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Research Paper

GIS-based suitability analysis of agrometeorological stations in Pampanga, Philippines

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ABSTRACT

This study aimed to identify suitable sites for agrometeorological (agromet) stations in Pampanga, Philippines using Geographic Information Systems (GIS) and the Analytic Hierarchy Process (AHP). The study evaluated multiple criteria which are slope, land use/land cover (LULC), accessibility, proximity to water bodies, existing weather stations, and host institutions, all are based on World Meteorological Organization (WMO) guidelines. For factor weighting, the experts performed AHP and GIS tools facilitated spatial analysis, including rasterization, reclassification, and buffer zoning. Results indicate that Floridablanca, Minalin, Candaba, and Arayat are highly suitable for agromet station establishment, while areas like Angeles City and Mabalacat exhibit localized constraints. This study highlights the importance of a comprehensive and strategic approach to weather station placement, highlighting Pampanga's potential for enhanced weather monitoring and agricultural support. The findings showed a framework for sustainable agromet infrastructure development, addressing both academic and community needs.

Keyword: Suitable sites, Agromet station, Weather station, GIS, AHP, Spatial analysis, WMO guidelines

The agricultural sector is at the forefront of climate change and its consequences. It is heavily reliant on climatic and weather characteristics, which define the total agricultural activity. The current temperature and weather conditions are also inextricably linked to natural resource use, such as the amount and timing of irrigation. Weather-related variables that drive plant growth include photosynthetically active radiation, radiation use efficiency, rainfall, and even humidity, which can create favorable conditions for pests and diseases, as well as management practices such as cropping calendar, optimal harvest date, and fertilizer application (Felipe *et al.,* 2024). Furthermore, meteorological, environmental, and geophysical observations serve multiple purposes, including real-time weather analysis, forecasting, and severe weather warnings. They also support various weather-dependent activities such as disaster preparedness, flight scheduling, hydrological construction, agricultural meteorology, and research in meteorology and climatology (Yildirim *et al.*, 2016). A well-optimized distribution of observation stations enhances observational efficiency and improves the accuracy of analytical results (Takahashi *et al.,* 2011). This objective can be achieved through the use of weather stations and the latest technological advancements (Amorim *et al.,* 2011).

The Philippines is highly vulnerable to various natural disasters, including earthquakes, flash floods, landslides, and forest fires, due to its geographical location, topography, vegetation cover, and precipitation patterns. More than twenty flood events occur annually, primarily triggered by typhoons, making flash floods the second most devastating natural disaster after earthquakes (Rinoza, 2021). To address this, the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) currently operates 122 automated weather stations nationwide (PAGASA, 2022) but in the province of Pampanga, there is only one existing weather station. Due to the insufficient number of weather stations for collecting critical data needed for disaster prevention, PAGASA aims to establish an adequate network of weather stations in strategic locations across the country.

Identifying the most suitable locations is essential for the success and long-term sustainability of the weather station (WS) network (WMO, 2010). Selecting a WS site involves various spatial analyses, including proximity to different land use zones, slopes, roads, and population centers, as well as nearness to natural hazard-prone areas like landslide zones. Therefore, careful planning is required for the WS monitoring network. Attempt has been made

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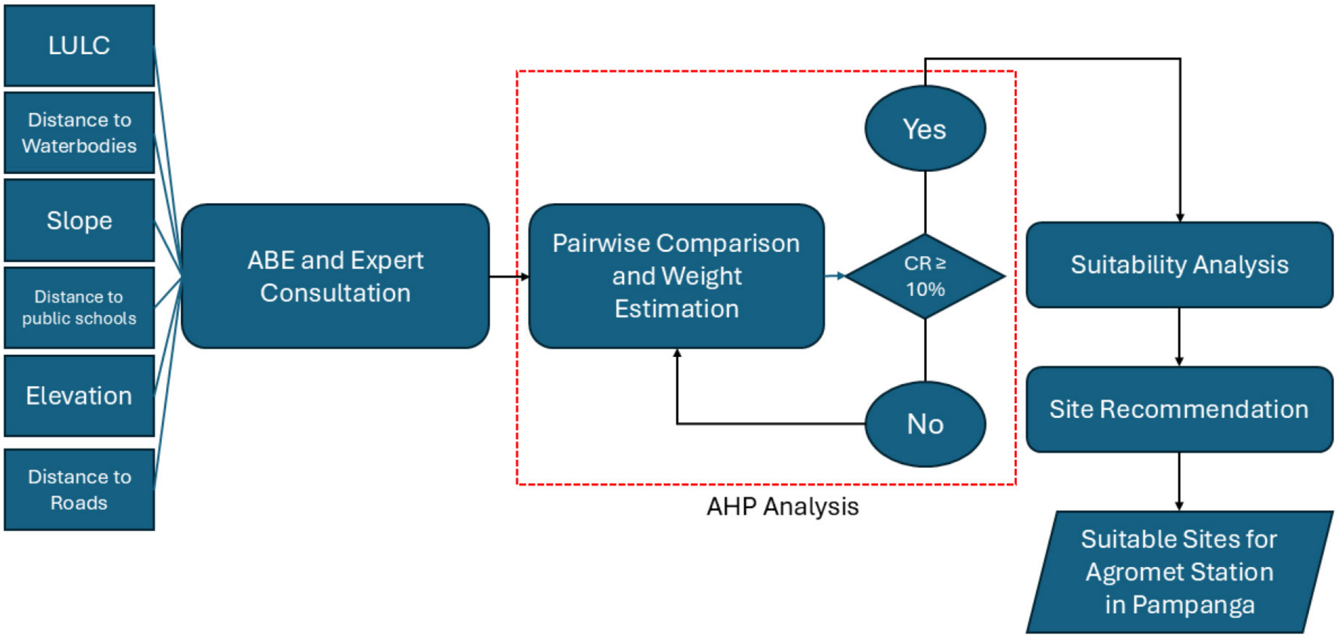

