information is limited to foster the development of appropriate adaptations and policies toward climate-resilient communities. This study assessed the climate trends and the changes, impacts, and adaptation strategies of farm households in five barangays in the Roxas mountain range, Koronadal City, South Cotabato. The study conducted household surveys with 265 respondents, focus group discussions, and key informant interviews. In using Mann-Kendall test statistics, time series analysis and one-way analysis of variance, the findings from 1981 to 2012 show increasing trends with significant changes ($p < 0.01$) in mean minimum temperature, increasing by 0.74°C for three decades. In contrast, mean maximum temperature showed a decreasing trend with an average decrease of 0.65°C , $p < 0.01$. In three decadal periods, an average increase of 0.04°C in monthly mean temperature was observed. Rainfall patterns during the same period also show significant changes in the months of June ($p < 0.01$), August, and December ($p < 0.05$); these findings suggest that climate change occurred. Floods, landslides, and droughts were experienced by the communities, which had devastating socioeconomic and environmental impacts. The existing adaptation strategies are just stop-gap solutions that address the effects of climate change but do not consider the root causes. To consider future changes in climate patterns, the socioeconomic and political structure and processes of the communities need to change; this can be achieved if multifaceted drivers of climate change hazards and their impacts are appropriately and immediately addressed. Some grassroot-level transformative adaptation strategies identified in the study consist of socioeconomic facets, specifically, *investment in children's education, financial management, family planning, and development of alternative on-farm and nonfarm livelihood options*. The environmental aspect, which includes *promoting agroforestry system, water impoundment technologies, and advanced early warning system*, were also considered.

Keywords: climate trends, variability, climate change, climate impacts, transformative adaptation

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Highlights

- The monthly and yearly temperature and rainfall patterns from 1981 to 2012 significantly changed, which suggest that climate change occurred in Roxas Mountain Range, City of Koronadal.
- The manifestations of climate change observed and experienced by the local farmers include intense heat and rainfall, floods/flashflood, landslides, and drought. These manifestations have adverse social (e.g., migration, decreased working time at the farm, loss of lives and properties), economic (declined crop yields, increased occurrences of pests and diseases, delays in planting) and environmental impacts (reduction of water supply and loss of landscapes aesthetic value) to the local farmers.
- The local government plays a crucial role in facilitating and promoting appropriate adaptation strategies against climate change. These strategies have increased the local communities' awareness of climate change and have transformed the socioeconomic, environmental, and political structures and processes in the communities. Some of the potential transformative socioeconomic adaptation strategies identified are *investment in education* through scholarship programs and the *support provided for alternative on-farm and nonfarm livelihoods*. In addition, *promoting agroforestry system* or diversified farming has enhanced the aesthetic landscape and has served as the best adaptation and mitigation option to climate change.

Introduction

The City of Koronadal has been declared several times under a state of calamity due to incidents of flash floods and landslides, such as those that occurred in July 2013 and in June 2015 (Philippines News Agency [PNA] 2015). In 2016, the city was yet again placed under a state of calamity twice due to the severe drought in March (CNN Philippines, 2016) and to the flooding in October (Canlas, 2016).

The communities commonly experience intense heat and heavy rainfall. In 2020, the *Philippine News Agency* (PNA) reported that the City of Koronadal experienced episodes of flooding and landslide, which affected more than 200 families in several villages. These hazards were caused by a two-hour heavy rains, which then caused the Bulk Creek to overflow after a large volume of water from upland villages flooded into the creek (Estabillo, 2020). These climate risk events have consequently affected properties, facilities, infrastructures, and the people and their livelihood sources that are highly dependent on the weather (i.e., agricultural production). It is unclear, however, if such climate risk events experienced by the affected

farmers in the City of Koronadal are related to climate change and climate variability.

According to the Intergovernmental Panel on Climate Change (IPCC), *climate change* is a change in the state of a climate, which can be identified through the changes in the mean and/or the variability of its properties that persist for an extended period, typically decades or longer. Meanwhile, *climate variability* is defined as the variation in the mean state and other statistics (e.g., standard deviations) and the occurrence of climate extremes on all spatial and temporal scales beyond that of individual weather events (IPCC, 2013b). The increasing mean temperature; significant variation in precipitation patterns; rising sea level; and increasing frequency and growing intensity of extreme weather events (e.g., drought, floods, and landslides) are the manifestations of the changing climate and variability (Asian Development Bank, 2009). Consequently, these manifestations have adversely affected the agriculture sector—a sector that highly depends on the weather (Gentle & Maraseni, 2012)—and the people living in rural areas who have limited adaptive capacity (International Fund for Agricultural Development, 2009).

In view of these, climate change adaptation is needed in order to cope effectively with the impacts. Moreover, adaptation strategies must be considered as an integral part of a holistic response to building the capacity and resilience of communities such that they can withstand the range of shocks and stresses (CARE International, 2009; IPCC, 2007). Hence, transformative adaptation strategies are needed (Tabara, Jager, Mangalagiu, & Grasso, 2018). *Transformational adaptation* changes the fundamental attributes of a system in response to climate and to its effects (IPCC, 2014). It requires local leadership and the efforts of various actors in implementing transformative adaptation (Kates, Travis, & Wilbanks, 2012).

