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Defining Philippine Climate Zones Using Surface and High-Resolution Satellite Data

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Abstract

Philippine climate zones traditionally were classified from a rain-gauge network, using the Modified Coronas Classification (MCC). MCC uses average monthly rainfall totals to define four climate zones: Types I-IV. Types I and III have wet and dry seasons, whereas Types II and IV have wet seasons but no dry seasons.

The present study redefines Philippine climate zones by applying cluster analysis to the average monthly rainfall amounts from surface-based rain-gauge observations, and dense, high-resolution satellite data from the Tropical Rainfall Monitoring Mission (TRMM). To determine the optimal number of climate type clusters, both single-linkage hierarchical and K-means cluster analysis algorithms were used, together with known characteristics of Philippine rainfall distributions and attributes.

Employing single linkage hierarchical and K-means methods in tandem identified six different Philippine climate types, which is two climate types more than the currently accepted MCC climate classification. Due to the far greater number of TRMM observations compared with the rain gauge network, the study provides more clearly defined cluster characteristics including the spatial and temporal variability of climate divisions. This study uses known meteorological factors contributing to the identification of six distinct climate types. This paper is intended to assist agricultural stakeholders with planning and decision-making.

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Keywords: cluster analysis; Philippines; climate types; high-resolution rainfall satellite data; K-means; single-linkage

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1. Introduction

The Philippines, because it is situated in the tropics, experiences an annual temperature range that is not large enough to produce the four distinct seasons typical of the extra-tropics. The Philippine archipelago has high levels of solar radiation year round as it is located entirely between the Equator and the Tropic of Cancer. Consequently, the single variable best describing the Philippines climate is rainfall, which is greatly influenced by other factors affecting rainfall amounts and patterns, such as prevailing wind systems, tropical cyclone activity, topography and geographical locations, thunderstorms, location of the ITCZ, and surface temperature. The Philippines conventionally is classified into four climates zones, based on the Modified Coronas Classification (MCC) applied to a relatively small network of surface (rain gauge) observations. The primary purpose of this study is to apply cluster analysis to two sets of monthly rainfall data: surface-based rainfall observations, and the much denser Tropical Rainfall Measuring Mission (TRMM) high-resolution satellite rainfall data. TRMM satellite rainfall data are used to identify distinct spatiotemporal rainfall patterns that redefine the MCC-based climate types of the Philippines. The clusters obtained from the rain gauge data are used to assess whether the TRMM rainfall data accurately captures the Philippine general rainfall patterns.

There are techniques available for classification and several studies used cluster analysis to classify rainfall data. Both [1] and [2] employed K-means algorithm, whereas [3] and [4] used agglomerative hierarchical clustering. In this study, the single linkage hierarchical and K-means non-hierarchical cluster methods are used to define the climate zones of the Philippines as a function of rainfall characteristics.

A unique feature of the study is the application of two cluster algorithms on surface-based and satellite rainfall data, and the integration of the known attributes of Philippine rainfall as influenced by the interaction of several factors to define the most appropriate clusters.

2. Data and Methodology

2.1 Rain Gauge Observation Data

Monthly surface-based data, from 52 rain gauge stations, are obtained from the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA). The PAGASA monthly rainfall for each month, January to December, from 1961-2015 was averaged and used in the clustering process.

2.2 TRMM Satellite Rainfall Data

The Tropical Rainfall Measuring Mission (TRMM) is a joint U.S.-Japan satellite mission that monitors tropical and subtropical precipitation and estimates its associated latent heating. In this study, the 3B43 product is employed. The dataset is from the Giovanni online data system of the National Aeronautics and Space Administration (NASA) Goddard Earth Sciences - Data and Information Services Center (GES-DISC). The product provides the best precipitation estimate from all global data sources, namely high-quality microwave data, infrared data, and analyses of rain gauges. Spatial resolution is 0.25° by 0.25° and extends from 50°S to 50°N. The temporal resolution is monthly, provided as hourly rain rate (mm/hr) during 1998-2016. Monthly averages are hourly rain rates multiplied by the total hours in each month.

2.3 Methods

Cluster analysis is a tool for classification such that objects in the same cluster have similar properties, and those with dissimilar features belong to another cluster. The single linkage technique falls into a category called agglomerative hierarchical clustering and is a simple, widely used method. The procedure is characterized by the tree-like structure established in the course of the analysis [5]. Initially, this type of procedure starts with each object representing an individual cluster. These clusters are then sequentially merged according to their similarity. First, the two similar clusters (i.e., those with the smallest distance between them) are merged to form a new cluster at the bottom of the hierarchy. Next, another pair of clusters is merged and linked to a higher level of the hierarchy, and so on. This allows a hierarchy of clusters to be established from the bottom up.

Another popular cluster technique is K-means, a simple method that follows a partitioning procedure. It is an entirely different concept from the single linkage method discussed earlier. This algorithm is not based on distance measures from one observation to another observation, but uses the within-cluster variation to form