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Mapùa University
School of Civil, Environmental, and Geological Engineering

Event-Based Rainfall Runoff Forecasting in Marikina River Basin, Philippines using Artificial Neural Networks (ANN)

by

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Chapter 1:

INTRODUCTION

Introduction

Floods are the most common type of natural disaster that occur worldwide. In recent history, floods are becoming more frequent and more damaging and is even named as the most damaging natural disaster that occur (Badilla, R., 2008) By realizing the extent damages of this natural disaster and its impact to urban development, neighboring countries have committed themselves into developing flood management approaches in order to address flood risk management. Developing countries like the Philippines, however, have a more vulnerable economies and thus are affected in a much severe way when flood disaster strikes.

Philippines have been struggling with this perennial problem that occur during the southwest monsoon season. In Central Luzon, among the cities in Metro Manila, Marikina City has had an extensive history of flooding caused by its low-lying location and poor drainage systems. One of the greatest flood events in Marikina City happened in 2009, when the typhoon Ketsana dumped a month's worth of rain in less than one day causing the rivers to overflow that overwhelmed impenetrably populated areas, industrial and commercial zones. This flood caused severe damage to human lives and properties.

The use of ANN models can theoretically represent the river basins realistically this can possibly make the rainfall data easier to analyze for the disaster management for the local disaster office and readily available for future researchers that opts to find mitigation for the flooding or the lack thereof.

Background of the Study

Philippine Geography

The Philippines is said to be ranked as the 3rd out of 171 countries in terms of being vulnerable to natural hazard, it also known that the Philippines is one of the key countries in the pacific ring of fire. The Philippines is nature-rich for it is close to the oceans, having three prominent bodies of water such as the Pacific Ocean, the Celebes Seas, and West Philippines Sea. The Philippines also consists of 13.2 million Ha of Natural Forest, almost more than half of its total land area to forest. This land is one of the greatest hits of the global warming, as rain fall hard, the unstable piece of lands creates landslide that eventually clogs the water ways and becomes dead loads to dams.

Marikina River

The Marikina River located at the east of the Philippine Center, Manila. It is divided into two parts giving the upper part as part of the Montalban water gauging station and the lower section is a part Manggahan Floodway to Napindan Channel. It stretches to 27 kilometers.

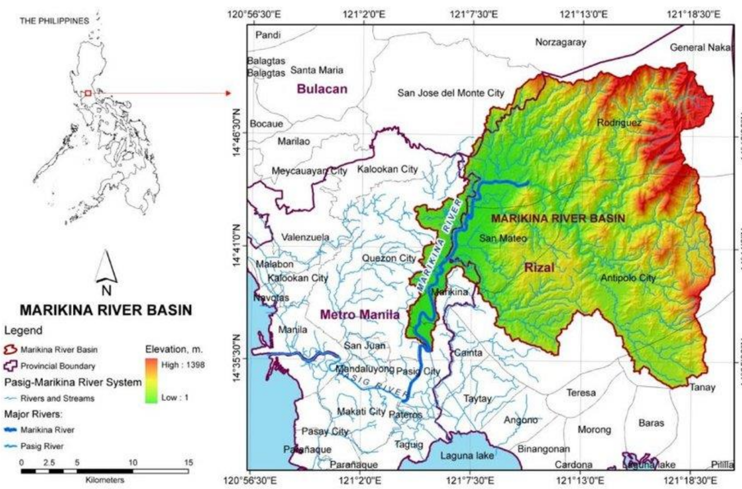

Figure 1. Markina River Basin

Research Setting

The researchers conducted the study in Marikina River Basin, located in Rizal, Bulacan, and Antipolo City provinces in Luzon Island, Philippines. Marikina River Basin is a reserved area that collects water in its nearby provinces. The approximate land area of the Marikina River basin comprises 698.26 k. According to the 2010 census, it has a population of 7,503,671 people. It composes of 197 Barangays with 15 cities and towns. The Marikina River Basin watershed had experienced abrupt social development throughout the decades. These flooding events have been a significant problem that leads to the destruction of human lives, resources, and infrastructures.

Statement of the Problem

The Marikina River over the course of recent flooding in the last three decades has have expected to not withhold the rainfall during the monsoon season, giving constant scare to residents near the river basin of getting flooded as the duration of the rainfall prolongs. The goal of this study is to create a system where data from past flooding will be accurately represented using Artificial Neural Network using computer software MATLAB ©.

