

Long Paper

# Spatiotemporal Data Analysis and Forecasting Model for Forestland Rehabilitation

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## Abstract

**Purpose** – Deforestation is one of the Global Forests issues that concern the United Nations (UN) for several decades and it thus leads to a vision of increasing the forestland area by 2030 that is the same size as South Africa. With this concern, spatiotemporal data analysis had been an effective way to visualize and represent the area that have been damaged and affected with the integration of the use of Geographical Information System. The National Greening Program (NGP) of the Philippines is in charge of the rehabilitation of unproductive, denuded and degraded forestlands in every province.

**Method** – Using the spatiotemporal data in the form of shapefiles, predictors that could contribute on how the forestland may be rehabilitated were analysed and foreseen. Also,



with the analysis stage of Artificial Neural Network (ANN) with Back Propagation, a forecasting model was identified.

*Result* – It has been determined that with the combination of ANN and Spatiotemporal visualization, possible additional increase in the size of the rehabilitated forestland and its representation can be done efficiently.

*Conclusion* – Thus, the finding may be used as a helpful way for the NGP for forestland rehabilitation and reforestation strategic planning and resource management.

*Practical Implications* – A dynamic and interactive web application may be implemented to monitor implementation of the program. Furthermore, public awareness may be initiated about the importance of forestland.

*Keywords* – artificial neural network, back-propagation algorithm, forecasting model, forestland rehabilitation, shapefile, spatiotemporal data and visualization

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## INTRODUCTION

A keynote from the United Nations (UN) during the International Day of Forests, 2019, stated that a country's economic growth and social development is impacted by how rich and wide forests are growing in that place. Forests play a significant role in the livelihood of many people; it eliminates hunger and helps alleviate poverty through the crops, fruits and raw materials that are converted into finished products. Forests are important sources of clean air and water, and are crucial as breeding place and vital habitats for biodiversity and millions of species all over the world. Forests also serve as protection and buffer from natural disasters such as flood and erosions, and are crucial for combating climate change (United Nations, 2018; Storch, Dormann, & Bauhus, 2018).

Moreover, one of the Sustainable Development Goals (SDG) boosted by the United Nations which is "Life on Land" promotes and emphasizes the importance and role of forests worldwide which leads to a vision to increase and inflate global forests by 2030, to 120 million hectares which is similar to the size of South Africa, was discussed during the UN Forum on Forests on January 20, 2017 along with 197 Member States including Philippines (United Nations, 2017).

Nevertheless, the Philippines' response to this concern was initiated collaboratively by the Department of Environment and Natural Resources (DENR) along with the establishment of National Greening Program under DENR Memorandum Circular (DMC) No. 2011-01 which has been expanded through the Executive Order (EO) No. 193 s. 2015 known as "The Expanded National Greening Program", propagates the agenda and vision to plant 1.5 billion of seedlings covering 7.1 million hectares of unproductive, denuded and degraded forestlands all over the country which is in support to government priority

program to reduce poverty, sustain food supplies, protect biodiversity, and improve climate change mitigation and implementation from year 2016 to 2028.

As of 2016, National Greening Program had already rehabilitated 1.66 million hectares of denuded and degraded forest areas and had planted 1.37 billion seedlings for agroforestry. And yet, it still needs to cover 5.44 million hectares until 2028. That is why the government extended NGP and so called the Expanded National Greening Program. This serves as the motivation of the study. Specifically, the study aims to develop a forecasting model for forestland rehabilitation.

Thus, this study is anchored to one of the objectives of the National Greening Program which is stipulated in the “Department of Environment and Natural Resources (DENR) Memorandum Circular – DMC No. 2011-01 which is to Promote public awareness as well as instil social and environmental consciousness of the value of forests and watersheds”.

### ***Objectives of the Study***

The study focuses on how the spatiotemporal data from NGP can be used to create patterns in forecasting the possible increase in the size of the rehabilitated forestland with spatiotemporal visualization. Moreover, the motivation for this study was aligned to the objective of the National Greening Program that concerns rehabilitation, reforestation and replantation of identified unproductive, denuded and degraded forestlands. Thus, this study aims to a. analyze the spatiotemporal data provided by NGP Pampanga; b. identify the municipalities that contributed greatly in the rehabilitation program of NGP Pampanga; c. determine the total size of rehabilitated forestland per year; d. present the NGP data using spatiotemporal visualizations; e. determine factors and predictors that may significantly affect the size of the rehabilitated forestland; and f. develop a model to forecast additional or change in the size of the rehabilitated forestland area using ANN with back-propagation algorithm.

