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TRENDS IN RAINFALL AND THE CAUSES OF FLOOD EVENTS IN THE MUNICIPALITIES OF LOS BAÑOS AND BAY, LAGUNA, PHILIPPINES

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ABSTRACT – Trends in rainfall in the municipalities of Los Baños and Bay, Laguna were described. Five past flood events were mapped to determine their extent. Experiences, perceptions and records were obtained to determine the factors that contributed to the flood events.

Annual rainfall has been increasing, while the intensity of extreme rainfall events showed no significant trend from 1954 to 2012. However, the amount of rains and intensity of extreme rainfall during the wet season in the two municipalities were mostly higher in 2006 to 2012 than the 59-year average. Frequency of days with rainfall greater than 200 mm was also higher in 2006 to 2012 than the baseline value as projected.

Analysis of decadal monthly rainfall and the occurrence of flood events showed that there are other factors that may have contributed to floods. Major contributors to flooding identified were anthropogenic activities that adversely affected watersheds, natural waterways and accumulation of wastes. Data from past flood events also showed that the extent and persistence of floods were a combined effect of rainfall and the proliferation of communities in the lakeshore areas and in the sole outlet of the lake.

Keywords: rainfall and floods, Los Baños Laguna, Bay Laguna

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INTRODUCTION

Disastrous floods are common in the Philippines due to the magnitude of the hazard and the failure to cope with the physical and socio-economic impacts *(Eleazar, 2011).* Among the most recent disastrous flood events particularly in the province of Laguna were those caused by typhoon *Ondoy* (International Code Name *Ketsana*) and succeeding typhoons in 2009 and the floods caused by excessive rains from the Southwest monsoon as enhanced by typhoons *Gener* (International Code Name *Saola*) *and Haikui* in 2012.

The Philippines has been experiencing changes in climate**;** however, such changes were more pronounced in terms of temperature than rainfall and the occurrence of extreme events ***(****PAGASA, 2011).* Given medium greenhouse gas (GHG) emission scenarios, rainfall in the province of Laguna was projected to increase by 2.9% in 2020, covering the period from 2006 to 2035. The increase is from baseline values obtained from 1970 to 2000 for the rainy season covering the months of June to August and September to November at 845.0 mm and 1,066.5 mm, respectively. The number of days with rainfall exceeding 200 mm is also expected to increase from the baseline value of 6 d to 14 d for 2020.

Los Baños and Bay are among the flood-prone municipalities surrounding the Laguna Lake. Wet season is from the month of May and may extend up to December *(Bay MPDO, 2011; Los Baños MPDO, 2010).* Aside from being lakeshore municipalities, large areas fall within the watersheds of Mt. Makiling that are tributaries to the lake *(Rimando et al., 2010)*.

A World Bank study *(2013)* that led to the development of the Master Plan for Flood Management in Metro Manila and Surrounding Areas showed that lake water levels have exceeded the flood level of 12.5 m in 23 years, 13.0 m in eight years and 13.5 m in four years. Other sources reported increased lake water level occurrences up to 14.62 and 14.35 m in 1919 and 1943, respectively *(LLDA, 2009; Lasco & Espaldon, 2005).* The recent flood event in 2012, due to rains brought by the South West Monsoon, registered lake water levels of up to 13.8 m *(Inciong, 2013-Unpublished)*.

The study examined rainfall events from 1954 to 2012 and revisited past flood events that occurred in the municipalities of Los Baños and Bay, Laguna. Specifically this paper aimed to: describe trends in rainfall events in the two municipalities; determine the extent of five past flood events in the coastal communities; and determine the contributory factors to the flood events.

METHODOLOGY

Research Design

Eclectic methods were used to gather data. Maps, local rainfall and lake water levels, and other data from related studies were gathered. Key informant interviews (KII) with LGU officials and school heads and focus group discussions (FGD) with teachers, students and other school stakeholders were conducted.

Procedure

Requests for documents and permission to conduct KII and FGD were sent to concerned agencies prior to data gathering.

Gathering of Documents

Daily rainfall data from 1954 to 2012 were obtained from the UPLB Agro-meteorological

Station to represent conditions in the two municipalities. Moreover, data on tropical cyclones that crossed Laguna and 100 km radius from its boundaries from 1948 to 2010 were obtained from the Philippine Atmospheric Geophysical and Atmospheric Services Administration (PAGASA)

Maps and geographic images were gathered from National Mapping and Resource Information Authority (NAMRIA). A Digital Terrain Model (DTM) with 5 m resolution derived from Inter-ferometric Synthetic Aperture Radar (IfSAR) images was obtained. A Hydrographic Survey on the Depth of the Laguna de Bay, at the scale of 1:60,000, was also provided. The survey was done from October to November 2009.