Conceptual Framework

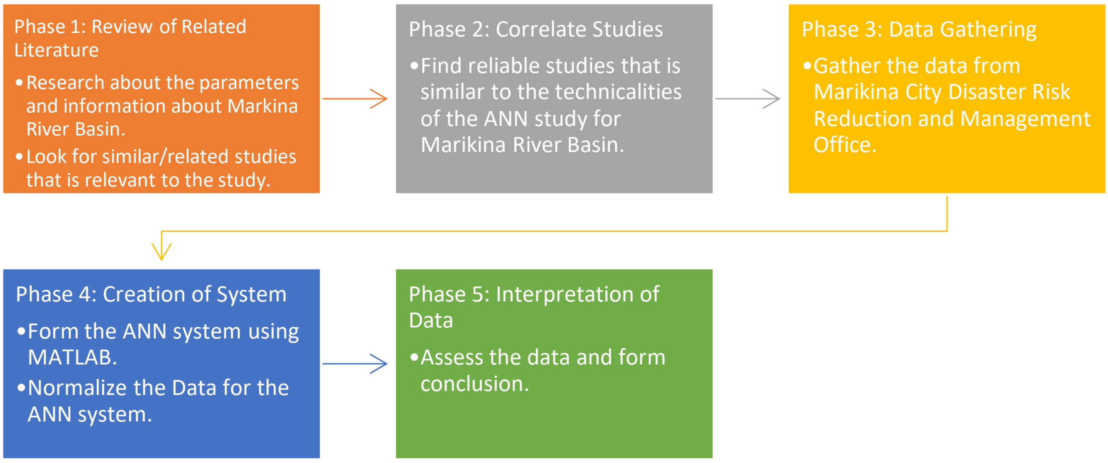

Figure 2. Conceptual Framework

Objective of the Study

The main objective of this research is to forecast the event of flooding in the Marikina River Basin with the aid of stimulation of Artificial Neural Networks (ANN). The Artificial Neural Networks creates a series of relationships between the rainfall and the basin's water level that predicts water level overflow.

Specific Objectives:

- Artificial Neural Network stimulation reduces accidents and fatalities during the incident of flood by triggering a warning alert beforehand to nearby residents to evacuate immediately.
- To investigate and observe the rise of water level in Marikina River Basin.
- Determining major causes of flood in Marikina River Basin to design a flood model.

Scope and Limitations

This study focuses on forecasting floods in Marikina River Basin, Philippines, using Artificial Neural Network (ANN). With the numerous occurrences of the calamity in the Marikina River Basin, a flood modeling tool (ANN) is essential to improve forecasting that provides an accurate and beneficial prediction that can mitigate accidents and casualties. It is essential to consider the low-lying areas in Marikina River Basin, which are most likely to experience flood.

The group chooses the ANN flood modeling tool to mimic the function of the brain to formulate and process data to forecast floods without any personal judgment to influence the data.

The flood forecasting also does not include the Pasig River, which the study will solely focus on flood forecasting and data gathering in Marikina River Basin.

The group gathers the rainfall data and measures it within the range of the Marikina River Basin from the year 2019 to 2020.

The study will only cover events based on typhoons and continuous rainfall that may cause or trigger flooding in the Marikina River basin.

The respondent of this study is the local government of Marikina who's monitoring the level of rainfall. The group also used existing data from PAGASA (Philippine Atmospheric, Geophysical, and Astronomical Services Administration) and simulated it using ANN.

Significance of the Research

This research will possibly invite new researchers to have continual study about the water system in Marikina using the historical data in the course of three decades. This will be a steppingstone for future researchers to easily design, plan, and mitigate the current crisis we are experiencing in the lack of catching basin or not withstanding redirector for overland flow and to provide flood warning for the residents living near the Marikina River Basin.

Chapter 2:

REVIEW OF RELATED LITERATURE

2.1. Flood

2.1.1. International Flooding

Flood is said to be the leading cause of natural disaster deaths worldwide, affecting nearly 2.5 billion people and claiming more than 244,000 lives between 1994 and 2013. According to Pan Hu, et al. published 2018, the flood frequency and flood-induced mortality are the largest in Asia, specifically, China, India, Indonesia, and Philippines.

This natural phenomenon is often caused by abnormally prolonged rains in such intensity, breakage of dikes, dams, extremely high tides, and tsunamis.

On 1960, in the state of the Idaho, United States of America the state's dam had two 0.24 CF or less seeps that eventually broken down a dam, this has resulted to 11 casualties, and has create great damage that costs over $400 Million Dollars (or 20 billion pesos), this is one of example of dam breakage flooding.

In Africa, the 2007 flooding in the continent has affected the lived of 2.5 million people and has even taken the lives of 250 people, this is one of the worst cases of flooding in the history.

The flood risks are often underestimated, and climate change are being ignored. Even so, over the years, there have been numerous research studies conducted in flood prevention. According to Henonin Justin, et al. (2103), All drainage networks in urban areas are designed to manage maximum rainfalls, and hydrological rainfall run-off models can be used to simulate distributed river discharges.