## **LITERATURE REVIEW**

### ***Big Data and Data Mining***

Technology nowadays is without a doubt continuously advancing and evolving. Human activities may it be simple or complicated done at home, at work, in school, or anywhere people go creates volumes of data; things, moving or not also contribute and produce vast amount of data; aquatic, aerial and terrestrial plants and animals also generate data. Data come in various forms and from numerous sources, different fields and disciplines. As the technology and lifestyle improves so as the rising and increasing in volume and speed of data which forms and create Big Data (Gulia, 2018; Malgaonkar et al., 2016; Acharjya & Ahmed, 2016).

## ***Spatiotemporal Data***

One way to form data on forests is through Geographical Information System or GIS. Earth observation and GPS satellites produces massive data sets with better spatial and temporal resolution obtained from spatiotemporal observations which are associated to spatial locations, and GIS is an efficient way to deal with these data in the form of geometry types such as point and polygon to represent locations (Ferreira, Oliveira, Miguel, Monteiro, & Almeida, 2016). Since forests changes its form and states over time, some data relating to forests are in the form of Spatiotemporal Data. Spatiotemporal data are data that relate to both space and time, and describe a phenomenon in a certain location and time or spatial fields evolving in time. The use of spatiotemporal data may be seen in biology, medicine, meteorology, transportation, ecology and forestry (Amini Parsa, Yavari, A., & Nejadi, 2016; Lindstrom et al., 2013)

## ***Spatiotemporal Visualization***

In order to make use of such data sets, which are typically available in terms of sampled points and to make them visually readable, spatiotemporal visualization has been developed (Kuzniar & Zajac, 2015). A significant advantage of spatiotemporal visualization is that it provides a global view of activities or progress, from which evolutions and overall tendencies can be detected. Consequently, with the utilization of spatiotemporal data, forest changes and deforestation trends can be estimated as with the case in the Island of Tanzania and it was found out in the research of (Kukkonen & Käyhkö, 2014) conducted on 2014 that there was already an alarming rate and threat in the eco-system in the East-African landscape. König et al. (2019) also conducted a research using spatiotemporal data approach in the monitoring of biodiversity. All the species data were summarized and established through the Global Biodiversity Information Facility database including the location where these species can be found. With the said database, spatial distribution of the species where identified per region, which led them identify loss of biodiversity and imbalances in the environment (König et al., 2019). Moreover, Yu et al. (2018) established that visualizations is important means of communicating and representing massive data sets. Spatiotemporal visualization sometimes in a form of shapefile can be widely used as an instrument to depict results for decision-making processes. Spatiotemporal visualization may be applied in transportation and traffic simulations, land cover change, land use and land scape simulation, flood management or spreading of diseases. “The situation of today’s environmental issues and the need for sustainable development increase the importance of spatiotemporal visualization, which transforms dynamic modelling of multidimensional data into visual representations and consequently makes such data more accessible to experts as well as non-expert users”, they added.

## **Artificial Neural Network (ANN)**

To achieve meaningful interpretation and transformation of data particularly Forestry Big Data, data analytics techniques and algorithms, and processing tools should be carefully taken into consideration. Kuzmar and Zajac (2015) emphasized in their paper that the success of neural networks lies significantly on the form of pre-processing method applied. As an alternative method in processing and representing unpredictable data and modelling nonlinear and complex phenomena in Forestry and Environment, Imada (2014) acknowledged the findings of Peng in 1999 that Artificial Neural Network or ANN is good at non-linearity processing approach. Peng and Wen (1999) also mentioned that ANN can provide optimal solutions to forest management problems through its predictive capability based on supervised learning and training of the system. Moreover, in the research of Imada and other researchers, ANN was applied to predict forest wildfire or risk of fire occurrence in the forest based on air temperature, humidity, wind speed and rain using Multilayer Perceptron (Kuzniar & Zajac, 2015; Imada, 2014; Peng & Wen, 1999).

## **METHODOLOGY**

Identifying how the data were collected and what composes the shapefiles determines which approach to be adopted in this study. With the underlying nature and characteristics of data and established objectives, Descriptive Research Design was implemented. Particularly to achieve the main objective of this study which is to analyze data and transform into spatiotemporal visualization, data provided by the NGP in the form of shapefiles need to be processed in a form suitable to be fed in a computational technique particularly Artificial Neural Network or ANN. Descriptive study will be implemented since it establishes associations between variables which in this case the NGP Shapefiles, Forecasting Model and Spatiotemporal Visualization for Forestland Rehabilitation.