The United States National Research Council (2010) cited that understanding climate change and its evidence is vital for decision makers such that they can respond effectively to its various causes and impacts. Accordingly, assessing the impacts of climate change on smallholder farmers and identifying the appropriate adaptation strategies need to be done as the information on these aspects at the grassroots level are very limited (Harvey et al., 2014). In addition, localized evidence-based information on climate-related trends and changes in Koronadal City is still limited and not well established. This set of information could serve as scientific baseline information for local government units (LGUs) when crafting policies that would reduce the adverse impacts of climate change. Specifically, these policies could focus on either enhancing the existing conditions or developing appropriate adaptation measures.

In this context, this study aimed to:

1. Examine the climate trends and changes in

- temperature and rainfall patterns, and the communities' perception of climate change in the study area;
2. Determine the impacts of climate change to farming livelihoods; and
 3. Examine the current and potential transformative adaptation strategies in response to climate change impacts.

Methodology

Location of the study

The study was conducted in five farming *barangays* (districts) (i.e., Assumption, Saravia, Carpenter Hill, Paraiso, and San Isidro) in the Roxas mountain range in Koronadal City, South Cotabato province (Figure 1). The Roxas mountain range was selected as the study site because it is vulnerable to climate-related hazards that affect farming livelihood sources. Based on the 2010 report of the Mines and Geosciences Bureau–Region 12, two out of the eight barangays within the Roxas mountain range are highly susceptible to landslides (i.e., Barangay Assumption and Barangay Saravia), while three are moderately susceptible

(i.e., Barangay Carpenter Hill, Barangay Paraiso, and Barangay Sta. Cruz). However, the localized scientific baseline information on the impacts of and adaptation measures on climate-related risks in these areas are still limited. Accordingly, these are important components to reinforce the adaptation planning in the locality.

The residents within the Roxas mountain range have farming as their means of livelihood. The area provides food and other important natural resources (e.g., water, forest and non-forest products) to these communities and nearby barangays. Majority of the households cultivate corn, rice, root crops, vegetables, and other high-value commodities (e.g., banana and coconut, in farmlands with areas of from 0.5–4.0 ha.

The Roxas mountain range was decreed as a watershed area by of virtue Proclamation No. 607 and has a total land area of 1,137 ha. As a watershed with full vegetation, it should be that the area is capable of holding water and preventing erosion, landslides, and flashflood. However, the flood events in Koronadal City are usually caused by the large volumes of water coming from the upland villages (Estabillo, 2020), such as those from the Roxas mountain range.

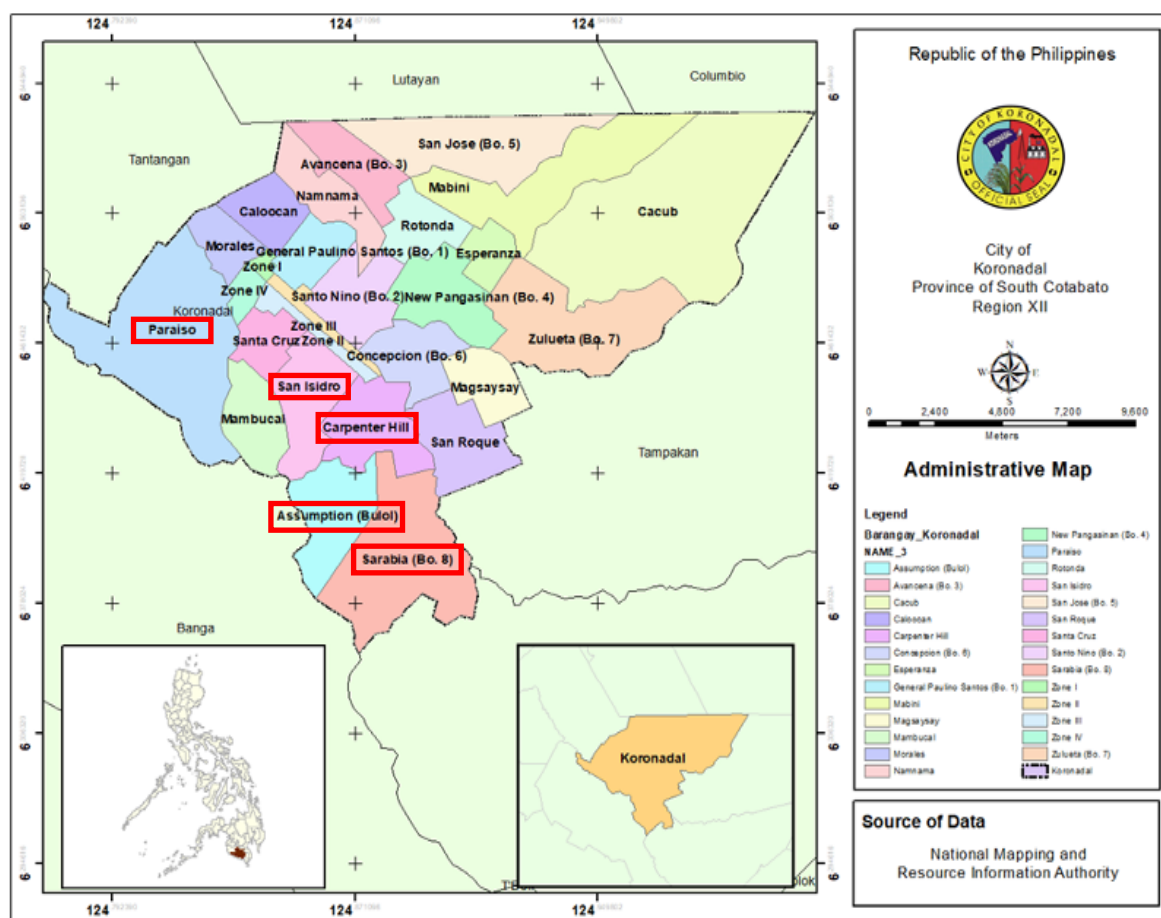


Figure 1. Administrative map of Koronadal City, South Cotabato

Notes: The study sites are boxed in red.