Over the years, there have been numerous research studies conducted in flood prevention. There are diverse types of numerical models widely used for urban flood prediction. Hydrological rainfall run-off models can be used to simulate distributed river discharges. One-dimensional Saint-Venant flow equations, can be applied for simulating the surcharge or drainage of the underground drainage network.

2.1.2 Local Flooding

The depleting ground water resources has always been a problem in Metro Manila, Metro Cebu, and other areas in the Philippines, since there is only overall, 95 small and poorly regulated hazardous wastewater treatment facilities— which gives a hint on the condition of the country's surface waters. Immediate assessment of the water quality must be conducted especially in the residential areas and the nearby polluted surface water and ground water that are prone to harmful effects. Marikina River is a natural waterway that collects and conveys surface runoff with marginal change in its bathymetry and the floodplain. It has a surface runoff of 2,025.40 mm/year. The Marikina River only has an annual discharge of 102.95 cubic m/s, with a maximum discharge of 1487.90 cubic m/s and a minimum discharge of 6.39 cubic m/s. (Dela Peña, Jowell P. et al., 2009). Knowing this—there are still no infrastructure built alongside the river to protect the surrounding areas, should the water level rise above the banks.

One of the main flood control measures of the City of Marikina is the Manggahan Floodway. The Manggahan Floodway is a channel, artificially constructed in 1986 to divert the flow of water towards Laguna De Bay, and away from Pasig River. The water from Laguna De Bay would only then pass through the Pasig River and into

Manila Bay. The problem with this, as seen in the recent years, is that if the rainfall is too strong (typhoon), the Pasig River is being push through its maximum capacity and would be then overwhelmed by the amount of water from Laguna de Bay, causing disastrous floods. If Laguna de Bay reaches its water capacity, naturally, the Manggahan Floodway and Marikina River will also flood.

2.1.3 Artificial Neural Network

Artificial Neural Network is a machine processing model that composes various functions that calculate, estimate, and arrange variables based on data and inputs that can function to different conditions. ANN is based on the biological function of the human brain by using algorithms in processing different networks to form logic. An ANN consists of several "neurons" or "nerve cells" connected to each other using direct links, arranged into three layers: input, output, and hidden layers (Dawson, 2016).

ANNs can process the highly nonlinear relationship between analysts (inputs) and the ideal variables (responses) and adaptably understand the complex parameters. Using ANNs can interpret complicated sequences and patterns from various sets of data that can also provide a mathematical approach to enhance the computer algorithms and make findings of the functional forms in an adaptable approach (Rosa, 2016).

The predictors normally conduct ANN through electronics which is computer-generated with the help of software. The characteristics of ANN are:

1. The arrangement of the connection between the nodes (architecture).
2. The methods of identifying the values on the connection between (training algorithm).

3. Activation function (transfer).

4. The order and number of layers: single (storage of several layers), bilayer (Carpenter's ARN), and multilayer (MLP).

ANN can directly interpret the flow and the rainfall without involving empirical before data processing in the method of Baseflow separation and calculation of the rainfall, producing runoff. Therefore, it can simulate and forecast rainfall-runoff (Varoonchotikul, 2003).

2.1.4 Local ANN

Weather and climate are highly nonlinear and unpredictable phenomena that indicate computer software simulation and modeling for precise prediction. The utilization of ANN to predict the relationship of the nonlinear system turns into a sustainable method to analyze and predict data. This study also predicted its effectiveness of 20 years mean annual rainfall data of Pagasa, Echague, Isabela Philippines from 1990 to 2010 and around its 75 km radius. The researchers also stated that the ANN model was the most suitable forecasting device to predict rainfall, which surpasses the MRA model in Isabela, Philippines (Raymundo, 2012).

The Disaster Risk Reduction Management Office (DRRMO) utilized a conventional method of measuring the water level. This study was conducted at Masantol, Pampanga, to forecast real-time flooding using an ANN model wireless sensor. ANN wireless sensor is centered on monitoring the flood level from medium to high-risk areas; the data gathered was for short forecasting. The objective of this study is to give an early warning to the residents and community (Sahagun & Dela Cruz, 2017).

2.1.5 River Basin

When cloud precipitates, stormwater or run-off flows down mountains, terrains, roads, hills, etc., towards rivers and lakes. These landmasses near a considerable body of water are called river basins.