Daily lake water levels from 1919 to 2010 were obtained from the Laguna Lake Development Authority (LLDA). Copies of the report of the World Bank study in 2013 were provided both by the Department of Public Works and Highways (DPWH) and the LLDA. Gathering of documents and pertinent data was done from March 2013 to February 2014.

Gathering of Primary Data

Primary data were gathered through key informant interviews (KII) and focused group discussions (FGD) from June to October 2013. Experiences and perceptions on past floods were important not only to describe but also to elicit the possible causes of these events.

Twelve LGU and Department of Education (DepEd) officials at the provincial and municipal levels were interviewed to provide background on the flood events in the province and in the two municipalities. LGU officials included the provincial and municipal planning officers or the disaster risk reduction and management (DRRM) officers and representatives of health and social welfare and development offices. DepEd officials included the DRRM Coordinator at the division level and the district supervisors for the two municipalities. Sixteen school heads or their assigned representatives from the different school groups were purposively chosen to serve as key informants on the experiences in their respective schools.

Separate focus group discussions with a group of students and a group of stakeholders including teachers, parents, and barangay officials were held in four flooded schools (two elementary schools and two high school) in the coastal communities of Los Baños and Bay. Participants of the eight FGDs were recommended by their respective school heads.

Data Analysis

Trends in Rainfall

Rainfall and flood data were analyzed using STATA (Version 12) software. Total annual rainfall, annual maximum two-day rainfall, the number of days with extreme rainfall exceeding 200 mm, and the number of tropical cyclones that crossed the province were subjected to trend analysis to determine significant patterns through time.

Total and maximum two-day rainfall from June to December (coinciding with the wet season in the two municipalities), for each of the last 10 years, were determined. Values from 2006 to 2012 were compared with the average value for the same months for the entire period from 1954 to 2012. The number of days with rainfall greater than 200 mm in the two municipalities from 1971 to 2000 was compared with the frequency from 2006 to 2012 to confirm the projections for the province of Laguna for 2020, covering the period 2006-2035 *(PAGASA, 2011).*

Decadal Monthly Rainfall and Occurrence of Floods

Decadal monthly rainfall from June to December and the occurrence of water level higher than the flood level of 12.5 m in each of these months were compared graphically to determine if there were other factors that contributed to floods aside from rainfall.

Delineation of Past Flood Events

Inundated areas in five past flood events were mapped through Geographic Information System (GIS) using Arc View 3.2 and Manifold GIS Software. A map capable of depicting changes in flood level within a one-meter range was derived from DTM of IfSAR images and the Bathymetric data of the lake with the help of Ms. Fe Ociones and Mr. Alvin Olvida, both from the Ecosystems Research and Development Bureau (ERDB), Department of Environment and Natural Resources (DENR).

Maps were developed, marking-out flooded areas during the 1972, 1978, 1986, 1995 and 2009 flood events. The average of the water level readings from the different gauging stations around the lake at three different dates were converted to depth at mean sea level. Each of these water levels were represented by different color shades in the map. The third level, being the highest, showed the farthest distance covered by flood waters and was used to estimate the extent of flood in the two municipalities. The number of days for the water level to recede back to the initial flood level at 12.5 m was determined. This was done by verifying the data from the 2013 World Bank study with the daily water level data obtained from LLDA.

KII and FGD

Qualitative data were analyzed based on content. Recorded KII and FGD proceedings were transcribed, and entries in the transcripts were classified into themes and sub-themes based on the objectives of the study. The entries in each theme or sub-theme were organized and synthesized in order to provide the information needed in the study.

Experiences and perceptions derived from KIIs and FGDs, together with analysis of rainfall data and reports available in literature, were used to determine the contributory factors to past flood events in the area.

RESULTS AND DISCUSSION

Annual rainfall data

Five-year running averages of annual total rainfall show a significant increasing trend of 3.82 mm a^{-1} from 1954 to 2012 (Fig. 1). This is contrary to the general observation of *PAGASA (2011)* that reported no statistical significance in annual rainfall. This means that unlike most parts of the country, the amount of rainfall in these municipalities have been increasing for the last 59 years.

Rainfall parameters from June to December for the last 10 years were compared with their respective 59-year means to verify whether rains were indeed increasing during the recent period from 2006 to 2012 as projected by *PAGASA (2011)* for 2006 to 2035. Total accumulated rainfall for the wet season from 2006 to 2012 was higher than its 59-year average of 1715 mm in five out of seven years (Fig. 2). These were in the years 2006, 2007, 2009, 2010 and 2011 when rainfall in the two municipalities were recorded at 1919.9 mm, 1810.9 mm, 1941.7 mm, 1967.8 mm and 2135.8 mm, respectively.