Fig 1: Framework of the study

Table 1: Suitability criteria for weather stations (Felipe *et al*., 2024; Alejo, 2018).

Factor	Suitability criteria	Data needed
Slope	0-5%	DEM
Land use	Cultivated, production areas, grasslands	Land use/Land Cover
Accessibility	Maximum 700 m from the road buffer	Road networks
Location of existing stations (synoptic and agro-meteorological)	Areas outside its 9 km radius of influence	Existing Weather Stations
Water bodies (lakes and coastline)	Outside 1 km buffer	LULC & coastline
Availability of host institution	Inside 10 km radius	Locations of research-based government institutions

to identify the most suitable sites for agrometeorological stations in Visayas region of Philippines using WMO guidelines (Alejo, 2018). Geographic Information Systems (GIS) serve as a vital decision-support tool for selecting appropriate agrometeorological station sites, as they can process and analyze diverse spatial data (Sener *et al.*, 2012). GIS technology is particularly valuable for integrating multiple map and satellite data sources in simulations of complex natural systems (Rana, 2012). This study aims to utilize GIS technology to identify suitable locations for an agrometeorological station in Pampanga province of Philippines.

MATERIALS AND METHODS

Site description

Pampanga is a province in Central Luzon (Region III), Philippines, located along the northern shore of Manila Bay. It is bordered by Tarlac to the north, Nueva Ecija to the northeast, Bulacan to the east, Manila Bay to the south-central area, Bataan to the southwest, and Zambales to the west. Its capital, San Fernando City, also serves as the regional center of Central Luzon, while Angeles City is the largest Local Government Unit (LGU). Covering a total area of 2,002 km², Pampanga is positioned at 15°04′N latitude and 120°40′E longitude in the south-central part of the region.

Framework of the study

Fig. 1 presents the framework of the study adopted from Felipe *et al.,* (2024) which includes the processes observed. The criteria were based on WMO guidelines and existing literature. The researchers utilized GIS for the analysis including rasterization (conversion of vector shapefiles to raster shapefiles), reclassification (reclassification of criteria to their corresponding scores), and raster calculation (using the factor weights to analyze the suitability).

Data and criteria

In ensuring cost-effective suitability analysis of the Agromet stations, the criteria for developing an augmented station network in the province of Pampanga are based on the World Meteorological Organization’s recommendations for planning a meteorological station network. The following factors and criteria are used to cite additional weather stations in the region: a) slope; b) land use; c) accessibility; d) Location of existing stations; e)

