Artificial Neural Network Prediction to Identify Solar Energy Potential In Eastern Indonesia

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***Abstract*—The geographic location of Indonesia which climates almost entirely tropical provides exclusive potential for solar energy all through the year. This paper performs identification and prediction of solar irradiance in Eastern area of Indonesia. Modeling and estimation approach is carried out by using Artificial Neural Network (ANN) algorithm. Datasets for training and testing are highly correlated parameters from NASA climatological database for 20 years of historical data. The results of training and testing procedures in ANN show high accuracy of solar modelling and prediction. The study produces spatial mapping of solar irradiance intensity for the monthly average solar irradiance of 174 distritcs in Eastern Indonesia region.**

I. INTRODUCTION

Renewable energy resources are the key solution of energy shortage and climate issue for mankind around the world. They are not only available in a wide range, i.e. solar, wind, hydro, biomass are abundant in nature. Solar energy is one of the most promising renewable energy. It is more predictable than wind energy and less vulnerable to changes in seasonal weather patterns [1]. Planning for optimal use of solar energy requires accurate estimation of its amount and characteristic across the country.

National target of renewable energy generation in Indonesia is 23% by 2025. However, the realization by 2021 is only 11.7%. Eastern areas which are located in 13 Provinces/174 districts have an average solar irradiance above 5 KWh/m2/day. This reality is a significant potential of renewable energy resources. Therefore, knowledge and information about solar resources availability and its forecasting are essentially useful to learn about the potential of solar energy for power generation. It is beneficial at the early stage of renewable energy planning to implement solar energy power generation, especially for the technology and site selection of solar power generation system. Indonesia is an archipelago which has geographical condition such as island and widely remote area, the measurement of solar irradiation in the ground becomes difficult and expensive.

Indonesia has a great potential for solar energy harnessing due to the high level of solar irradiation and the length of sunshine duration. In a developing country which has geographical conditions such as islands and remote areas, the measurement of solar irradiation on the ground becomes difficult and expensive. There are large areas in the islands of Indonesia that spread over from east to west that do not have any weather stations. Estimation of solar irradiation data using appropriate models can be an alternative solution for developing country, such as Indonesia.

This paper studies about the development and usage of the ANN models in such location. In Indonesia, many meteorological stations only have relative humidity, temperature, wind speed, and sunshine duration recorders. Measurement of solar irradiation with reliable and calibrated pyranometers is not available or only available in limited areas.

Solar irradiation potential is required as reference for renewable energy implementation and also required for agriculture engineering. Indonesia lies on the equator, located between 6°N and 11°N latitudes and in between 95°E and 141°E longitudes. Most of the locations in Indonesia receive abundant solar energy throughout all the year. Eastern Indonesia is the most tropical climate area in Indonesia which has dry season in June to September, while the rainy season occurs from December to March.

The contribution of this study is to develop neural network models for estimating monthly averages global solar irradiation potential in many locations of Indonesia based on satellite data. Solar mapping is developed based on predicting the value by ANN model proposed using GIS technology. The knowledge of solar resources availability at a particular geographical location is useful for solar engineers, building engineers, and agriculture engineers in many applications of solar energy. A solar irradiation map per- forms theoretical potential of solar energy for a specic region and provides information that useful for site selection of solar energy system.

The theoretical potential can be an early stage for decision making to implement solar energy system. The theoretical potential can be achieved by developing solar irradiation map for the country. However, this study only limit to evaluate the resources potential, while other issues such as economic, and environmental were not considered.

The main objectives of the project are to define solar irradiance model for districts in Eastern Indonesia, to carry out solar irradiance forecasting, and to develop the solar irradiation mapping of solar energy potential in Eastern Indonesia.