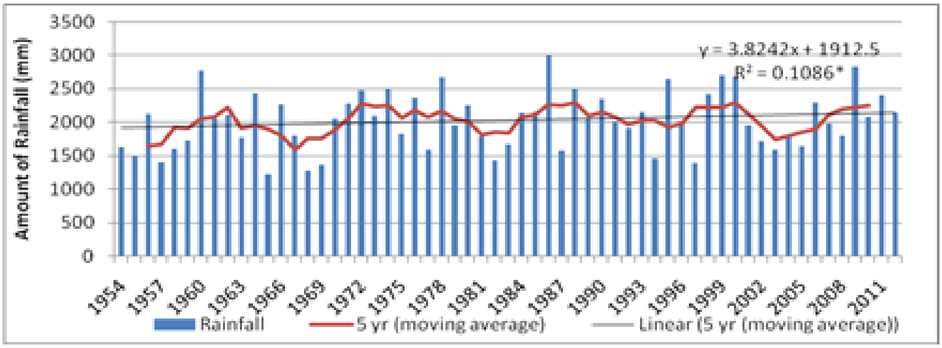

Figure 1. Trend in Annual Total Rainfall in the Municipalities of Bay and Los Baños, Laguna from 1954 to 2012. (Source: UPLB Agromet Station).

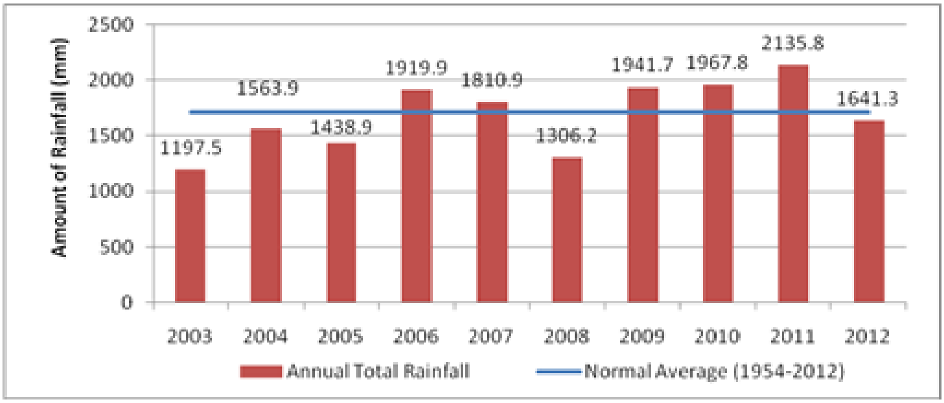

Figure 2. Comparison of wet season total rainfall for the last ten years with the mean from 1954 to 2012 in the Municipalities of Bay and Los Baños. Note: Mean from 1954 to 2012= 1715.08 mm

Occurrence of extreme rainfall events

There was neither significant increasing nor decreasing trend in the annual maximum two-day rainfall which usually occurs during extreme events like typhoons. However, the wet season maximum two-day rainfall from 2006 to 2012 was higher than the 59 year average of 230.4 mm in six out of seven years: 443 mm in 2006, 238.9 mm in 2007, 243.6 mm in 2008, 274.9 mm in 2009, 278.6 mm in 2010 and 255.2 mm in 2012 (Fig. 3).

The number of tropical cyclones that crossed the 100 km radius from the boundary of Laguna yearly from 1948 to 2011 did not show any statistically significant increasing or decreasing trend. However, data showed that from 2006 to 2012 alone, the two municipalities have already experienced 4 days with extreme rainfall exceeding 200 mm (Fig. 4). This could be translated to a 0.57 chance of occurrence which is higher compared to 11 days or a 0.37 chance for the period between 1971 and 2000.