In the study of engineering and management of rivers, it is vital to learn the characteristics of the geometry of the channel and the water flow. Bank erosion, sediment transport, flood hazard, aquatic habitat, and contaminant dispersion are associated with flow hydraulics. Flow traits being maximum depth, average depth, mean velocity, and secondary circulation is determined by channel properties. Channel properties such as bed and bank material size distribution, cross-sectional shape, riparian vegetation, and long channel shape play an important role in recognizing flow characteristics like flow resistance. These properties can act as a resistance to the flow which can affect the mean velocity of the flow therefore, it can predict the amount of water the channel can carry. The amount of water and flow resistance are in direct relationship with slope-area discharge gauging, calculation of channel capacity, stable channel design and flood routing. These problems are needed to be precisely predicted to avoid accidents. (Thorne,1997)

Activities such as flood control, irrigation, and provision of potable water were influenced by the research made in the United States and Europe. Integrated River Basin Model (IRBM) is a river basin planning that creates different water uses by correlating the river basin's various water resources. The model's extent correlates to the effects on aquatic life and controls soil erosion and runoff by watershed management.

To better understand streams, streams classify in a stream network into an order based on their tributary count. This method is also known as stream ordering. For instance, a first-order stream is composed of a single stream with no other stream flowing. A stream that consists of two or more first-order streams is named a second-order stream, while a stream with two or more second-order streams is called a third-order stream. When a lower order stream connects above with a larger order stream, the order of the stream below the junction will not change. For example, a second-order stream intersecting with a third-order stream will remain a third-order stream below the crossing (Dudula & Randhir, October 2016).

2.1.6 Local River Basin

The ancient civilization from ancient Egypt to China has relied solely to River Systems, this has given regions opportunities such as bartering, hunting, amongst others. The river flooding goes way back in history as Greek Historians has coined the river flooding as the "Gift of Nile" for it has make lands fertile for farming, this has marks as one of greatest civilization in agriculture, the same can be said about the history of lands in the Philippines.

Even now in our current times, the River Basin plays a vital role in the environment, development of society, and human consumption. Over the past decades, the development of society has been constant, and many bodies of water were affected.

The Philippines is abundant in natural resources. One of them is water which sheds its river basins and watersheds. The Philippines composes of 19 central river basins and 412 principal basins in 119 established watersheds. Cagayan River (Region II) is considered the longest river in Luzon, Philippines, which also involves two vital rivers in Luzon: Pampanga and Agno River, passing over through the provinces of Central Luzon. Considering the significance of each river basin and other natural resources, the Department of Environment and Natural Resources created the River Basin Control Office to improve the river basin conditions. With the help of the Department of Environment and Natural Resources River Basin Control Office (DENR-RBCO), it provides an order to monitor different activities happening on each river basin in the Philippines (Berkman International, Inc, 2015).

The DENR-RBCO organized series of specialized training for monitoring different rivers in Luzon, Visayas, and Mindanao. This activity demonstrates the conditions of the selected river on each island in the Philippines and provides a practical solution to the issues concerning the conditions of the basins. The DENR-RBCO should check the conditions of each river basin every five years to ensure that each watershed can sustain sources for human consumption and the environment (Department of Environment and Natural Resources, 2019).

2.1.7 Surface Runoff

The ocean acts a large depository of water that will eventually evaporate and become atmospheric moisture. Oceans are being kept full by the runoff and discharged from the rivers and the ground. Most of the water from rivers comes from the runoff from the land surface, which is defined as surface runoff. Urbanization affects the hydrologic processes such as surface-runoff patterns. In a "simplified manner", imagine that the land in the watershed beside the stream as a layer of sponges in different porosities, sloping away from the stream. When there is a storm, some of the water is being absorbed by the sponge, while some is runs off the surface and into the stream—hence runoff. When the storm lasts an hour or two, half of the rainfall is absorbed by the sponge, while the rest enters the stream. Naturally, the water in the sponges will start moving in a downward direction. With most of the watershed being replaced by roads, buildings, and other infrastructure, it has no means of infiltrating the impervious surfaces and will runoff directly into the stream, causing floods.

Surface Runoff is a water cycle in which it specifies the discharge within a specified period such as snow, rain fall, and others. This data that is gathered from historical input is crucial in creating model that turns gradually turn into million-billion-peso projects. One of the main usages of these that is the formation of sustainable drainage systems, site water network protection, creation of possible water attenuation storages, amongst others.

Stream flow data such as rainfall and runoff data create process called runoff-modeling, such information is said to be identified as the major element in designing water network planning and management. Apart from learning how to properly manage big water channels, this is also crucial for studies for untapped surface waters.

Forecasting water flows is necessary to balance the needs of the domestic population, agriculture, and industry whilst taking into account the aquatic and ecological system. thus, it is highly perceived in the hydraulic community to relate the rainfall and runoff.

2.1.8 Local Surface Runoff

Flooding generates excessive volume of surface runoff that exceeds the storage capacity of natural and artificial drainages (Brebante, Beverly, 2017). In disastrous events like Ulysses, Ondoy, and Vamco, the infiltration capacity of the city has exceeded, therefore will accumulate an enormous amount of water on the surface area which will eventually flow downslope (surface runoff) resulting in severe flooding in the area. The Department of Public Works and Highways (DPWH) are in the process of building flood control structures to prevent runoff, along Nangka River and Barangay Fortune, Marikina City, it is to ensure the protection of the residents affected during strong typhoons. The DPWH are also in the final stages of building the Pasig-Marikina flood walls and is expected to be completed in the year 2024.