II. Literature Review

Prediction approach can be implemented by model-based or data-driven method [2]. Nowadays, the forecasting purposes are processed by developing machine learning based algorithm. Earlier study in [3] examined the application of photovoltaic in remote area in Indonesia is cheapest compared to gasoline generator electricity due to the high cost in transportation. Since the design of anycost effective solar energy system depends on reliable data, and measuring solar irradiation is costly, therefore a method to estimate solar irradiation should be explored. Further study in [4] suggested a model which could estimate the solar irradiation potential with Neural Network method by using meteorological data in many locations. However, due to the limitation of meteorological data, it cannot cover the entire islands of Indonesia that has wide area from east to west.

Artificial intelligence techniques have been successfully developed to model different solar radiation variablein many locations. Study in [5] developed estimation of monthly mean of daily global solar irradiation using ANN method in inputs for the networks are latitude, altitude, and mean sunshine duration. Energy demand prediction using ANN model was combined with Electromagnetic Field Optimization (IEFO) algorithms studied by [6]. Previously, a study by [7] used ANN model with wind speed, relative humidity, air temperature and soil temperature as inputs to estimate hourly global solar radiation for La Serena in Chile. The results indicate strong correlation between hourly global solar radiation and meteorological data. Another estimation for monthly average global solar irradiation on a horizontal surface has been studied in Gusau, Nigeria by [8]. In 2018, [9] published a mapping of solar energy potential using artificial neural network and GIS technology in the southern part of India. A recent study by [10] assess the potential for the establishment of renewable energy farms (solar, wind, biomass, and geothermal) in the eastern regions of Iran. Analytical Network Process (ANP) and Fuzzy logic are used to investogate environmental and economic criteria for the assessment. Furthermore, another case study in Arabian Peninsula was conducted by [11] for hourly solar radiation and wind speed prediction using ANN.

III. Research Methodology

The way neurons communicate with one another in the human brain is the inspiration for the machine learning technique known as neural networks. A neural network may be trained to identify patterns, classify data, and predict future occurrences since it can learn from data. An ANN's input layer is the initial layer that takes in input data. It is followed by hidden layer which performs a variety of mathematical operations and identify the patterns of data input. The learning results are obtained in the output layer. The procedures of learning in ANN algorithm is presented in fig 1.

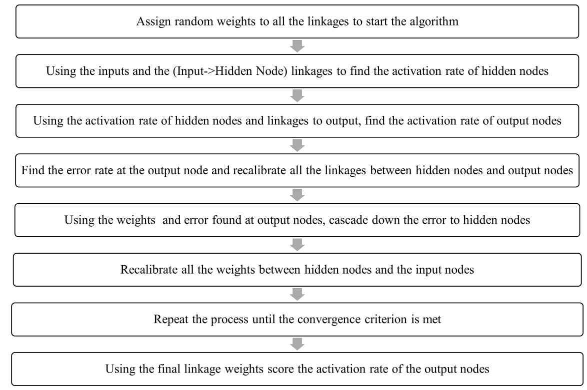

Fig. 1. ANN Algorithm

Datasets for system identification of solar irradiation modelling are generated from climatological data in NASA database. The data are utilized for training and testing the estimated model. Testing datasets were not used in the training stage of network in order to give an indication of the prediction performance at unknown locations. In this study, a machine learning algorithm, Artificial Neural Network, is implemented to estimate dynamic model of solar irradiation and approximate the monthly solar irradiation. Validation of the estimated models are evaluated based on error analysis in Mean Square Error (MSE) value. Furthermore, solar irradiance prediction is implemented based on the estimated model. Eventually, the historical and predicted data of solar irradiance are plotted and mapped to have a clear visualization of solar energy potential in Eastern Indonesia.

Initial dynamic identification procedures is data pretreatment by normalizing data in monthly average value. Secondly, dataset is split datasets into training and testing sections and designing the network of ANN. The predicted value will be occurred as the result of training and testing. The performance of model estimation and prediction accuracy are analysed based on the statistical error value Mean Squared Error (MSE). The measured and predicted values are compared.