### ***The Motivation: Global and Philippines Status***

Deforestation is a global issue for several decades according to UN and thus it leads to a vision to increase the forestland to 120 million hectares (same size as South Africa) by 2030, along with 197 member states including Philippines. Forest Resources Assessment and Davies (2019) reported during the International Day of Forests on March 2019, world population will climb to 8.5 billion by 2030 and forests will be the most and important constituent in sustaining the lives of these people. A study said that one mature tree can support 2 humans for their oxygen intake yearly. And it takes 10-15 years or even 20-30 years to grow and have a mature tree. There will be scarcity of clean air and oxygen as the population continues to grow and inflate every year and as trees are continuously being cut down.

## The Conceptual Framework

Figure 1 inspired from Shekhar et al. (2015), illustrates the process from input to spatiotemporal visualization and forecasting model. The NGP in every Provincial Environment and Natural Resources (PENRO) partners with community-based organization which are the manpower or planters who do the rehabilitation and reforestation activities. Sites are identified for possible seedling production and plantation and corresponding seedlings or species of plants and trees are provided to the organization to plant them. Data such as the location, measurement of land area to be planted, latitude and longitude, species, number of people involved or planters, and number of households, number of seedlings produced and number of seedlings planted are recorded through Geotagging which creates or produces the spatiotemporal data of NGP. From the Geotagged photos, shapefiles containing .shp, .shx and .dbf were pre-processed using WEKA to identify the factors and predictors that significantly affects the size of rehabilitated forestland. After which, a computational technique which is the Artificial Neural Network (ANN) was applied to produce a model and forecast possible increase of rehabilitated forestland in the succeeding year.

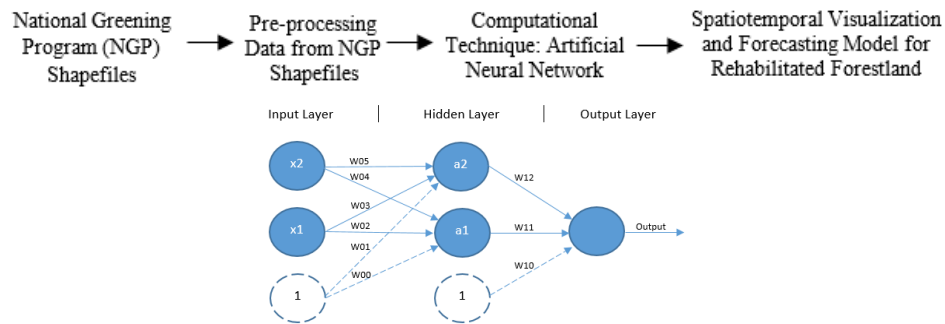


Figure 1. Spatiotemporal Data Analysis with Forecasting Model for Forestland Rehabilitation

## Specific Procedure

### Spatiotemporal Data Analysis and Visualization using Shapefiles

Shapefiles are composed of .shp, .shx, and .dbf files which are a collection of polygons, points and lines that contains information on the activities done by NGP during the Site Assessment and Site Mapping Procedure (SMP), Species Selection and Spacing, Seedling Production and Nursery Establishment, Plantation Establishment, and Maintenance and Protection based on the recorded latitude and longitude of the barangays within the province of Pampanga. From the shapefiles provided by NGP Pampanga from year 2011 to 2018, the following data were extracted using Excel: Region, District, PENRO, Barangay, Municipality, Province, Area, Name of Organization, Type of Organization, Component, Commodity, Species, Year, Zone, Tenure, Remarks, Area Code, Species Replanted, Category, Unique ID, Longitude, and Latitude.

Also using the GIS feature of Excel, shapefiles were plotted through the .shp files. The map was formed with several layers sorted out by year. The visualization shows the progress of the projects done by the National Greening Program from 2011-2018, shown on Figure 4 in the Results and Discussion.

### Pre-processing and Data Cleaning

Using WEKA Select Attributes and Ranker methods, predictors were ranked based on their significant contributions on the size of the rehabilitated forestland based on historical data from 2016 to 2018. Predictors were ranked as follows: Number of Projects, Number of Households, Number of Municipality, Budget Allocated, Number of Planted, Number of Barangays, and Number of Seedlings as shown in Figure 2.