The landscape of the Roxas mountain range is one of the distinct physiographic features of the City of Koronadal which is a land-locked area situated in Southern Mindanao. It is composed of 27 barangays and has a total land area of 277 km² (City Development Planning Office, 2009). It is also home to some of the B'laan indigenous people. The climate in the study area belongs to the fourth type under the Corona Climate System Classification, which is characterized as mild and subtropical with June to October as the rainy months. The City of Koronadal used to be typhoon-free, albeit this has changed over time.

Data Collection

A courtesy visit to the city government of Koronadal City was conducted, and subsequently secured a study permit to conduct data collection in the five barangays. Household survey, focus group discussion (FGD), and key informant interviews (KII) were then conducted from April 2013 to July 2015.

A total of 265 randomly selected farm households served as survey respondents. The number of respondents was determined using the formula of Sukhatme (1953) (Equation 1). Stratified random sampling using lottery technique and proportional allocation were also done to determine the sample size per barangay (Table 1). Majority (59%) of the respondents in the household survey have been living in the community for more than 30 years, and their ages ranged from 20 to 84 years old. About 59% were female, while the rest were male.

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

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)

Secondary data, such as the observed climate data from 1981 to 2012, were taken from the station of the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA)-General Santos 55 and from the PAGASA central office since there was no available historical climate data in the study area. Meanwhile, the potential adaptation plans were identified through the household survey and FGD; these strategies were developed based on the 2011 PAGASA

climate projection downscaled scenarios in Region 12. Baseline maps and sociodemographic profiles were also gathered from the LGUs.

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

Barangay	Sample Size
1. Assumption	17
2. Saravia	64
3. Carpenter Hill	58
4. Paraiso	52
5. San Isidro	74
Total sample size	265

Data analysis

The data gathered were analyzed qualitatively and quantitatively. The climate data were subjected to trend and change analysis using time series analysis. Specifically, five-year moving averages and simple linear regression were used to analyze the climate trends. The five-year moving average was calculated by getting the average every five years within the 31 year climate data. The nonparametric Mann-Kendall test statistics were also performed to test the presence of monotonic increasing or decreasing trend in the time series data. A simple linear regression was used to show the long-term annual trends in temperature (minimum, maximum, and mean) and rainfall data from 1981 to 2012. Subsequently, the coefficient of determination (r^2) was computed.

The entire time series data were divided into three decadal periods to determine the changes in rainfall and temperature patterns. The changes in climatic patterns were analyzed in two ways. First through running a monthly analysis of the three time periods using the F-test through a one-way analysis of variance (ANOVA), whereas the second method is through performing a yearly decadal analysis of the three time periods using the T-test and one-way analysis. These were employed to do a pairwise comparison of the three decadal periods. The analysis was divided into three periods: Period 1: 1981–1990, Period 2: 1991–2000, and Period 3: 2001–2010.

On the other hand, the data on the communities' perceptions of the observed changes in climatic conditions and its causes, which were gathered from the household survey, were analyzed. The identified impacts of and adaptation to climate variability and

change were also analyzed using descriptive analysis. The 2011 PAGASA downscaled climate scenario (medium range) of South Cotabato was used to identify the potential transformative adaptation options that could be used by the affected communities. The trend and change scenarios for 2020 and 2050 were explained during the household survey, and this became the basis for identifying the potential transformative adaptation strategies.

Results and Discussion

Observed climate trends, climate change and community perception

Observed trends

The results of the regression analysis and Mann-Kendall test statistics of the annual mean minimum temperature ($t_{\min}$) from 1981 to 2012 show a significant increasing trend (Figure 2) at a rate of 0.0266 ± 0.0061 . In 1987 and 2002, $t_{\min}$ drastically increased by 0.61°C and 1.39°C , respectively; and a drop was detected in 1983 and 1985. In contrast, the annual mean maximum temperature ($t_{\max}$) exhibited a statistically significant decreasing trend (Figure 3) at a rate of -0.0340 ± 0.0101 . In 1988, $t_{\max}$ spiked by 0.85°C and then dropped by 1.35°C and 1.28°C in 1999 and 2011, respectively. The significant increasing trend in $t_{\min}$ and decreasing trend $t_{\max}$ implies episodes of *El Niño* and *La Niña*, respectively.