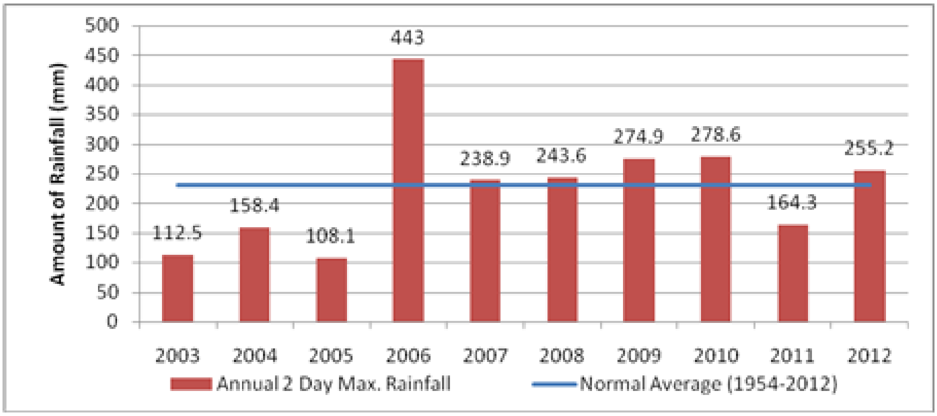

Figure 3. Comparison of wet season maximum two-day rainfall for the last ten years with the mean from 1954 to 2012 in the municipalities of Bay and Los Baños. Note: Mean from 1954 to 2012 = 234.8 mm

Though it might be too early to conclude, the data suggests an increasing number of days with extreme rainfall exceeding 200 mm. This is consistent with the projection by PAGASA for 2020 based on medium greenhouse gas (GHG) emission scenarios.

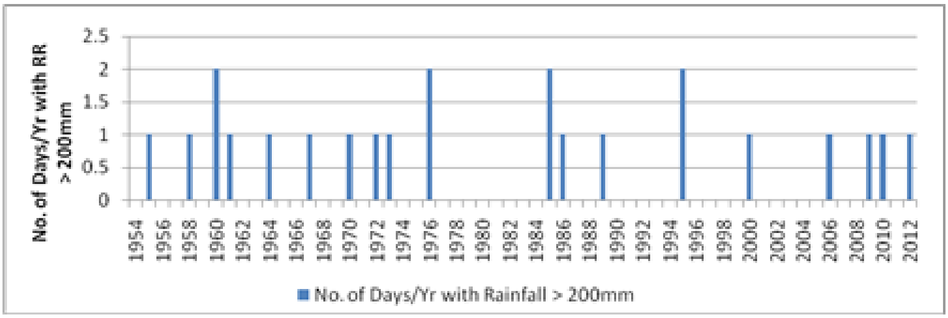

Figure 4. Number of days with rainfall greater than 200 mm in the Municipalities of Bay and Los Baños,Laguna from 1954 to 2012. (Source: UPLB Agromet Station)

Occurrence of Floods in the two Municipalities

Key informants and FGD participants reported that the floods encountered in these municipalities were of different nature. These were either coastal floods, riverine floods or floods caused by urban runoff.

Most of the floods in the coastal barangays were due to the increase in the water level of the Laguna Lake brought about by extreme weather disturbances and continuous rains. These include *barangays (Bgy.) San Antonio, San Isidro, Tagumpay, Maitim, Dila* and *Sto. Domingo* (especially in *Sitio*) *Kabaritan* in Bay and also in *Tadlac, Bambang, Baybayin, Malinta, Mayondon* and *Bayog* in Los Baños. These events that take several days or even months to completely recede back to the normal level of 12.5 m have been experienced since 1972. Depths of floods depend on location. Some were higher than a man's height while in other areas, floods can be as high as the roof or the second level of houses.

Flash floods caused by the overflowing of rivers affected not only the coastal areas but also the inland and even upland barangays particularly those near the major tributaries. *Bgy. Masaya, Paciano Rizal, Puypuy, Maitim, Sto. Domingo* and *Dila* in Bay were flooded in 2006 during Typhoon *Milenyo* (International Code Name *Xangzane*) which caused the overflowing of the *Calo, Tabon* and *San Nicolas Rivers* in *Bay*. Even *Bgy. Bagong Silang* and Sitio *Dampalit*, located in the uplands of Los Baños were not spared from flash floods and landslides from Typhoon *Milenyo* that claimed several lives in these areas. Although floodwaters did not persist long, the rush of flood water carrying debris caused tremendous damage to the affected areas.

The third kind of flood that occurred several times in *Mayondon* Elementary School in Los Baños was due to urban runoff coupled with unsound development which made the school a catch basin, preventing water from draining out from the area.