The model prediction is implemented for Eastern Indonesia which scattered in several islands. There are 174 districts in 13 provinces included in this study. The selected districts In order to train the neural network, satellite data from the cities are divided as training (166 districts) and testing (8 districts) data. All districts are division of administrative regions in Indonesia after provinces that has higher population among the city within the region. in all the provinces in Eastern Indonesia. The retrieved satelite data based on latitude and longitude

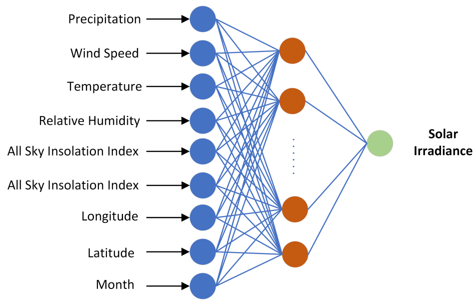

Fig. 2. ANN Layers

of all the evaluated districts. The 8 districts for testing are Masamba (Sulawesi Barat), Kaimana (Papua Barat), Biak (Papua), Donggala (Sulawesi Tengah), Tomohon (Sulawesi Utara), Sidrap (Sulawesi Selatan), Dompu (Nusa Tenggara Barat), Limboto (Gorontalo). These districts are representing most of the provinces in Eastern Indonesia. The remaining cities indicated in the map were used for training data in the neural network proposed.

IV. Result and Analysis

In this study, ANN models were developed in order to define the solar resource potential in Indonesia using back propagation algorithm. The ANN network is trained to find the relationship between input and output, then the relationship will be applied for testing section to get the output by providing the input values. Output variable is solar irradiance level of each district. The performance of model identification is evaluated by the error statistic Mean Squared Error (MSE).

The input and output variables are in monthly average value of each parameters. Data of 8 districts are for testing while the rest of dataset are utilized for training model estimation. A 20 years historical dataset from NASA database of daily climatological data are used for training the neural network. A stage of pre-treatment data is conducted to look up the data structure, to calculate monthly average value of input output variables and data normalization.

The results of ANN design in backpropagation algorithm with 2 hidden layers for a network of data from 176 cities for 20 years have shown significant accuracy in output prediction. Table I provides the Mean Squared Error value from the output of 8 testing cities.

TABLE I
Statistical Error of Testing Results

No	District	MSE	No	District	MSE
1	Mamasa	0.0269	5	Sidrap	0.0176
2	Kaimana	0.0175	6	Dompu	0.0334
3	Biak	0.0235	7	Tomohon	0.0551
4	Donggala	0.0287	8	Limboto	0.0415

The maps divided the areas into three categories : high irradiance (> 5.25 KWh/m2), medium irradiance ($4.9 - 5.25$ KWh/m2) and low irradiance (< 4.9 KWh/m2). It can be