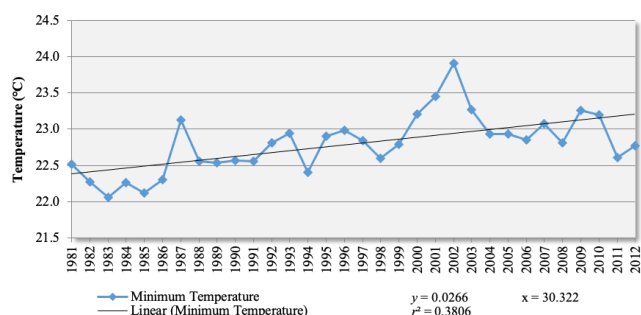


Figure 2. Observed trends of annual mean minimum temperature in 1981–2012

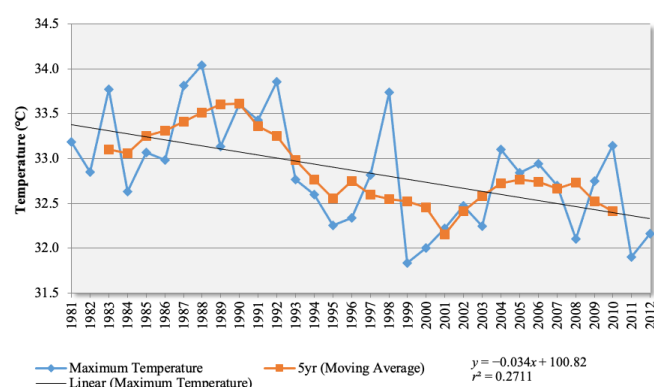


Figure 3. Observed trends of mean annual maximum temperature in 1981–2012

The daily minimum temperatures are projected to increase faster than the daily maximum temperatures. This will consequently decrease the diurnal temperature range and increase the likelihood that extreme weather events (e.g., droughts, landslides, and flooding) would occur (Meehl et al., 2007).

Droughts were observed in 1987 and 2002 in the Philippines (Hilario, Guzman, & Ortega, 2009; Climate Change Prediction Center-National Oceanic and Atmospheric Administration, 2015). Accordingly, a warming trend in minimum temperature can significantly affect crop yields, which then calls for the development of suitable adaptation strategies to sustain production (Rao, Chowdary, Sandeep, Rao, & Venkateswarlu, 2014). For every 1°C increase in minimum temperature, rice yield could decline by as much as 10% (Laborte et al., 2012).

The observed $t_{\min}$ and $t_{\max}$ trends in the study area are different from the observed current climate trends in the country. According to Cinco, Hilario, De Guzman, Emma, and Ares (2013), $t_{\max}$ and $t_{\min}$ trends from 1951 to 2009 were increasing by 0.36°C and 1.0°C , respectively; the same goes for the annual mean temperature. Such differences in the observed results may be due to the scope of measurement since all areas of the country had been covered by Cinco et al. (2013), which was wider in range and hence, more varied.

The results of the linear regression and the five-year moving average (Figure 4) as well as the Mann-Kendall test statistics of observed annual mean temperature also show a decreasing, although not significant, trend at a rate of -0.0037 ± 0.0059 . Mean temperature dropped in 1984, 1999, and 2011 by 0.41 , 0.54 , and 0.60 , respectively. Moderate-to-strong *La Niña* events also occurred in the years mentioned. Meanwhile, the total annual rainfall (Figure 5) shows an increasing trend, albeit the increase is not significant. There are years, however, when rainfall decreased. For instance, the annual mean rainfall in 1991 and 1992 decreased by 200 mm and 143 mm, respectively. On the other hand, the highest annual rainfall is about $1,346.4$ mm in 1999, which coincided with episodes of *La Niña*.

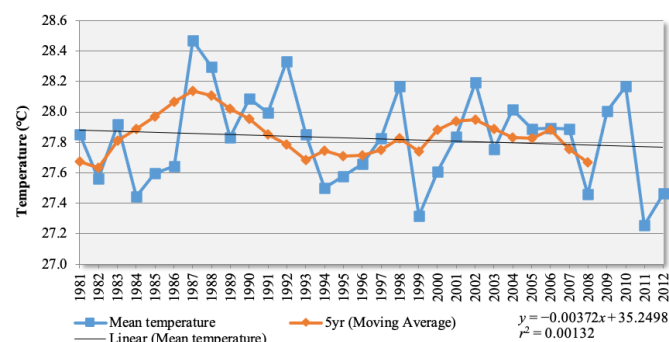


Figure 4. Observed trends of annual mean temperature in 1981–2012

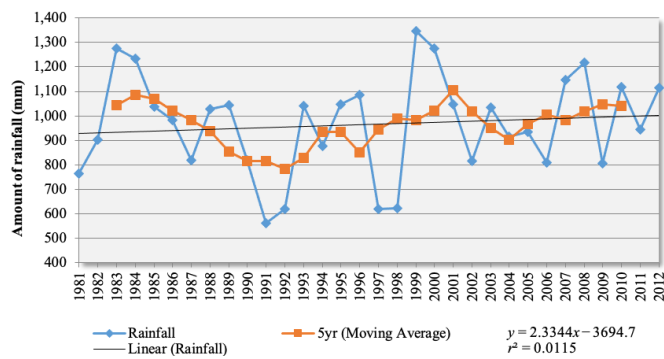


Figure 5. Observed trends of annual total rainfall in 1981–2012

Observed climate change

Monthly analysis of observed changes in annual t_{min} from 1981 to 2012. The monthly analysis of the three decadal periods indicates a statistically significant change from January to December ($p < 0.01$). The annual t_{min} significantly changed from 1981 to 2012, particularly the annual t_{min} in the summer months from March to May. The annual t_{min} during the month of March in period 1 is 22.5 °C. In the months of April to May, the decadal increase in temperature in periods 2 and 3 are 0.2 °C and 0.8 °C, respectively. This implies that the annual t_{min} in all months, except January, exhibit changes during the three decadal periods (Figure 6).