Table 1. Summary of the lake water levels at three different dates used in delineating the five flood events and the total area flooded at peak water level

* Obtained by subtracting the gauge zero value from the average gauge reading. Note: Gauge zero value=10.39 m (World Bank, 2013)

YEAR	DATE	AVERAGE GAUGE READING (m)	HEIGHT AT MEAN SEA LEVEL* (m)	HEIGHT OF WATER > 12.5 M (m)	TOTAL AREA FLOODED AT PEAK WATER LEVEL (m^2)
1972	7/16/1972	11.81	1.42		
	7/21/1972	13.17	2.78		
	8/2/1972	14.03	3.64	1.53	2,599,606.54
1978	10/10/1978	12.4	2.01		
	10/17/1978	13.38	2.99		
	10/28/1978	13.58	3.19	1.08	1,885,319.40
1986	10/5/1986	12.29	1.90		
	10/8/1986	13.20	2.81		
	10/13/1986	13.33	2.94	0.83	1,471,128.39
1995	11/2/1995	12.43	2.04		
	11/5/1995	12.69	2.30		
	11/8/1995	12.94	2.55	0.44	804,133.75
2009	9/25/2009	12.73	2.34		
	9/28/2009	13.84	3.45		
	10/4/2009	13.87	3.47	1.37	2.344,912.94

Delineation of Five Flood Events in Coastal Communities

Lake water levels and the total inundated area in the two municipalities at peak flood level during five past events are shown in Table 1 while a comparison of the extent of flooding are presented in Fig. 5. The 1972 event was the deepest flood among the five events with a peak water level at 3.64 meters above the mean sea (masl) inundating about 2.6 million m^2 of land in the lakeshore area of the two municipalities. The least serious among the events was in 1995 at 2.55 masl inundating about 0.8 million m^2.

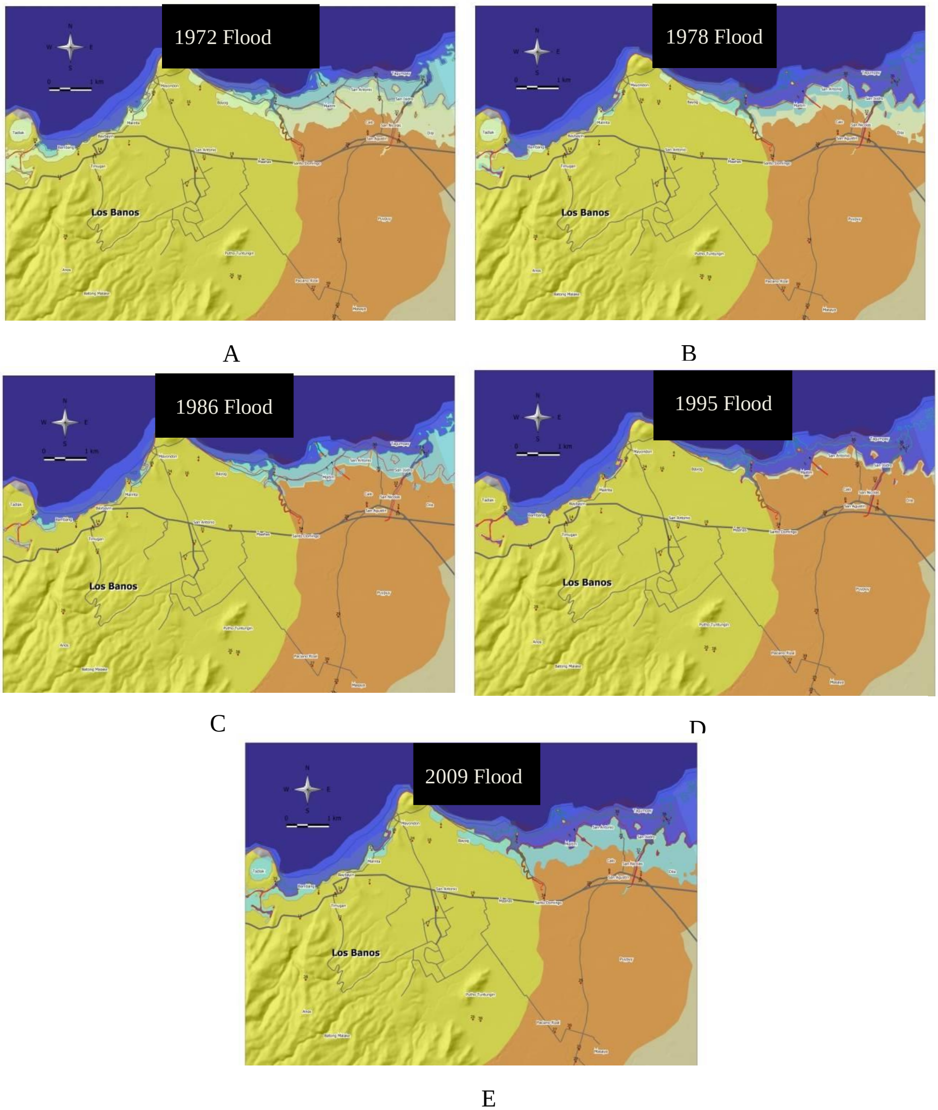

Figure 5. Comparison of the five flood events in the coastal areas of Bay and Los Baños, Laguna

Contributory Factors to Floods

Most of the key informants and FGD participants agree that climate change, particularly rainfall, is a contributory factor to flooding. However, majority believed that together with the changes in climate, there are other factors that further enhance flooding. A few even insisted that floods were purely manmade and were consequences of the damage that man has done to the environment. They pointed out further that in recent times, just a little rain could cause flooding unlike before when it does not easily flood, no matter how strong the rains were.