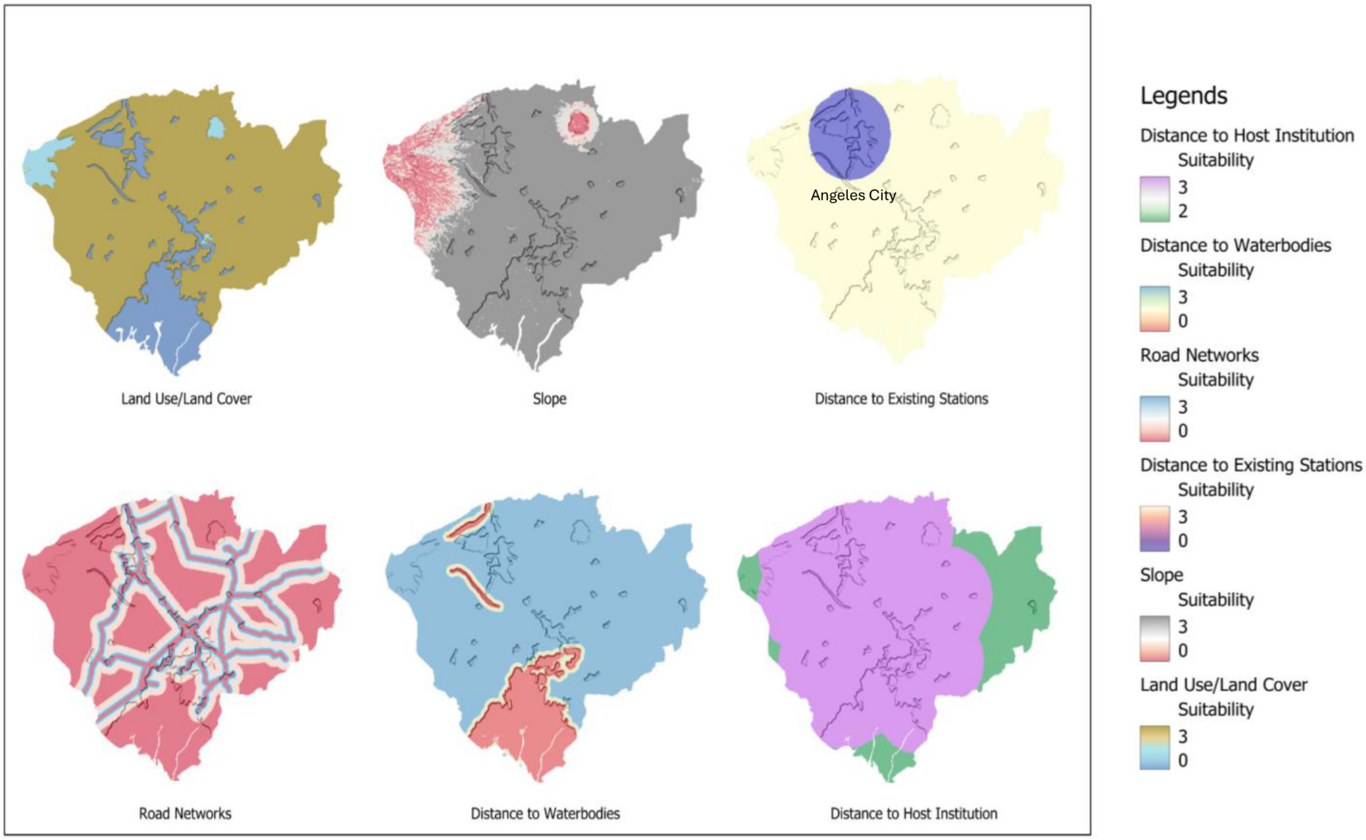

Fig. 2: Suitability analysis per criteria Fig. 3: Suitability map of agromet stations in Pampanga

Table 2: Suitability criteria scoring (Felipe *et al*., 2024)

Criteria	Highly suitable (3)	Moderately suitable (2)	Marginally suitable (1)	Not suitable (0)
Slope	≤5%	5-15%	15-25%	≥25%
LULC	40	20, 30, 60	>100	0, 50, 80, 90
Distance to water bodies	≥1km	0.5-1km	0.25-0.5km	≤ 0.025 km
Distance to roads	0-0.7 km	0.7-1.2 km	1.2-2.2 km	≤0.3/≥
Distance to SUC	≤10 km	10-50 km	50-100 km	≥100 km
Distance to existing weather stations	≥9 km	5-9 km	3-5 km	3≥km

*For LULC: 0 = No Data; 20 = Shrubs; 30 Herbaceaous Vegetation; 40 = Cropland; 50 = Built-up areas; 60-Barren/sparse vegetation; 80= Water bodies; 90 = Wetland; >100 = all forest*s

water bodies; f) Availability of host Institution; g) elevation. Table 1 summarizes the details of these considerations and criteria. In summary, the criteria and data required for developing an Agrometeorological station is presented in Table 1.

The data and information necessary for the conduct of the study were sourced from various agencies and websites. The landuse/landcover (LULC), and inland water bodies and coasts were obtained from the ArcGIS living atlas of the world website. Meanwhile, the slope map and road network were extracted from the Geportal PH website. Based on information made available by the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA), the location and status of existing weather stations were determined. In terms of available host institutions, the researchers manually plotted the points through GIS with google map guides.