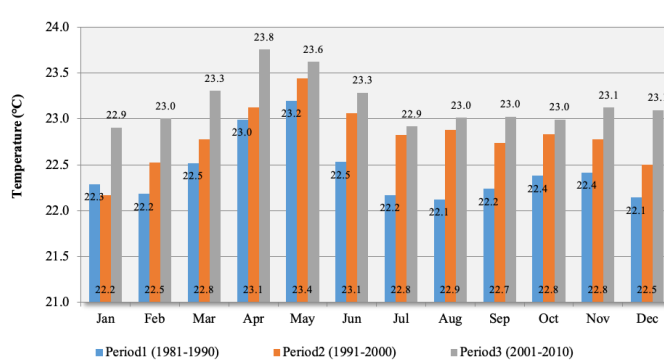


Figure 6. Monthly mean annual minimum temperature

Monthly analysis of observed changes in annual t_{max} from 1981 to 2012. The monthly analysis of the three decadal periods for annual t_{max} also reveals statistically significant changes from January to December ($p < 0.01$), except for the months of June and September. Similarly, changes in the monthly annual t_{max} for the three decadal periods can be noticed (Figure 7).

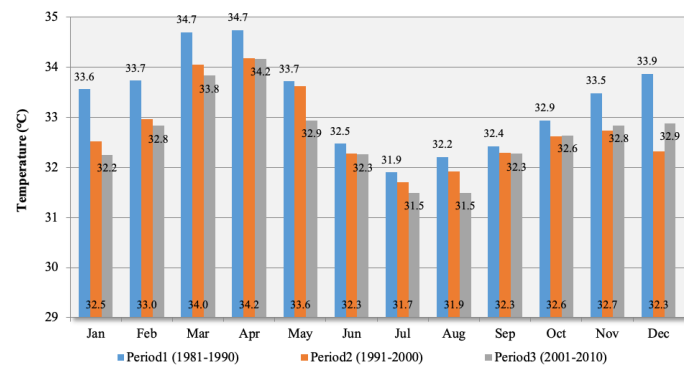


Figure 7. Monthly mean annual maximum temperature

Monthly analysis of observed changes in annual mean temperature from 1981 to 2012. Similarly, the monthly analysis of mean annual temperatures reveal statistically significant changes ($p < 0.01$) for January, April to September, and December (Figure 8).

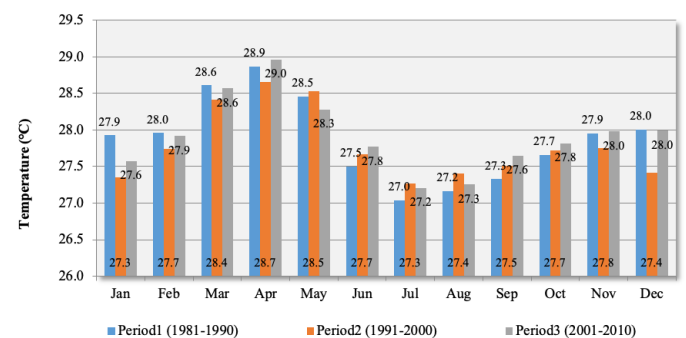


Figure 8. Monthly annual mean temperature

Monthly analysis of observed changes in total annual rainfall from 1981 to 2012. The monthly total rainfall for the three periods show statistically significant changes in June ($p < 0.01$), August and December ($p < 0.05$). No significant changes can be observed in the other nine months. Figure 9 shows the trend in monthly total annual rainfall for periods 1, 2, and 3. The month of June exhibits a very drastic drop in annual rainfall in periods 1 and 2.

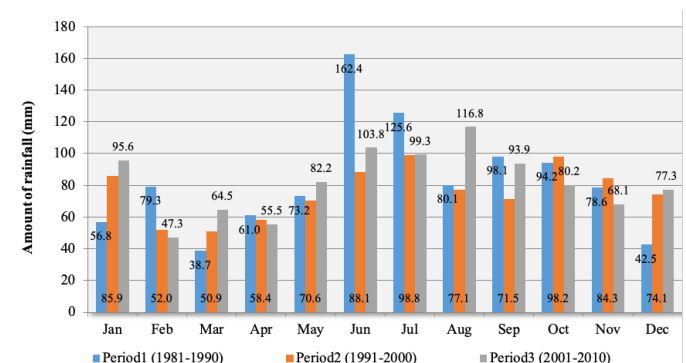


Figure 9. Monthly total rainfall

Yearly decadal analysis of observed changes in climate parameters, 1981–2010

The maximum, minimum, and mean annual temperatures significantly changed ($p < 0.01$) throughout the three time periods; there was no significant change in the rainfall parameter. Meanwhile, the results of the t-test that compare the changes in climate parameters in the different periods show that the minimum temperature at all periods significantly changed ($p < 0.01$). Specifically, the maximum temperature in periods 1 and 2 and periods 1 and 3 significantly changed at 1% level of significance. Periods 2 and 3 also indicate significant changes, albeit at a 5% level of significance. On the other hand, the annual mean temperature significantly changed ($p < 0.01$) in periods 1 and 2 and periods 2 and 3; no significant change can be detected between periods 1 and 3. No t-test was conducted for the rainfall variable since the results of the analysis of variance gave no significant changes.