2.1.9 Runoff Modeling

Runoff Model focuses on surface runoff data as it tabulates the data of water discharge, a strategy is created to meet the demands for people’s safety. For instance, the local government unit of West Midlands in England has created a runoff modelling that eventually resulted to sustainable drainage strategy, this research that has started as feasible study has set the standards in Staffordshire, England for it created a mitigated strategy that made the area’s standard of living high and it creates a sustainable water network.

The flood risks were regulated using the usage of historical input of flood water, gradually the authorities have created water courses for water to flow to, this has increased the rapid surface flow whilst the land infiltration decreases.

The runoff rate in an area is distinguished using the data from hydrology reports, a proper tabulation of data will help the researchers to easily estimate the allowable amount allowable discharge rate gaining the local government unit an objective to investigate the catchments, how it will respond to rainfall, and to derive the flood equations for improvements as well as evaluation of peak rates of flow that is equally esteemed.

2.2.0 Hydrologic Cycle

A water network modeling requires ample understanding in hydraulic cycle at catchment scale, this includes many processes, and it includes all factors in water cycle.

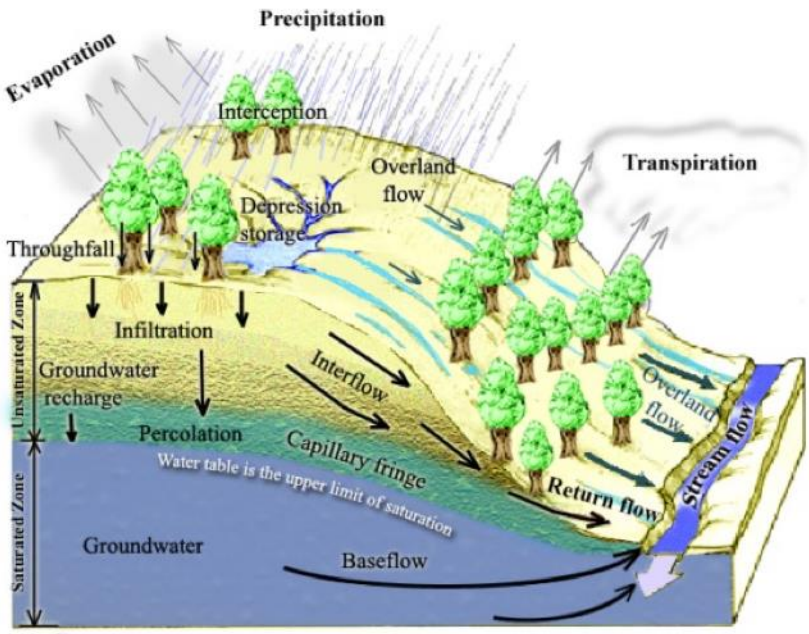

Figure 1. Runoff Generation (Tarboton, 2013)

The runoff most essential process is precipitation, for it causes distribution of rainwater in our ecological system, this rainfall travels in different direction. The water released during precipitation in forms of snow, rainfall, dew, amongst others become infiltrated water in lands, or it can be called as rainfall from depression storage this can evaporate again or sometimes gets to flow back naturally to the streams or can be redirected by mechanisms.

The process in this system also must take into consideration realistic factors such as sediments that has been accumulated during the movement of overland flow, interflow, and others.

2.2.1 Monsoon Season

There are two major seasons in the Philippines, one is the dry season during months December to May, the dry season is divided into two, the cool dry season and the other one is the hot dry season. The second season is the rainy season that takes place in the months of June to November.

There are four climate types recognized in the Philippines and these are classified as Types I, II, III, and IV, respectively. The first type consists of two seasons, but the dry season only occurs within November to April will the rest of the year experiences wet season. Type II has no dry season, the next type has dry season for only two-three months, and the last one is like type two but with not evenly distributed rainfalls.

Figure 2. Climate Map of the Philippines (PAGASA, 2014)

2.2.2 Typhoon

Ondoy

The Tropical Storm Ondoy (internationally called Ketsana) have affected Metro Manila in a massive scale as it has taken lives of over 600 people due to flooding. One of the most affected areas that the typhoon has affected is Marikina as big parts of the city was submerged in water due to knocked down banks of the river. This easily have killed seventy-eight (78) people due to the sudden rise in water.

The TS Ondoy is said to be of rarity as it only occurs once in 100 years where it is said to be emitting 350mm in 24 hrs of rainfall, almost 450 cu. m. per second flood water during its six hours of duration.