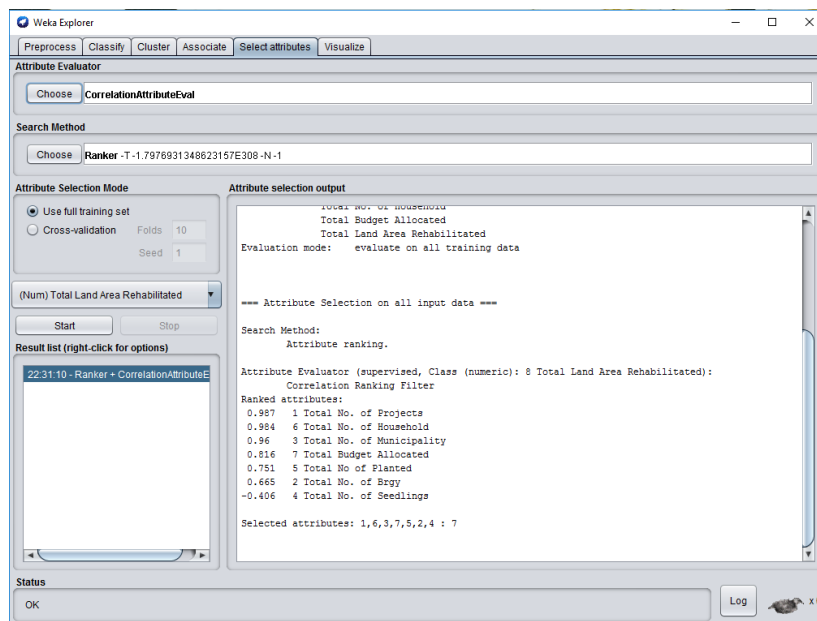


Figure 2. WEKA Select Attributes and Ranker Methods

After which, WEKA Classifier – Multilayer Perceptron was applied to generate Neural Network Single-Hidden Layer with corresponding sigmoid nodes as illustrated in Figure 3.

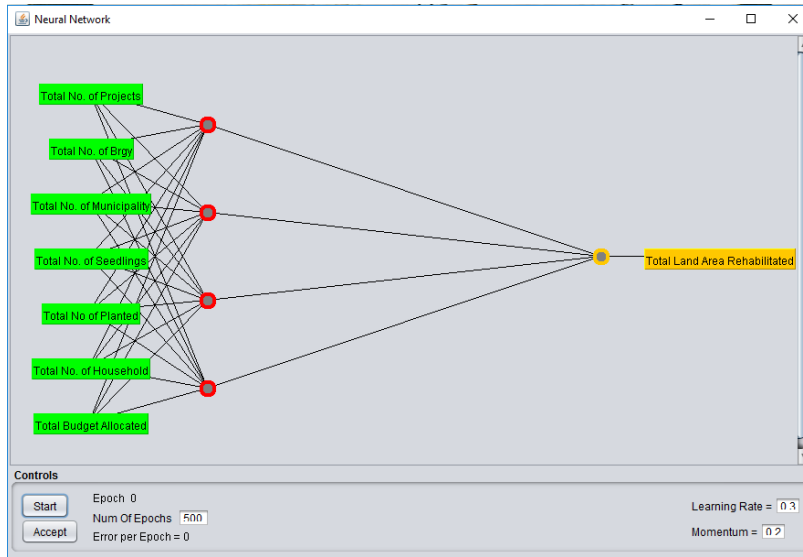


Figure 3. Multilayer Perceptron with Single-Hidden Layer for Forestland Rehabilitation

As shown in the generated diagram in Figure 3, to forecast the Total Land Area Rehabilitated, a single-hidden layer with four sigmoid nodes were formed. The diagram formed and provided by WEKA with sigmoid weights and threshold values were used in the development of the forecasting model particularly the back-propagation algorithm. Figure 4 shows the sigmoid nodes weights and threshold which were utilized in the computation shown in Figures 5 and 6, both for Feedforward algorithm and Back-propagation Algorithm.

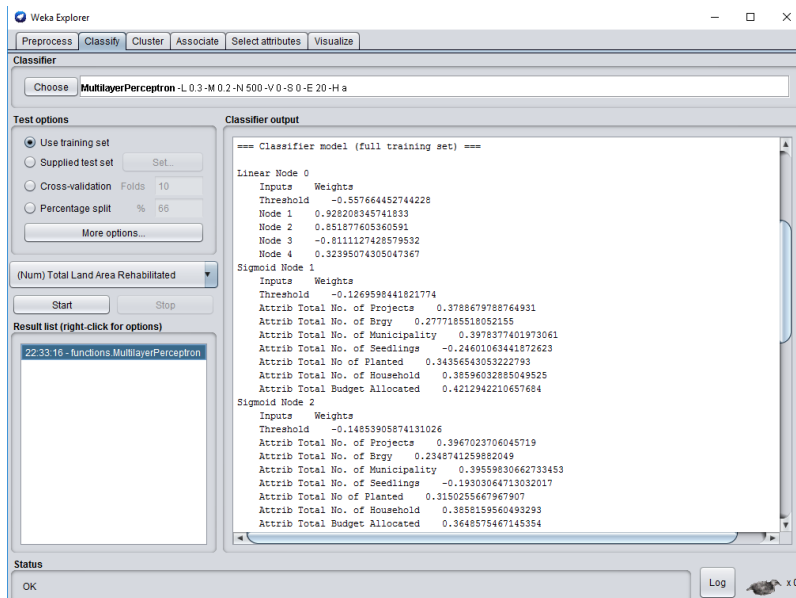


Figure 4. Sigmoid weights and threshold values

Table 1 shows the corresponding weights of the nodes and sigmoids generated from the multilayer perceptron method of WEKA. The computational technique (ANN) on which these weights were applied are shown on the Results section.