The trends in extreme daily rainfall in the country are not statistically significant, although there have been changes in certain areas in the country. Likewise, the frequency of extreme rainfall exhibits an increasing trend, albeit the increase is statistically insignificant (Cinco et al., 2013). The projections by PAGASA on the frequency of rainfall predict that there would be fewer

rainfall events in most provinces in the country during the summer season, thereby making the usually dry season even drier (PAGASA, 2011).

The above findings in both monthly and yearly analyses for three decadal periods reveal significant changes in climatic patterns. This suggests that climate change occurred and were felt by the farm households in Roxas mountain range, City of Koronadal. Accordingly, this condition demands a transformative adaptation mechanism in order to reduce the communities' vulnerability and to build their resilience to climate change.

Community perception on climate change and its causes

Almost all (99.6%) of the respondents believe that the climate has changed in the past 30 years. More than half (58.6%) consider deforestation as the major cause of the changing climate. About 98.15% have noticed the abnormalities in rainfall and temperature patterns in the area. During the FGD, the participants relayed the historical climate variability extreme events experienced by the local people from the 1970s up to 2015 (Table 2). The occurrences of drought, flashflood/flood, and landslides are usually experienced, which have led to

Table 2. Historical climate-related extreme events experienced by the communities in Roxas Mountain Range, City of Koronadal, 1970–2015

Decade/Year		Type of event	Impacts of events on livelihood and people's lives
1970s	1973	Drought (7 months)	Crop failure
1980s	1982	Drought (9 months)	Crop failure
	1986	Flashflood	Crops affected Water level increased up to waistline
	1988	Drought (7 months)	No production
	1989	Flashflood	Three houses were washed up and destroyed
1990s	1998	Drought (7-8 months)	Plants dried/died Farmers have eaten <i>kayos</i> (wild yam)
2000s	2007	Drought (3 months)	Crop production affected
	2008	Flashflood	Houses destroyed
	2012	Landslides	Crop damaged
	2013		Property damaged (e.g., cars) Four persons died
	2015	Flashflood	Crop production affected
		Drought (4 months)	No harvest
		Landslides	Crops damaged Seven houses damaged

crop failures, damage to properties, and even loss of lives.

The Philippines, including the City of Koronadal, experienced in 2007 a two-month dry spell during the rainy season (July to August) (Yumul, Cruz, Dimalanta, Servando, & Hilario, 2010). These abnormalities consequently affected the cropping pattern of the smallholder farmers. The local farmers used to have two cropping seasons: one during the wet season from June to October (*panuig*), whereas the cropping season is planted during the dry season (*panolilang*). Farmers used to expect a very good harvest during the *panuig*, while harvest during the *panolilang* was considered just enough for their consumption. However, due to the abnormalities in rainfall and temperature and unpredictable weather conditions, there is no longer a clear demarcation between the two cropping seasons.

As observed by the respondents, the wet season has become wetter, thereby bringing floods and landslides in the study area. Similarly, the local residents have experienced intense heat during the summer, such that there have been instances when farmers could no longer work beyond 9 a.m. Moreover, there have been cases when the dry months have become the wet months.

Climate change impacts

The communities in Roxas mountain range have experienced yearly intense rainfall and temperature and have suffered prolonged droughts for 7–9 months which was observable within 5–10 years. The residents also experienced floods/flashfloods and landslides in August 2008, specifically in Barangays Carpenter Hill, San Isidro, and Saravia, and in Sitio Elgawel and Cabuling. These climate risks experienced by the communities are manifestations of climate change, which have caused socioeconomic and environmental impacts on the farming livelihood of the smallholder farmers.

Socioeconomic impact on farming livelihoods

Climate change has damaged the local farmers' crops, thereby substantially reducing their crop yield. Almost all respondents (96.6%) consider the decrease in crop yield as a major impact of climate change (Table 3). Likewise, the 2011–2015 data of the South Cotabato Provincial Agriculture Office cited that about 120 farmers in the study area experienced crop damage mostly due to heavy rainfall and flashfloods, thereby causing a lodge of corn and rice crops. About 40% total farming area (72.35 ha of 179.35 ha) were damaged during these events. As such, about 329 metric tons in

Table 3. Identified impacts of climate change on livelihood (Approach 2 Stage I)