Ullyses

The Tropical Cyclone Ulysses (internationally called Vamco) is a rarity of its kind for it only gets to be experienced once in 50 years, this typhoon was branded as the worst flooding in the country's capital. This typhoon has emitted 455mm amount of rainfall in 24 hrs. giving 30-40 cu. m. per second flood water and this has latest for 14 hours.

This typhoon was marked to be slowly but deadly for its long duration, it has caused 102 fatalities and 10 missing individuals.

In this typhoon it was said that the water network that came from Cagayan River from the upper right side of Luzon has a wide opening that looks like the fruit Durian. This opening has a lot of stems, but these stems connected to the opening is too narrow making the stems or the other water basins below it not enough to handle the water that the Cagayan River has let go off, this water from the top was too much, including effects of deforestations in central Luzon, this has caused major flooding in Provinces like Cagayan, Isabela, Pampanga, to the river of Marikina.

Chapter 3:

Methodology

This study is a quantitative research study that interprets and analyzes the rainfall-runoff data of the Marikina River Basin, which causes flooding. The forecasting approach is used to predict the flooding in Marikina River Basin.

Site Study

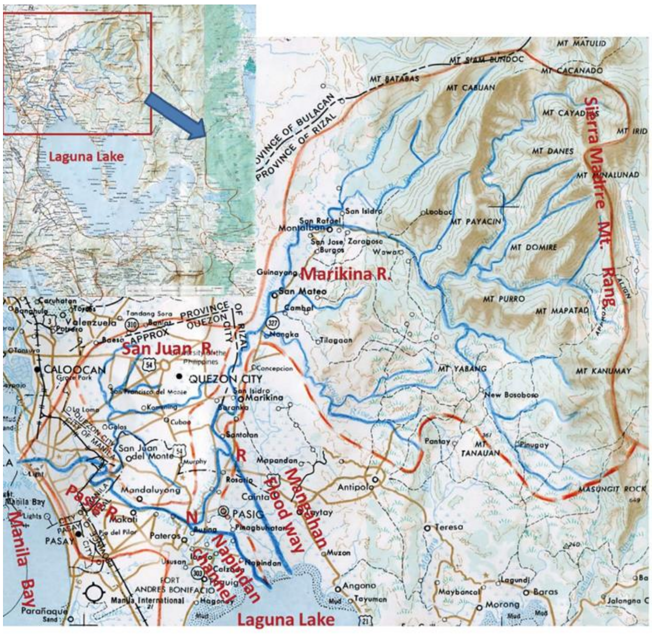

Figure 1: Marikina River Basin

The Marikina River Basin (Fig. 1) is located in one of the most developed places in Metro Manila. Its catchment area consists of 698.26 k, which lies from the western slopes of the Sierra Madre Cordillera. Numerous rivers comprise the Marikina River Basin, such as Wawa, Montalban, Boso Boso, Tayabasan, Nangka, and Manga, leading to a 31 km Marikina River streams south.

This area experiences a Type I climate that indicates two pronounced seasons: a dry period from November to April and a wet period throughout the year. It is also illustrated that there are occurrences of significant rainfall from June to September.

The average yearly temperature is 27.7 °C. The hottest month is May, with a monthly average of 29.7 °C. On the other hand, the coldest month is January, with an average of 25.7°C. The temperature's development and changes showed an increase with the duration of hot days but decreased with cold days.

The average yearly rainfall is about 2574.4 mm and August indicates the highest average rainfall of 504.2 mm. The dry period from November and April illustrates an average of 14.6 mm to 148.8 mm, while February showed the lowest average of 14.6 mm. Generally, the occurrences of high intensity of rainfall lessen but increase the high frequency of rainfall in the region.

The average percentage of typhoons passing in some parts of Luzon, including the Marikina River Basin, lies from 11% to 30%. The comparison of data indicates that about six typhoons pass through within a year, according to an average typhoon occurrence of 20 per year.

Conceptual Framework

The research will consist of five phases for its conceptual framework, the study will aim for effective representation of rainfall runoff data from Marikina River from 2019 to 2020.

Phase 1: Review of Related Literature

For the first phase, the researchers will investigate for the parameters and relevant information about the Marikina River basin. For the second part of the first phase, all relevant data that might be affecting the study such as climate, history, and system, amongst others must be established to help the researchers have a grasp of the scope and limitations of the study.

Phase 2: Correlation of Studies

The researchers will analyze data from relevant data existing similar/related studies to rainfall runoff analysis using ANN, this will be especially important in the study for this will help the researchers establish the technical aspects of the ANN system.

Phase 3: Data Gathering

In this phase, the researchers will be gathering the information data on the Marikina rainfall reading stations, rainfall runoff, and water level of the river basin in 2019 to 2020 from the Marikina City Disaster Risk Reduction and Management Office.