Table 1. Nodes and Corresponding Weights

Inputs	Weights
Threshold	-0.557664452744228
Node 1	0.928208345741833
Node 2	0.851877605360591
Node 3	-0.8111127428579532
Node 4	0.32395074305047367

## RESULTS

### *Spatiotemporal Data Analysis and Visualization using the NGP Shapefiles*

Table 1 and Figures 5, 6 and 7 provides the result of the analyzed NGP Spatiotemporal data and the visualization of the shapefiles from 2011-2018 showing the progress and changes happening in the forestland area in Pampanga.

Table 2 presents the different species planted per municipality. Extracted from the .dbf file of the NGP shapefiles, Porac, Apalit, Floridablanca, Magalang and San Simon have the most numbered types of species planted. From this table, different species may be identified by municipality.

As shown in Figure 5, year 2013 has the highest total rehabilitated area gained from all the municipalities of Pampanga followed by the year 2015, 2014, 2018, and 2017. This means that there were more projects and municipalities and barangays participated in the rehabilitation program of the NGP Pampanga. Figure 6 shows that Porac has the highest rehabilitated forestland due to its land area which is followed by Floridablanca and Arayat which also have bigger size of land area, from years 2011 to 2018.

Deriving from the spatiotemporal visualization on Figure 7 Porac, Floridablanca and Arayat have the biggest or highest contribution in rehabilitating the forestland in Pampanga. Figure 6 also showed that Porac have rehabilitated 2961.9 ha of forestland in eight (8) years, followed by Floridablanca with 1938.42 ha, Arayat with 1853.4 ha, Magalang with 685.4 ha, and Macabebe with 638.08 ha. These municipalities contributed significantly in the increase in size of the total rehabilitated area in the whole province of Pampanga from years 2013 to 2018 which are shown on the shapefiles on Figure 7.

Table 2. Species planted per Municipality

Municipality	Species	No. of Unique Species
Angeles City	Bamboo, Banaba, Fringon, Golden Shower, Tulip	5
Apalit	Banaba, Mahogany, Narra, Kawayang Bayog	31
	Alibangbang, Akleng Parang, Kupang, Molave, Atis, Cashew, Duhat, Guyabano, Jackfruit, Rambutan, Coffee, Sampalok, Bamboo, Banaba, Fringon, Golden Shower, Tulip, Mahogany, Narra, Bayog, Bignai, Narra, Paitan, Tuai, Cacao, Dao, and other indigenous spp. Eucalyptus,	
Arayat	Molave, Kawayang Bayog,	3
Bacolor	Banaba, Fringon, Golden Shower, Tulip, Kawayang Bayog	5
Candaba	Bakauan, Nipa, Kawayang Bayog	3
City of San Fernando	Banaba, Fringon, Golden Shower, Tulip, Mahogany, Narra, Kawayang Bayog	7
Floridablanca	Acacia Mangium, Banaba, Kakauate, Mahogany, Narra, Yemane, Atis, Cacao, Coffee, Guyabano, Jackfruit, Fringon, Golden Shower, Tulip, Cashew, Guyabano, Jackfruit, Tamarind, Kakawate, Kawayan Tinik, Kawayang Kiling, Molave	20
Guagua	Banaba, Fringon, Golden Shower, Tulip, Mahogany, Narra	6
Lubao	Bamboo, Banaba, Mahogany, Narra	4
Macabebe	Api-api, Bakauan, Nipa, Banaba, Mahogany, Narra, Kawayang Bayog	7
Masantol	Bakauan, Nipa, Pagatpat, Agoho, Banaba, Eucalyptus, Kawayang Bayog	7
Magalang	Atis, Camachile, Cashew Guyabano, Langka, Siniguelas, Duhat, Rambutan, Banaba, Fringon, Golden Shower, Tulip, Mahogany, Narra, Molave, Cacao, Dao and other Indigenous Species, Kawayang Bayog	17
Mexico	Banaba, Fringon, Golden Shower, Tulip, Mahogany, Narra, Molave, Kawayang Bayog	8
Minalin	Bakauan, Nipa, Banaba, Mahogany, Narra, Kawayang Bayog	6
Porac	Acacia Mangium, Eucalyptus spp., Mahogany, Narra Achuete, Calamansi, Duhat, Guava, Guyabano, Jackfruit, Rambutan, Suha, Tamarind, Atis, Cacao, Camachile, Cashew, Avocado, Mango, Tamarind, Kupang, Banaba, Fringon, Golden Shower, Tulip, Coconut, Coffee, Ipil-ipil, Kakawate, Kawayang Tinik, Kawayang Bayog, Molave, Narra	33
San Luis	Kawayang Bayog	1
San Simon	Alibangbang, Banaba, Golden Shower, Banaba, Mahogany, Narra, Kawayan Tinik, Nipa	8
Santa Ana	Banaba, Mahogany, Narra	3
Sasmuan	Bakauan, Pagatpat	2
Sta. Rita	Banaba, Mahogany, Narra	3
Sto. Tomas	Banaba, Mahogany, Narra, Kawayang Bayog, Nipa	5