Impacts	Brgy. Assumption (n = 17)		Brgy. San Isidro (n = 74)		Brgy. Paraiso (n = 52)		Brgy. Carpenter Hill (n = 58)		Brgy. Saravia (n = 64)		Overall Total: n = 265	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Decline in crop yields	17	100.0	67	90.5	52	100.0	56	96.6	64	100.0	256	96.6
Occurrences of pest and diseases	17	100.0	71	95.9	51	98.1	47	81.0	50	78.1	236	89.1
Decreased working time in the farm	17	100.0	74	100.0	41	78.8	27	46.6	60	93.8	219	82.6
No production due to drought	17	100.0	54	73.0	52	100.0	34	58.6	61	95.3	218	82.3
Delay in planting	17	100.0	37	50.0	45	86.5	40	69.0	60	93.8	199	75.1
Reduced water supply	17	100.0	54	73.0	23	44.2	14	24.1	24	37.5	132	49.8
Loss of livelihood sources	13	76.5	12	16.2	7	13.5	2	3.4	43	67.2	77	29.1
Loss of and damage to properties and aesthetic	0	0.0	4	5.4	1	1.9	2	3.4	18	28.1	25	9.4
Loss of lives	0	0.0	6	8.1	0	0.0	2	3.4	3	4.7	11	4.2
Migration/transfer	0	0.0	1	1.4	6	11.5	1	1.7	26	40.6	34	12.8

production were lost, which translates to a monetary loss of PHP 3,962,947. Meanwhile, the cash assistance given by the LGUs to the affected families amounted to PHP 272,550.00.

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2014) cited that the *yield in staple crops* (e.g., maize, rice, and wheat) is projected to further decrease as temperature rises. Prices of agricultural commodities are also expected to be more volatile, and food quality would also further deteriorate due to climate change. Likewise, Cruz et al. (2017) mentioned that the variation in rainfall patterns and distribution are adversely affecting agricultural productivity.

Climate change has also *disrupted farm working schedule*. Approximately 82.6% of the respondents reported that they no longer follow their 7 a.m. to 12 p.m. farming schedule due to the intense heat and frequent occurrences of heavy rains. About 75.1% have experienced *delays in planting* due to the abnormalities in weather patterns. In addition, 82.3% of the farmer respondents said that they have *stopped planting crops* during extreme dry season and droughts, consequently leading to lack of income and hunger.

About 89.1% of the respondents mentioned that the climate change-induced *pest and disease infestation* is another factor that significantly reduces their crop yield. Based on the local farmers' experiences with upland rice farming, about 40%–100% of their production in a 1-hectare land is affected whenever pest and disease infestations occur. The pests and diseases that pervade the farmers' crops during the dry season include rats, black bugs, coconut beetles, bunchy top virus, leafhopper, aphids, fruit flies, corn borer, army worm, cut worm; meanwhile, leaf hopper and fruit and stem borer attack cereals and vegetable crops during the rainy season.

Climate change also has social impacts in the study area, as manifested in the *loss of human lives and properties* due to the flash floods in Barangay San Isidro in 2012. In addition, around 12% of the respondents relayed that they also *migrate temporarily* to other places during periods of drought.

Environmental impact on farming livelihood

Climate change has also directly affected the water supply in the research area as attested by about 49.8% of the respondents. The local residents observed that their water sources have been reduced, especially during periods of intense heat and drought. Apart from crops, physical structures of land resources have also been destroyed due to flashfloods and landslides, which destabilized the livelihoods of 30% of the farmer respondents. Moreover,

the flashflood in 2012 *damaged crops and livestock and destroyed landscapes* according to 9.4% of the respondents.

Current and potential transformative adaptation strategies

Current adaptation to climate change

The farmers in the study area have developed adjustment mechanisms in order to cope with the climate change-related stressors affecting their farming activities. Majority (84.5%) of the households have sought *off-farm work as an alternative livelihood source*. Such off-farm work includes waged labor, tricycle/scooter driving, trading, carpentry, construction, bamboo stick making (*tatad*), trading, and doing laundry work within the community. Many households (70.2%) have stopped planting due to crop failures, thereby abandoning their farms for a period of time. Some respondents have *shifted to planting other crops* like corn or rice to cassava and vegetables (58.1%), whereas others (46.4%) have *sought material or financial assistance from the LGU*. Some respondents (30.1%) have opted to *change their planting calendar*, whereas other households with financial capability/capacity *continued working at the farm* by planting trees/fruit trees.

Most of the respondents' current adaptation measures are just superficial solutions to climate change impacts—they do not resolve the underlying causes of climate change issues. Although integrating trees on the farm and seeking alternative livelihood options should be continued, the current adaptation strategies still need to be enhanced. Vital transformative adaptation strategies that are based on future climate scenarios and that consider the multifaceted drivers of climate change should be developed in order to protect and improve farming livelihoods.

Potential transformative adaptation to climate change

The 2011 PAGASA report projected that seasonal mean temperature would increase by 1.1–1.2 °C (2006–2035) and by 2.0–2.3 °C in 2050 (2036–2065). This projection is based on the downscaled climate scenario of South Cotabato province under the A1B medium range scenario. Moreover, the amount of rainfall is projected to decrease while the number of extreme events would increase in 2020 and 2050. The projected decrease in annual precipitation would be from –6.8% to –12.1% in 2020 and –6.8% to 18% in 2050 (PAGASA, 2011).

These projections and their possible impacts were presented to the community during the FGD and household survey. Accordingly, the potential transformative adaptations strategies identified.

Socioeconomic adaptation strategies

Adaptation varies based on the socioeconomic status and educational attainment of an individual. As such, majority of the farmers (61.5%) mentioned that *investing in children's education or in human capital* is one of the best potential transformative adaptation strategies to combat climate change. The farmer-respondents believe that this will have a spillover effect on their own economic and environmental conditions. Education enhances people's knowledge, skills, understanding, and behavior; thus, the farmers believe that investing in their children's education will help their children to have better jobs than their current unsustainable farming and forest activities (e.g., charcoal making). Educated children will sustain life and will help their parents to acquire innovative and sustainable farming system practices. In view of this, one measure to combat climate change is to *increase the number of scholarship grants* that local governments and other institutions provide to qualified students in the communities.