Phase 4: Creation of System

The researchers will first Normalize the data gathered from phase 3, these data will be inputted to the ANN system using MATLAB.

Phase 5: Interpretation of Data

The researchers will evaluate and interpret the data from the ANN of the Rainfall runoff in Marikina River Basin, the researchers will seek for professional counsel to create a more feasible conclusion.

Data Preparation

The depth of water in the Marikina Basin, the rainfall rate, along with the runoff data from 2019 to 2020 were gathered and will be provided by the Marikina City Disaster Risk Reduction and Management Office.

This study focuses on the rainfall level during the dry monsoon season of 2019 to 2020.

1. The Marikina-CDRRM office's were able to gather the data of rainfall, depth of rainfall, and rate of flood depth from the reading stations, these stations serve as a representator of the data for the model. the data gathered will then be

normalized using the normalization formula intrinsic in MATLAB Neural Network Toolbox using Eq. (1) (Malaguit, Makahiya, and De Lara, 2016)

$$p' = 2\frac{p - \min(p)}{\max(p) - \min(p)} - 1 \quad (1)$$

For Eq. (1), p and p' represents the original and the normalized flood depth data, respectively whilst the min(p) and max(p) represents the minimum and the maximum data. the data will be split into two computational components, the training and validation sets, these are used as calibration for the developed model.

After normalizing the data, it will be inputted in the MATLAB Neural Network Toolbox, then data will be then classified randomly into two groups creating a 70-30 ratio for training set and validation sets, respectively. (Malaguit, Makahiya, and De Lara, 2016)

Model Development and Implementation

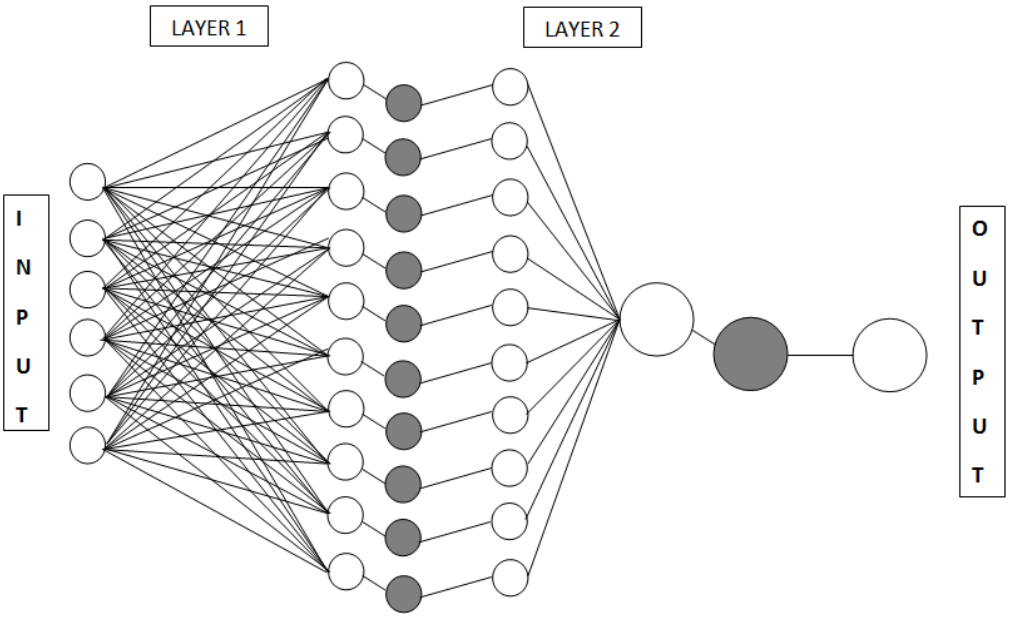

Figure 2.Visualization of ANN

Artificial Neural Network is based on the neurological behavior of a functioning human brain by using different algorithms such that it can process networks to form logic. ANN requires input (neuronal junction) which are then multiplied by weighted numbers, and mathematical functions that will determine the activation of "neurons" or "nerve cells". The function will then compute for the total output of the said neurons. In this study, the researchers use Feed-Forward Neural Network and Backpropagation for the algorithm of the ANN Model, as shown in figure 2.

The hyperbolic tangent sigmoid *(tansig)* function is given by the eq.

$$tansig(n) = \frac{2}{1+e^{-2n}} - 1 \qquad (2)$$

This *tansig* function is used in the problem for all the input-output relation in the model. (Malaguit, Makahiya, and De Lara, 2016)

References

Abhijit, P. (2014). Flood Prediction Model using Artificial Neural Network.

Abon, C. (2016). Verification of short-term runoff forecasts for a small Philippine basin (Marikina) .