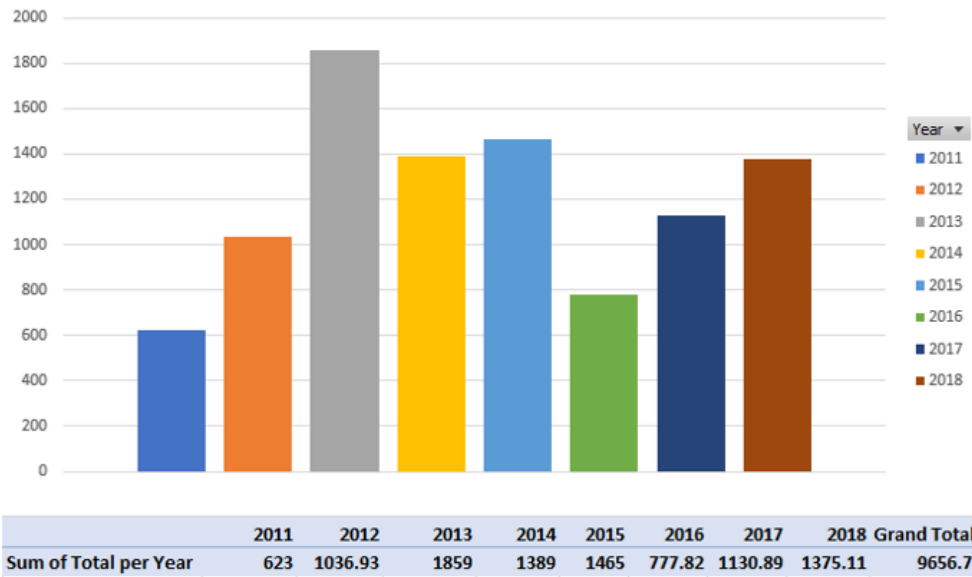


Figure 5. Total Rehabilitated Area (in ha) per Year

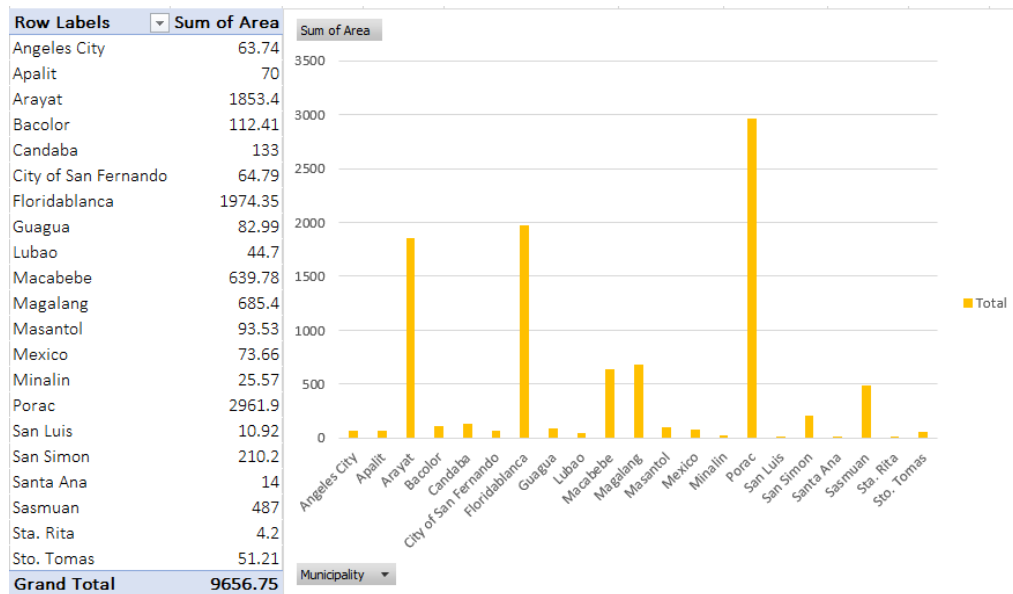


Figure 6. Total Rehabilitated Area (in ha) per Municipality

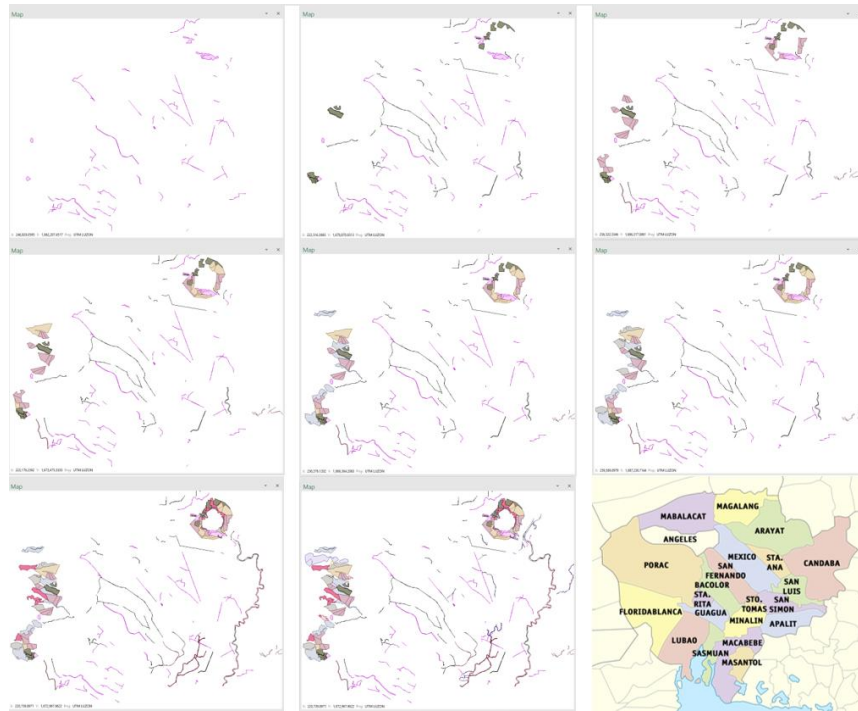


Figure 7. Spatiotemporal Visualization of the Rehabilitated Forestland from 2011 to 2018 including the flat map of the province of Pampanga indicating the municipalities

### Application of Forecasting Model

The following tables present the predictors with their corresponding weights on every sigmoid generated by the multilayer perceptron of the neural network in WEKA (Table 3).

Table 3. Predictors and Corresponding Weights on Sigmoid Nodes

Inputs	Sigmoid Node 1 Weights	Sigmoid Node 2 Weights	Sigmoid Node 3 Weights	Sigmoid Node 4 Weights
Threshold	-0.127	-0.149	-0.127	-0.127
Total No. of Projects	0.379	0.397	0.379	0.379
Total No. of Brgy	0.278	0.235	0.278	0.278
Total No. of Municipality	0.398	0.396	0.398	0.398
Total No. of Seedlings	-0.246	-0.194	-0.246	-0.246
Total No of Planted	0.344	0.315	0.344	0.344
Total No. of Household	0.386	0.386	0.386	0.386
Total Budget Allocated	0.421	0.365	0.421	0.421
Threshold	-0.127	-0.149	-0.127	-0.127
Total No. of Projects	0.379	0.397	0.379	0.379
Total No. of Brgy	0.278	0.235	0.278	0.278
Total No. of Municipality	0.398	0.396	0.398	0.398
Total No. of Seedlings	-0.246	-0.194	-0.246	-0.246

Seemingly, Tables 3 consistently shows that the highest weight or the predictors that contributes greatly to the increase in the size of the rehabilitated forestland based on historical data are Total Budget Allocated, Total No. of Municipality, Total Number of Projects, Total Number of Household and Total No. of Planted. And the Total No. of Seedlings consistently has negative impact on all the sigmoid nodes since that attribute represents the number of seedlings produced but not have been planted yet.

Using the back-propagation algorithm and applying the weights of the predictors and sigmoid nodes' threshold, the model to forecast possible increase in the forestland rehabilitation was developed. Back-propagation was executed using Excel, Data Solver Parameters and GRG Non-Linear Method. Weights and input data were adjusted and played out until a more realistic value or forecast have attained, thus the formation of the forecasting model.