A few farmer-respondents (10.2%) said that *promoting more appropriate nonfarm alternative sources* is a good adaptation option to lessen their dependence on farming. Currently, when the household respondents cannot grow crops due to climate-related stressors, they do off-farm work (e.g., scooter driving, carpentry, waged labor) as alternative sources of income. The female workforce, together with their children, prefer making bamboo sticks, trading, and laundry work within the community. The city government of Koronadal has been providing trainings on nonfarm livelihood options (e.g., massage, spa manicure and pedicure, welding, food processing, etc.) to its populace. Despite this, however, there is still a need to further increase the number of beneficiaries and to explore more possible entrepreneurial, nonfarm livelihood activities based on available resources.

A few respondents (1.5%) also raised *family planning* as an adaptation strategy, while 18.1% mentioned that *knowledge on financial management or increasing personal savings* is an important aspect to consider in order to adapt to climate change.

Environmental/Biophysical adaptation strategies

One promising transformative adaptation strategy identified by the respondents during the FGD and household survey (46.8%) is *to enhance and to continue supporting the current practice of agroforestry or diversified farming system*. Agroforestry is a system that incorporates planting of trees or fruit trees and coconuts into farms as complementary crops to their annual main crops such as corn, rice, root crops. Likewise, raising livestock can also be integrated into their farming system. Aside from the socioeconomic benefits the system offers, the respondents mentioned that agroforestry has environmental benefits as well (e.g., balancing the temperature).

Agroforestry system is a sustainable solution to address the current and future climate change. It serves as both mitigation and adaptation strategy for enhancing smallholders' resilience (Uthappa, et al., 2018). As opposed to monocropping, this system assures continuous income from harvesting the complementary crop in times of crop failure of the main crop. The local people used to practice monocropping or planting single crops such as corn. Accordingly, smallholder farmers would be able to adopt agroforestry if they are provided with technical capacity development and planting materials.

Since 2009, the City of Koronadal has been conducting tree-growing festival activities every 29th of June. Different government and private agencies, farmer groups, and individual volunteers participate in this endeavor. This initiative promotes the stakeholders' collective efforts to protect and rehabilitate watershed areas. In 2019, the City of Koronadal celebrated its 9th tree growing festival, and the participants planted more than 100,000 seedlings (fruit and timber trees) to a 300-hectare land within the Roxas and Quezon mountain ranges (Estabillo, 2019).

Other adaptation strategies

About 43.8% of farmer respondents also suggested *establishing advance early warning systems (EWS)* that convey climate-related information to the local communities. In line with this, the city government of Koronadal has already set up an automated weather station (AWS) in 2013 to help monitor the weather patterns properly. The established AWS can capture weather-related data, such as rainfall, wind speed and direction, humidity, and temperature. This kind of EWS helps to reduce the impacts of climate change and to manage and reduce disaster risk. According to Travis (2013), early detection and warning systems for severe and/or abrupt climate change would benefit both adaptation and preparedness. This idea has then led the LGU and the communities to use the monitored data as a basis in enhancing the adaptive capacity of smallholders to climate change.

During the FGD, the participants also mentioned *water impounding or using water pumps to irrigate the crops* during the dry periods as an adaptation option since water supply is highly crucial in dry season farming. Other alternative adaptation mechanisms mentioned include *shifting to other crops* that are best suited to the changing conditions. These crops that thrive in intense heat include sorghum, cassava, and other root crops. Farmers could also plant varieties that are resistant to pests and diseases and drought.

Conclusion

The findings for both monthly and yearly decadal analysis from 1981 to 2012 show significant changes and increasing trend in mean minimum temperature and decreasing trend in mean maximum temperature. An average increase of 0.74 °C in mean minimum temperature and decrease of 0.65 °C in mean maximum temperature were observable changes in three decades. The rainfall patterns during the same period also significantly changed, particularly in the months of June, August, and December. These suggest that climate change occurred in the Roxas mountain range, City of Koronadal. The farm households have observed and experienced extreme weather events, including intense heat, intense rainfall, floods, landslides, and drought. These manifestations of climate change have devastating socioeconomic and environmental impacts on the livelihoods of the farm households.

The current adaptation strategies of the farmers in the study area are mere temporary measures that do resolve the underlying causes of climate change. Hence, based on the PAGASA downscale scenario data, the possible impacts of climate change and the corresponding potential transformative adaptation strategies were identified. Accordingly, socioeconomic and environmental transformative adaptation strategies are necessary to reduce the adverse impacts of climate change. These adaptation strategies include *investing in children's education of the farmers and providing nonfarm livelihood opportunities*. Likewise, investing in the development of farm landscapes through *continued promotion of agroforestry farming practices/diversified farming, enhancing the technical skills of the farmers, and establishing advanced early warning system* are potential strategies for addressing climate change impacts.

Local government support plays a crucial role in increasing the stakeholders' awareness of climate change and in strengthening local leadership in protecting the environment. The findings of this study provide vital baseline information on climate-related impacts, which are necessary to enable policy makers to enhance the existing strategies and to further develop other adaptation strategies that will focus on climate-related stresses at the grassroots level.

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