Amano, A. (2011). Hypoxia in Manila Bay, Philippines during northeast monsoon.

Badilla, R. (2008). Flood Modelling in Pasig-Marikina River Basin.

Berkman International, Inc. (2015). *inal Report: Formulation of an Integrated River Basin Management and Development Master Plan for Abra River Basin.* Retrieved from https://faspselib.denr.gov.ph/sites/default/files//Publication%20Files/Page%201-159_%20Abra%20River%20BASIN%20IRBMD%20master%20plan%20v2.pdf

Clanor, M. D.-R. (n.d.). Rainfall-runoff Modeling of the Molawin Watershed of the Makiling Forest Reserve Using Five Lumped Conceptual Models (thesis).

Cruz, L. (2020). Transport of floating litter within Manila Bay, Philippines. .

Dawson, C. (n.d.). Applied Artificial Neural Networks. Basel, Switzerland: MPDI AG, 5p. . 2016.

Dela Cruz, R. (2020). =Importance of Dam Safety Program. "Disaster Resilience is the New Normal". Manila.

Dela Peña, J. P. (2009). Surface and Groundwater Quality Assessment of Marikina River .

Department of Environment and Natural Resources. (2019). *DENR-RBCO holds Technical Workshops for the Formulation of the State of the River Basin Report of selected major River Basins in Luzon, Visayas and Mindanao. River Basin Control Office 2019.* Retrieved from https://rbco.denr.gov.ph/denr-rbco-holds-technical-workshops-for-the-formulation-of-the-state-of-the-river-basin-report-of-selected-major-river-basins-in-luzon-visayas-and-mindanao/

Dudula, J. &. (2016). *Modeling the influence of Climate Change on watershed systems: Adaptation through targeted practices. Science Direct.* .

Hey, R. D. (1997). *Applied Fluvial Geomorphology for River Engineering and Management. Chichester: John Wiley & Sons.* .

ICExplains: The 2020 Marikina and Cagayan Flooding by Dr. Guillermo Q. Tabios III. (2020).

Luis, B. (2020). The Philippines' Marikina River.

Mabao, K. &. (2014). Assessment and Analysis of the Floodplain of Cagayan De Oro River Basin . Mindanao Journal of Science and Technology, 12(1). .

Mckelvie, G. &. (n.d.). Four Ashes Energy from Waste Plant Sustainable Drainage Strategy Statement (Vol. 1 of 1, Final Report, pp. 1-29) (England, Enviros Consulting LTD, Staffordshire County Council). London: Enviros Consulting Limited. .

Nguyen, H. Q. (2009). Rainfall-Runoff Modeling in the ungauged can le catchment, Saigon River Basin (thesis). .

PAGASA. (2021). Retrieved from http://bagong.pagasa.dost.gov.ph/information/climate-philippines.

PAGASA/DOST . (2014, August). *GOV PH.* Retrieved from bagong.pagasa.dost.gov.ph.

Pan Hu, e. a. (2018). *Flood-induced mortality across the globe: Spatiotemporal pattern and influencing factors.* .

Raymundo, R. (2012). *Rainfall Forecasting Model in the province of Isabela. KITE E-Learning Solutions.* Retrieved from https://ejournals.ph/article.php?id=684

Rosa, J. G. (2016). *Artificial Neural Networks: Models and applications. Rijeka, Croatia: InTech, 27p* .

Sahagun. M.M., &. D. (2017). *Wireless sensor nodes for flood forecasting using Artifical Neural Network. IEEE Xplore, 10.1109/HNICEM.2017.8269462* .

Sato, T. &. (2011, No. 45, February). 2009 Typhoon Ondoy Flood Disasters in Metro Manila. Natural Disaster Research Report of the National Research Institute for Earth Science and Disaster Prevention. pp. 63-74.

Surface Runoff and the Water Cycle . (n.d.). Retrieved from https://www.usgs.gov/special-topic/water-science-school/science/surface-runoff-and-water-cycle

Tarboton, D. (2020). *Surfaace.* Retrieved from Runoff Generator: https://edx.hydrolearn.org/courses/course-v1:HydroLearn+HydroLearn402-1+2019_S2/courseware/7882d80d36274a4f9618b647e43ee760/b5dbca4eff474e34912a4e1a3a19f121/1?activate_block_id=block-v1%3AHydroLearn%2BHydroLearn402-1%2B2019_S2%2Btype%40vertical%2Bblock%40

Varoonchotikul, P. (2003). *Flood Forecasting Using Artificial Neural Networks. Lisse, The Netherlands:Swets & Zeitlingers B.V., 12p.* .

Vizzuality. (n.d.). *Philippines Deforestation Rates & Statistics: GFW. Global Forest Watch.* Retrieved from https://tinyurl.com/f87kpzcn.