Table 4 and Table 5 show sample forecasted value for additional rehabilitated area or size in Pampanga given the input values. The number of municipalities already optimized its maximum value, seemingly only the number of projects and barangays were adjusted and created 23% increase in the size of the rehabilitated forestland based from the previous forecast.

Table 4. Sample Forecast Value for Additional Rehabilitated Area/Size in Pampanga

<b>Predictors</b>	<b>Assigned/Forecasted Value</b>
Total No. of Projects	48
Total No. of Barangay	92
Total No. of Municipality	19
Total No. of Seedlings	1237549
Total No. Planted	125005
Total No. of Household	690
Total Budget Allocated	16437410
Additional Rehabilitated Forestland in Ha	129.45

Table 5. Sample Forecast Value for Additional Rehabilitated Area/Size in Pampanga

<b>Predictors</b>	<b>Assigned/Forecasted Value</b>
Total No. of Projects	60
Total No. of Barangay	120
Total No. of Municipality	19
Total No. of Seedlings	1237549
Total No. Planted	125005
Total No. of Household	690
Total Budget Allocated	16437410
Additional Rehabilitated Forestland in Ha	159.30

## **DISCUSSION**

From the data provided by the National Greening Program, significant factors and predictors were identified using the Ranker method of WEKA, on which the multilayer perceptron was applied and thus the forecasting model was derived through Artificial Neural Network with Back-Propagation Algorithm. Using the model with the identified factors or predictors, input values were played out which were used as basis on the forecasted possible increase or change in the size of the rehabilitated forestland which therefore could be used as a guide for strategic planning for forest management and rehabilitation. The National Greening Program Coordinator or Authorities could look on the possibilities of increasing the number of projects, number of municipalities and household involved. Based from the model, the number of seedlings produced does not significantly affect the size of the rehabilitated forestland based on the weights and threshold assigned by the Multilayer Perceptron method of WEKA to it which is -0.2460. Moreover, the number of households and allocated budget depends on the number of projects initiated and executed. Thus, the model suggests that to increase the size of the rehabilitated forestland, there should be more households and municipalities be involved and more projects should be done, thus requiring budget to be allocated.

Moreover, spatiotemporal visualization was considered a better way to represent data and to make the common people or the public becomes aware of the projects done of the NGP as well as the status of the forestland in the province. Numbers and Statistics can accurately present data and report however, visualizations, figures and images could make the public more aware and grasped the report more easily and could analyze changes happening in the forestland by municipality better and clearer as shown in the provided figures in the Results section.

With these two approaches, Forecasting Model and Spatiotemporal Visualization, NGP Authorities could have wider view and alternative method in presenting their data and have more options from where they could base their decision for planning and implementing forestland strategies and management approaches like how many projects should be implemented, how many households and municipalities should be involved and what kind of species could be planted in a specific barangay and be able to identify the possible increase in size of the rehabilitated forestland.

## **CONCLUSIONS AND RECOMMENDATIONS**

With the historical data of the National Greening Program enabled the researcher to utilized tools such as WEKA and implemented Artificial Neural Network with Back-Propagation Algorithm to it. The said data were used as test data to form or develop a forecasting model. And through the Attribute Selection, Ranker of WEKA significant factors were identified and using the Multilayer Perceptron Neural Network of the same

tool, a four sigmoid node single hidden layer was generated with corresponding weights and threshold which were applied in the execution of the back-propagation algorithm.

The process of determining the significant factors is crucial since it could suggest to authorities and National Greening Program officials where to focus and they could use the result to analyze or plan a more effective strategy in forest management and rehabilitation. The predictors and factors may be used as bases in decision making such as how many projects should be done yearly, how many municipalities, household involved and seedlings to be planted in order to meet a specific change or increase in the size of the rehabilitation of forestland.

Lastly, Artificial Neural Network with Back-propagation algorithm was adopted in this study since it has the ability to model non-linear and complex relationships in which one thing does not clearly or directly follow from another such as the number of municipalities involved, number of seedlings planted and household involved. ANN can generalize after learning from the initial inputs. Using the back-propagation algorithm, more realistic forecast value on the possible increase in the size of the rehabilitated forestland was attained, after executing Excel Data Solver Parameter and applying GRG Non-Linear method several times.

## **IMPLICATIONS**

A dynamic and interactive web application should be implemented to accommodate monitoring and viewing of information such as top performing municipalities, number of projects done within a municipality per year, species planted in municipality per year or per project, number of households involved per project and per municipality which could easily be accessed by the public thus attaining one of the objectives of the NGP which is to “promote public awareness as well as instil social and environmental consciousness of the value of forests and watersheds”.

## **ACKNOWLEDGEMENT**

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