The decadal wet season mean monthly rainfall and the occurrence of floods show that floods were most prevalent not only during the months with the highest decadal average rainfall (Figure 6). In the month of October, water levels exceeded the flood level twice from 1984 to 1993 when the highest mean decadal monthly rainfall was recorded. However, water levels were higher than the flood level thrice in from 1994 to 2003 and twice from 2004 to 2012 when the mean decadal monthly rainfall were lower. For the month of November, floods occurred three times in each of the last three decades compared with the decade from 1964 to 1973, with the highest mean decadal rainfall, where floods occurred only once. These months were also the months in a year when average lake water levels were usually at the highest *(LLDA, 2009; World Bank, 2013)*. These suggest that other factors aside from the high amount of rainfall may have contributed to floods during the recent decades as claimed by the participants in the study

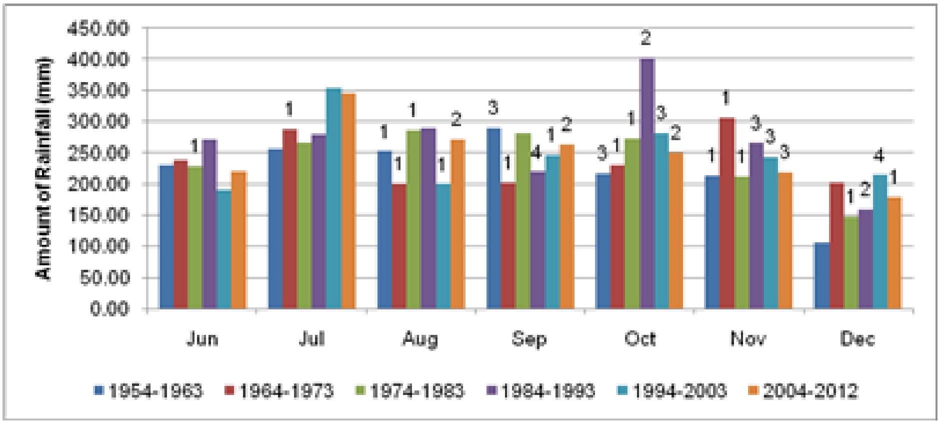

Figure 6. Decadal wet season mean monthly rainfall in Bay and Los Baños and the frequency of occurrence of water levels greater than the 12.5 m flood level. Note: Numbers above the bars indicate the frequency of occurrence of water levels greater than 12.5 m.

Key informants and FGD participants associated flooding with deforestation of watersheds; conversion of forests lands to other uses; urbanization and increase in impervious surfaces; construction and unplanned development in flood-prone areas and obstruction of natural waterways. They claimed that these manmade factors were driven by increase in population that consequently increased consumption of resources, the change in the way of life of people, and man's neglect of the environment.

Deforestation of watersheds was attributed to illegal logging, increased upland settlements and conversion of forest to other land uses. Study participants and the *LLDA (2009)* agree that forestlands in the Laguna de Bay (LdB) region were converted into agricultural, industrial, commercial and residential lands. Roads and other structural developments made of concrete were built preventing the natural infiltration of water through the soil surface. The LLDA further reported that in a span of five years, from 1996 to 2000, forest cover in the LdB region was reduced from 25 to 5%. These factors, according to them, have led to increased runoff and siltation of the lake and its river tributaries.

School heads interviewed as well as participants of the FGDs blamed the occupancy and unsound development of flood-prone areas and natural waterways for exposing people more and worsening flood occurrences. Even young students knew that the incidence of floods in their schools and homes were only normal since these are located in flood-prone areas.

The increased population in the Laguna de Bay region led to the increased generation of solid wastes. Poor management and disposal of wastes have affected the natural flow of water, the water quality, the depth of the lake and the infiltration of water in the lakebed *(LLDA, 2009)*. Lack of forest cover, impediments in the waterways, increased generation and improper waste management are major manmade factors that contributed to flooding, aside from rainfall due to climate change.

LGU officials added that floodwater from the Marikina river is diverted to the lake to protect Metro Manila from floods during adverse weather conditions. This claim was supported by earlier studies *(Lasco & Espaldon, 2005)* and the report of *LLDA* in 2009. They complained that the welfare of residents in the coastal communities around the lake is sacrificed in favor of those living in the Metropolis. Another cause of flooding mentioned by LGU officials and even by elementary students was the release of water from dams like the one in Caliraya, Laguna.