The majority of PAGASA Agromet stations nationwide often work in conjunction with State Universities and Colleges (SUCs). The final eligible places are to be chosen based on the general requirement that locations farther than 10 km from the collaboration institutions' centers and inside 9 km radius of influence of existing weather stations were excluded (Alejo, 2018). Therefore, the minimum influence radius of 100 meters for agrometeorological purposes and maximum of 10 km is considered for the analysis; this falls under the category of microscale and mesoscale, respectively. Additionally, stations are 10 km away from bodies of water and coastlines (WMO, 2010). It is estimated that the road buffer distance on the accessible distance for flat terrain is 700 m (Felipe *et al*., 2024). An additional station's distance from partnering institutions should be set to a 10 km radius with justification for ease of management and maintenance.

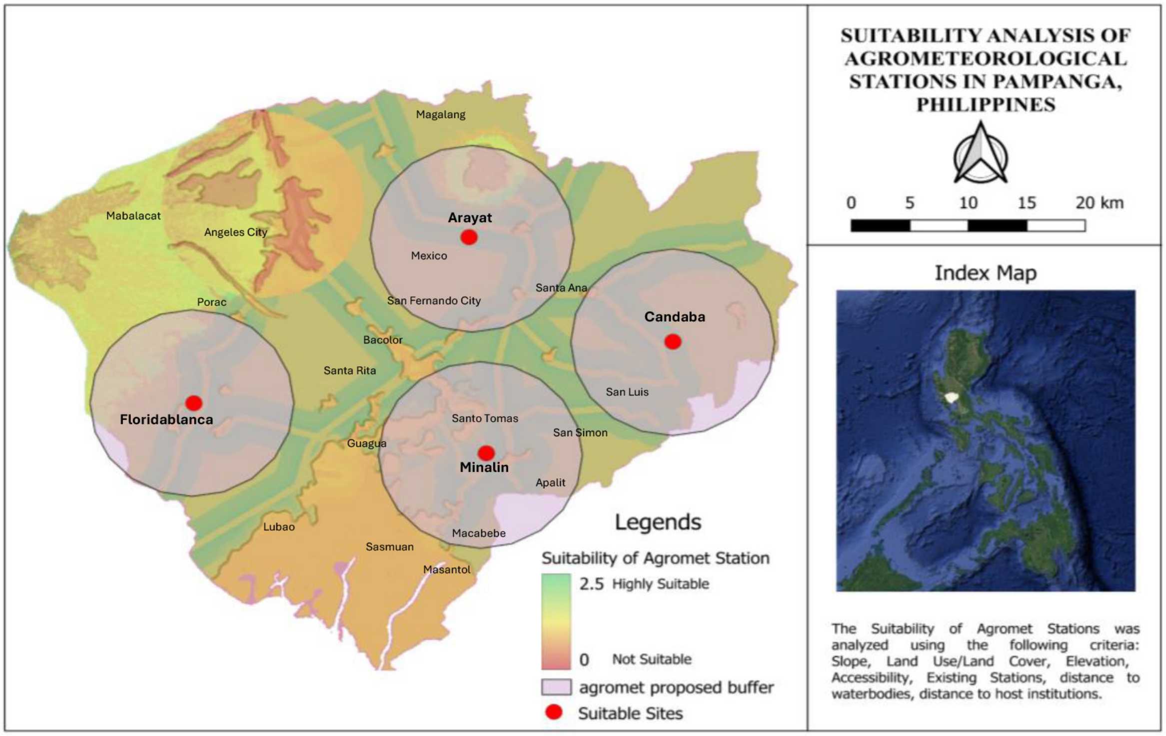

Fig. 3: Suitability map of agromet stations in Pampanga

Table 3: AHP of suitability criteria for agrometeorological stations

Factors	Weight
Slope (%)	16.4%
Land use/land cover	16.6%
Accessibility (km)	13.8%
Existing stations (km)	15.3%
Waterbodies (km)	12.4%
Institutions (km)	12.0%

Generation of thematic maps

The criteria in this study were subjected to reclassification analysis to group the respective values according to the criteria scoring adopted from the AHP study of Felipe *et al*. (2024), 3 being the most preferred values and 0 being the least and the scoring is presented with their corresponding interpretation as shown in Table 2.

Suitability mapping

The geographic information system (GIS), particularly QGIS, was used to perform the suitability mapping in this study. The criteria slope, land use and land cover, road accessibility, existing stations, waterbodies, and availability of host institutions were weighed using their corresponding percentage bearing as factors for the suitability. To determine each factor's weight, the researchers utilized the analytic hierarchy process (AHP) tool. There were 5 experts who weighed the factors, 1 is a researcher in weather station, 3 are personnels in Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA), and 1 is MS agrometeorology graduate working in an academic institution.