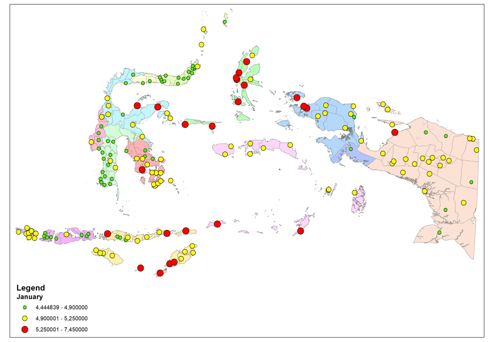

Fig. 3. January

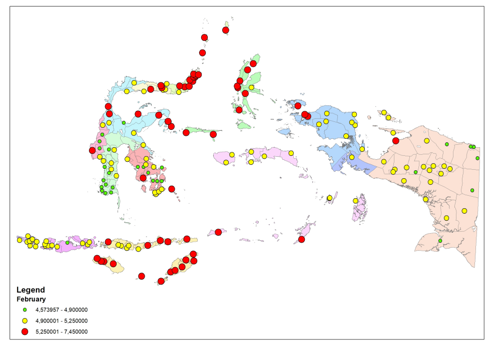

Fig. 4. February

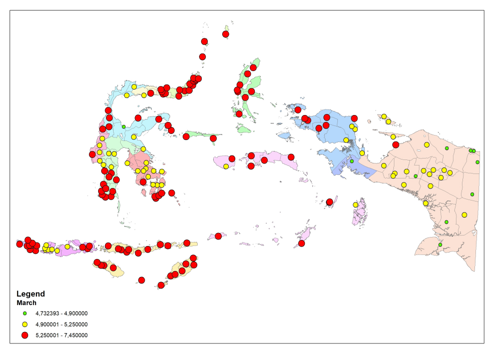

Fig. 5. March

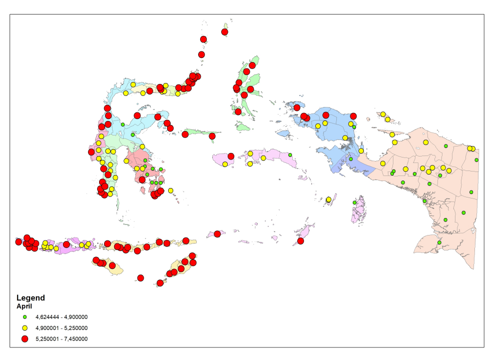

Fig. 6. April

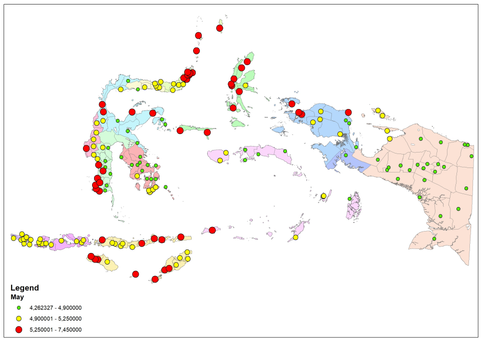

Fig. 7. May

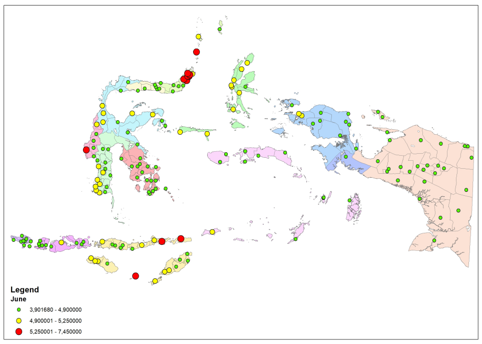

Fig. 8. June

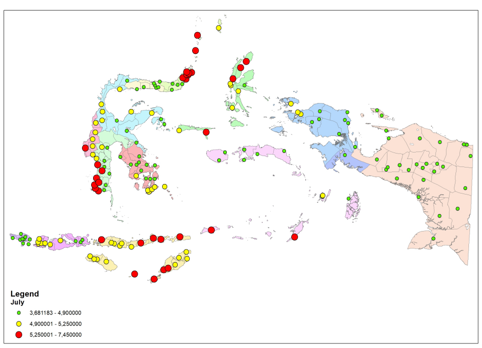

Fig. 9. July

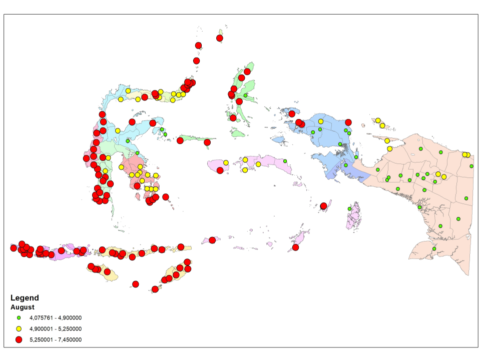

Fig. 10. August

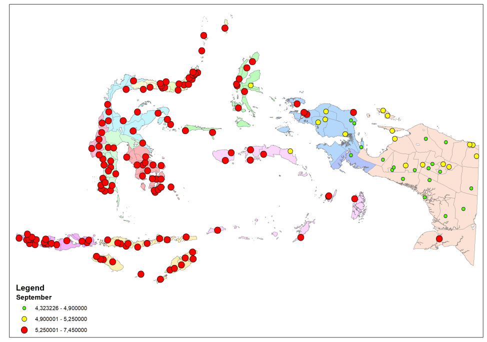

Fig. 11. September

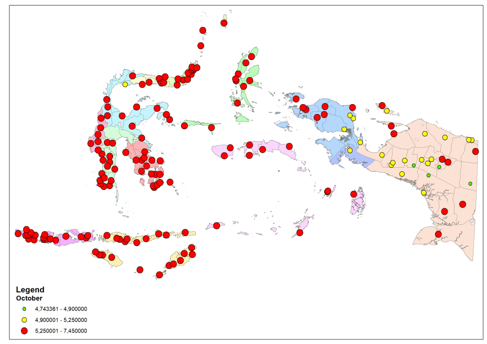

Fig. 12. October

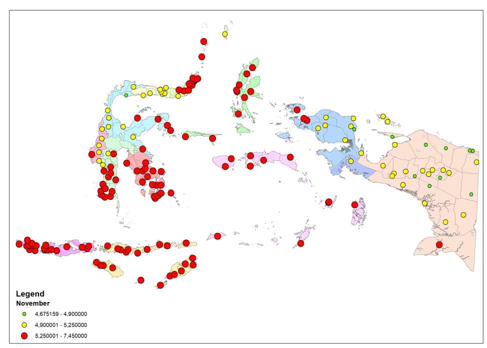

Fig. 13. November

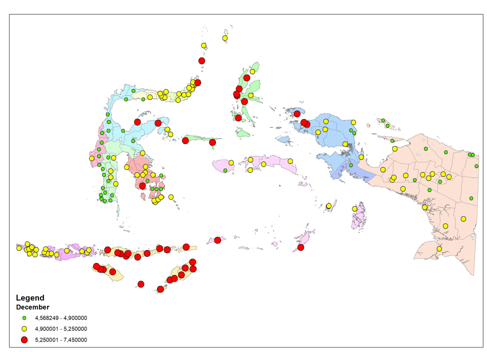

Fig. 14. December

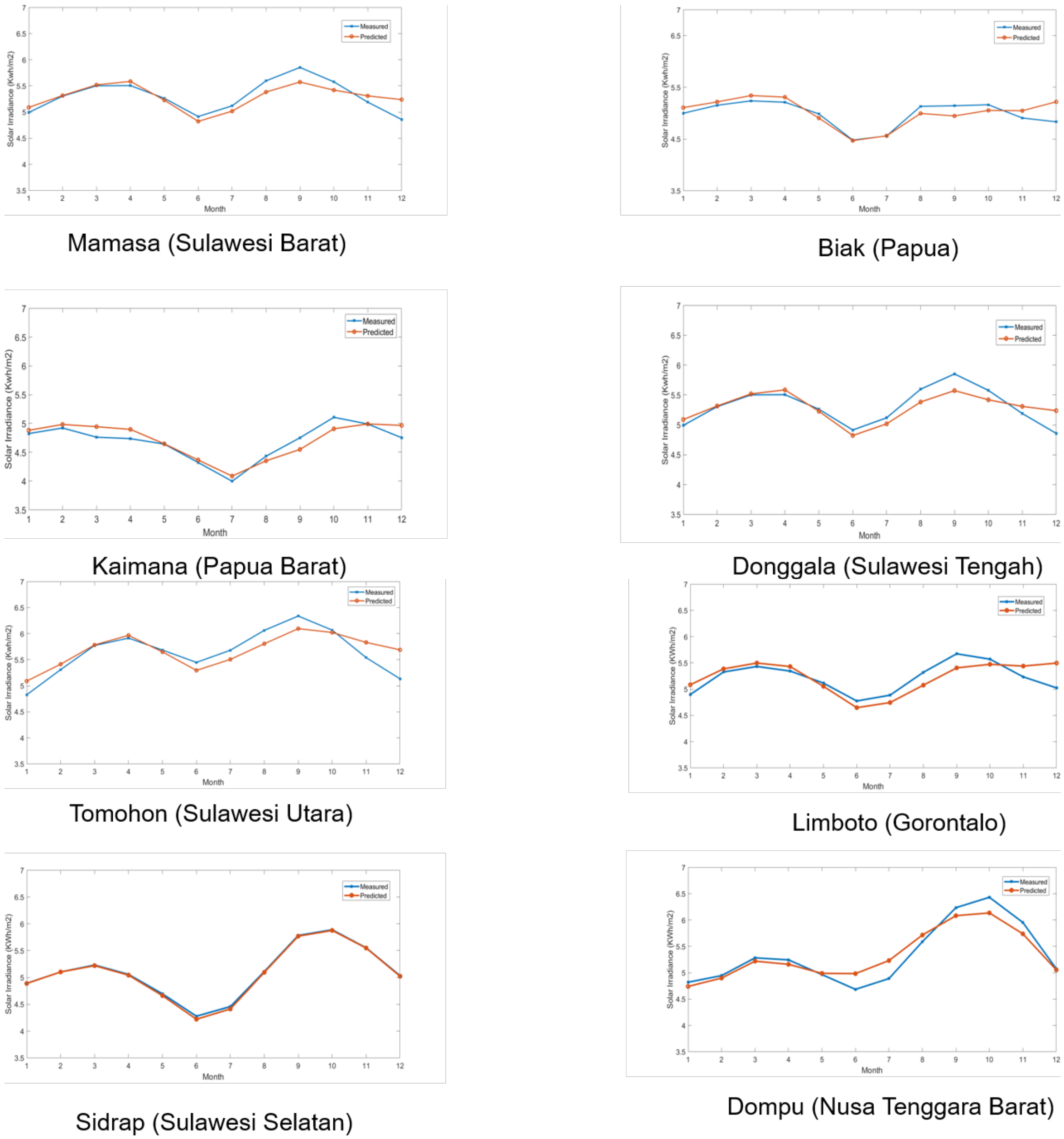

Fig. 15. Testing of 8 districts