Many FGD participants also cited that the ban on gathering snails from the lake has also contributed to flooding. Gathering snails according to them provided a means of dredging the lake of its sediments. They asserted that the ban also led to the decline in the duck industry that flourished in the area before.

Factors that Affected the Five Flood Events

Among the five flood events delineated, the 1972 flood, followed by the 2009 event, had inundated the biggest areas in both municipalities (Table 2). The flood that inundated the least area was the 1995 event. The extent of flooding was mainly due to high lake water level which was influenced by rainfall, the condition of the lake and the surrounding watersheds. Topography also influenced the extent of floods such that bigger areas in Bay were inundated due to more flood plains along the lakeshore area. The flood event that persisted for the longest period was the 2009 flood followed by the 1986 event. Although the 1972 event registered the highest flood level and caused the most extensive flooding, it only ranked third among the five events in terms of duration. Despite being less severe, the 1995 and the 1986 floods persisted even longer than the deeper and more widespread flood in 1978. It took even longer for the 1986 flood to recede than the deepest and most widespread flood of 1972.

Longer flood duration in 1986 compared to the 1972 and 1978 floods may be attributed to the amount of rains received in these years. In 1986, the Laguna Lake catchment area received a total of 2,691 mm of rainfall compared to 2,373 mm in 1978. Total rainfall in the two municipalities in 1986 was 3016.90 mm which is higher than the rainfall in 1978 and 1972 at 2673.20 mm and 2483.70 mm, respectively. The higher total rainfall in 1986 could mean that there had been more rainfall events after the peak of the flood and such rainfall events prolonged the flood in that year compared to the two previous events.

The longer duration of floods in 1995 compared to the 1978 event, on the other hand, may be due to the proliferation of communities in lakeshore areas and in the area along the Napindan Channel, coupled with the siltation of the channel, which may have delayed the flow of flood water from the lake to Manila Bay (*LLDA, 2009*). The longer flood event in 2009 compared with the one in 1972 could be attributed to more rainfall received in 2009 particularly from succeeding typhoons such as *Pepeng* and *Santi* (International Code *Parma* and *Mirinae*, respectively), which affected the province that year. Total rainfall in 2009 obtained in the two municipalities was 2,829.6 mm compared to 2,483.7 mm in 1972. Furthermore, the conditions in the lakeshore areas and in the Napindan Channel may have also prolonged the 2009 flood event (*LLDA, 2009*).

Table 2. Annual rainfall, water levels, extent and duration of six floods events in Bay and Los Baños, Laguna

YEAR	ANNUAL TOTAL RAINFALL IN LOS BAÑOS AND BAY (mm)	ANNUAL TOTAL RAINFALL LDB CATCH-MENT^{WB} (mm)	PEAK WATER ABOVE MEAN SEA LEVEL (m)	HEIGHT OF WATER > 12.5 M (m)	TOTAL FLOODED AREA IN LOS BAÑOS (m^2)	TOTAL FLOODED AREA IN BAY (m^2)	NO. OF DAYS FLOOD LEVEL >12.5m^{WB} (d)
1972	2483.7		3.64	1.53	1,115,358.97	1,484,247.57	87
1978	2673.2	2,373	3.19	1.08	785,280.76	1,100,038.64	60
1986	3016.9	2,691	2.94	0.83	602,697.27	868,431.12	91
1995	2652.9	2,209	2.55	0.44	321,269.19	482,864.56	82
2009	2829.6	2,530	3.47	1.37	995,390.93	1,349,522.01	108

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

The study was done to describe trends in rainfall and extreme weather events in the municipalities of Los Baños and Bay in the province of Laguna; to determine the extent of past floods; and the contributory factors to these events. The following conclusions are drawn from the results of the study:

1. Annual rainfall in the two municipalities has been increasing from 1954 to 2012. Although intensity of extreme rainfall events did not exhibit the same trend, the accumulated amount of rains and the intensity of extreme rainfall events during the wet season were mostly higher from 2006 to 2012 than the average value for the entire 59-year period. Moreover, the frequency of days with rainfall greater than 200 mm was also higher in 2006 to 2012 as projected.

2. Floods experienced in the two municipalities were of different nature. These were either due to the increased water level of the Laguna Lake, overflowing of rivers or due to urban runoff and unsound development in their area.

3. Spatial analysis of five past flood events was able to depict flooded areas and to estimate the inundated areas in the two municipalities. Among the past five floods delineated, the 1972 event was the most extensive while the least was in 1995.