The researchers utilized the QGIS software to carry out suitability analysis, which is a major part of geospatial decision-making. This tool facilitated integration and analysis of spatial data to identify areas that matched the criteria. Some of the advanced features used in the study include the buffer tool, which helped to create zones around geographic features to assess proximity-based suitability, such as areas near roads or water sources. The extraction tool, used in conjunction with the attribute table, was helpful in selecting and analyzing specific data points relevant to the study. Furthermore, changes in attributes facilitated manipulation of data layers in terms of accuracy and adherence to the study's goals. All these tools, in combination, provided an all-inclusive approach towards analyzing spatial data and meeting the goals of the study.

RESULTS AND DISCUSSION

Table 3 presents the analytical hierarchy process (AHP) of suitability criteria for agrometeorological stations in this study. As shown, the factor with highest percentage is the land use/land cover with 16.6%, highlighting the importance of land use in the suitability of agromet stations. The slope comes in second with 16.4%, followed by existing stations with 15.3%, accessibility to roads and elevation has factor weight of 13.8% and 13.5% respectively. Distance to water bodies is 12.4% and the existing institutions have 12.0%. These percentages make up the whole suitability criteria weight which were crucial in selecting sites for agromet stations in the province of Pampanga.

Suitability analysis per criteria

Fig. 2 presents the separate suitability analysis per criteria in the study. The criteria is composed of slope, land use/land cover, elevation, accessibility to roads, existing stations, waterbodies, and distance to host institutions. These were scored ranging from 3 to 0 (3 is highly suitable, 0 is not suitable), applied for all criteria. For LULC, a large portion of the province is highly suitable for agromet station, mostly located in the North, East, and some portions in the west of Pampanga. For Slope, almost 85% of the total area of Pampanga is highly suitable. The portion where the slope is not suitable are the mountainous areas in the province. For the distance to the existing weather station, since there is only one station in Pampanga, the areas outside the 9 km radius are highly suitable. In terms of accessibility to the roads, areas located 700 m in the road networks were considered as highly suitable, showing many possible sites for agromet stations which are almost uniformly distributed and covering almost all cities and municipalities of the province. For distance to water bodies, the areas located 1 km far from water bodies were considered as highly suitable, showing many suitable locations. Lastly, for distance to host institutions, many sites within a 10 km radius of public institutions were highly suitable, indicating that almost 75% are highly suitable for this criterion.

Suitability analysis of combined criteria

Fig. 3 presents the suitability map of agromet stations of combined criteria for the province of Pampanga. There were numerous suitable sites that were recommended which are Floridablanca, Minalin, Candaba, and Arayat (Fig. 3) which are considered highly suitable for agromet stations. Moreover, the not suitable sites are Angeles City, Mabalacat, Sasmuan, Masantol, and Guagua. Other cities and municipalities other than the mentioned above are also suitable but are still inside the 9 km radius of influence of Floridablanca, Minalin, Candaba, and Arayat. It indicates that the majority of the province meets the conditions necessary for establishing agromet stations. It also suggests a strong potential for expanding agrometeorological infrastructure across Pampanga, facilitating enhanced weather monitoring and agricultural planning, while noting specific areas where such installations may be less feasible.

CONCLUSION

Aiming to identify the suitable sites for agromet station in the province of Pampanga, the researchers utilized GIS and AHP tool for efficient and reliable suitability analysis. It is concluded that Floridablanca, Minalin, Candaba and Arayat are the municipalities of Pampanga which are suitable sites for the establishment of agromet stations. Overall, the findings emphasize Pampanga's significant potential for expanding agromet infrastructure, which could enhance weather monitoring and support agricultural planning and decision-making. Lastly, AHP tool serves as a reliable tool for weighing the criteria objectively. Bounded by existing literature, this tool has been proven effective for suitability analysis where experts were able to classify the criteria of the study.

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Conflict of Interests: The authors declare that there is no conflict of interest related to this article.

Data Availability: This study uses open platforms to obtain satellite data, and field data is only provided upon reasonable request.

Authors contribution: **D.M.K.Dawis:** Conceptualization, Methodology, Data collection, Data analysis, Writing-editing, Writing-review; **D.V.Dizon:** Methodology, Review, Map generating; **E.R.Castino:** Methodology, Data Analysis, Review; **A.C.Cuizon:** Methodology, Data Analysis, Review; **M.N.Teñido:** Writing-revision, Methodology.

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