seen from the map from Figure 13 to Figure 14 that Maluku and Nusa Tenggara islands are consistently provide high solar irradiance during all seasons. Districts in Sulawesi and Bali island have medium to high solar irradiance level during the period of dry season (April to October). Furthermore, on average value, districts in Papua island have the low to medium solar irradiance level.

Table II shows the composition of districts in Eastern Indonesia after the classification of solar irradiance level. The composition in Table 2 gives a valuable information about solar irradiance intensity in Eastern Area of Indonesia. If medium to high irradiance level could fulfil the requirement of solar power generation, it can be concluded that at least 2/3 of areas in Eastern Indonesia are suitable to be selected as solar sites.

TABLE II
DISTRICTS COMPOSITION BY SOLAR IRRADIANCE LEVEL

No	Month	Low	Medium	High
1	January	35%	50%	15%
2	April	20%	30%	50%
3	August	20%	20%	60%
4	October	2%	13%	85%

V. CONCLUSIONS

Characteristics of solar irradiance in eastern area of Indonesia have been identified in Neural Network framework. Big data of related variables are generated from NASA data for all districts in 13 provinces. Using a network with 2 (two) hidden layers provided very good accuracy. The estimation performance for the testing data have proven that the network could produce prediction value with high accuracy. In addition, the solar irradiation data of all districts are plotted in spatial mapping to describe the location and level of irradiance in eastern Indonesia. Nusa Tenggara, Maluku, Bali, and some areas of Sulawesi island are considered have the highest solar irradiance. Furthermore, the best intensity of solar irradiance is available on dry season (April to October).

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