4. Floods in the two municipalities were due to the combined effect of rainfall and anthropogenic changes in the entire Laguna de Bay region. The extent and duration of past floods in the lakeshore communities was affected by the amount of rainfall, the condition of the lake and its surrounding watersheds, increased population in the region and the proliferation of communities in lakeshore areas and along the Napindan Channel.

Recommendation

Results of the study show that annual rainfall has been increasing and that the projected increase in total wet season rainfall, frequency, and intensity of extreme rainfall events are imminent. Such changes in rainfall coupled with the rapid degradation of the natural environment will expose communities located in flood-prone areas to more serious flood events. Therefore, the importance of preparedness to these hydro-meteorological hazards cannot be overemphasized. The following recommendations are given to enhance preparedness of communities in flood-stricken areas to more potentially disastrous flood events

1. Preparedness will entail proper awareness not only of the causes and impacts, but more importantly, on how to mitigate and adapt to the effects of floods. The LGUs should be able to prepare the communities to these hazards through proper Information, Education and Communication (IEC) activities. The LGUs may tap experts or universities to provide assistance for such purposes.

Schools will play an important role by intensifying their integration of climate change adaptation (CCA) and disaster risk management (DRM) in the curriculum to enhance preparedness and improve capabilities of children and their families in responding to hazards like floods. Manmade factors that contribute to floods in the area should be emphasized in classes. Laws on forest conservation, protection of water resources, land use management, and solid waste management should also be integrated in the curriculum.

2. Strengthening DRRM committees in the barangay level is vital. The LGUs should continuously build up the capabilities of their personnel to prepare for more severe flood events in the future. The acquisition of rescue equipment such a motorized boats and life vests among others, is vital to enhance the capabilities of these teams.

Schools should not lag behind in these efforts. Teachers and other school personnel should be given continuous opportunities to improve their capabilities in CCA and DRM. DRRM committees should be assigned and maintained in each school to ensure preparedness to floods and other hazards.

3. An effective and reliable flood early warning system should be in place to provide timely and reliable alert on incoming floods events. This should include an effective means of disseminating warnings to all communities at risk.

Communities and schools as well should develop a system of disseminating warnings on incoming extreme weather events and impending floods. This can be done through SMS or by assigning personnel to spread such alert to other households that cannot avail of such services.

4. Structural preparedness such as improvement of drainage in the whole community will help avoid prolonged exposure of communities to floods. Structures should strictly adhere to building standards in order to withstand floods. Establishment of permanent evacuation centers must be prioritized and other potential evacuation centers must be identified.

School buildings should likewise be made climate resilient. School buildings with upper floors or those elevated on stilts are more resilient to floods. These structures must be provided with stairs and bridges to allow safe access for children. Old classrooms may also be retrofitted to provide hanging cabinets to store school materials higher than the highest flood level.

5. The LGUs should formulate or review plans and guidelines for an orderly evacuation specifying the procedures from preparatory to post evacuation, the responsibilities of each agency concerned, and a system for monitoring and evaluation. Evacuation centers must be identified and households should be pre-assigned to particular evacuation centers. The guidelines must include measures to reduce damage and the proper use of facilities in the evacuation centers. School heads must be represented in the planning and formulation of these procedures, especially if schools will be used as evacuation centers. The education of children must be a major consideration during these emergency situations. Schools, on their part, should always be prepared to be used as evacuation centers.

Recommendation for Future Studies

Due to the limited time and resources, the study utilized rainfall data obtained only from the UPLB Agro-meteorological Station, which covers the two municipalities under study. Further studies may be done using data coming from more weather stations within the Laguna de Bay Region to provide better representation of the dynamics of rainfall and lake water level in the area. Weather stations with extensive rainfall data include those in Science Garden, Quezon City (0430), Ambulong, Batangas (0432) and Sta. Cruz, Laguna (409).

The study used the Inter-ferometric Synthetic Aperture Radar (IfSAR) images with a resolution of 5 m. Although IfSAR images may provide the most accurate geographic data of the LdB region to-date, the interpolation procedure followed in the study may be subject to possible errors, which could affect the accuracy of the maps developed for the five flood events. The use of finer resolution and more accurate source of geographic data such as Light Detection and Ranging (LIDAR) technology, which may be available in the near future is recommended to verify the results of this study and to provide a more accurate reconstruction of past flood events.

In order to address the problem more appropriately, it is important to determine which among the contributory factors are influencing floods more. Future studies may include proper methods for analyzing the effect of these factors on the occurrence of floods.

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The final paper was done primarily by the senior author with significant contributions from the other authors.

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