GIS-Based Analysis of Spatial Distribution of Agrometeorological Stations Network in Northern and Central Luzon, Philippines

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Abstract: *This study determines the optimal spatial distribution of an agrometeorological station network in Northern and Central Luzon, Philippines using GIS technology and WMO guidelines. Factors such as slope, land use/land cover (LULC), accessibility, proximity to water bodies, and availability of host institutions were the basis of the analysis. Results showed that only 12.52% of the region is slope-suitable, and 60.91% meets land use requirements. After excluding the unsuitable areas, 26 proposed sites were identified and narrowed down to 5 priority sites in Regions I, II, III, and CAR. The current density of meteorological stations per climate type is significantly below WMO-recommended thresholds (200–300 km²/station) which emphasize the need for network expansion. The final output includes an augmented meteorological network map and a list of viable host institutions for station siting. This study further identified that accessibility is a limiting factor, highlighting the need for infrastructure development in some areas.*

Keywords: Agrometeorological Stations, Augmentation, GIS, Spatial Distribution, WMO

1. INTRODUCTION

Meteorological stations, in general, are used in monitoring and analyzing trends in rainfall patterns, drought conditions, and climate variations in specific regions. For example, in Khyber Pakhtunkhwa, Pakistan, meteorological stations have been crucial in detecting decreasing trends in annual rainfall in certain areas, which affects water availability for agriculture and hydropower generation. Additionally, these stations help in identifying extreme wetting and drying conditions, as well as spatial and temporal variations in rainfall patterns over the years [1,2]. There are various types of meteorological stations, including agrometeorological stations. This station has a crucial role in supporting farmers and boosting agricultural productivity. It allows for accurate weather predictions and timely alerts by continuously tracking weather patterns and providing real-time data [3,4]. Farmers can leverage this information to make informed choices regarding planting dates, fertilizer use, and other farming practices, leading to better harvests [5]. Moreover, this data helps mitigate the negative effects of extreme weather events on crops, safeguarding farmers' livelihoods and ensuring food security [6].

The Northern and Central Luzon, comprising 4 regions (CAR, Regions I, II, and III) is characterized by a tropical climate with a tendency for high humidity, heavy rainfall, and warm temperatures (PAGASA). This region is frequently affected by typhoons leading to significant rainfall which can cause flooding and landslides. Its diverse topography, with mountain ranges and valleys, contributes to the complex weather patterns observed in the area, requiring a comprehensive meteorological network to monitor and forecast weather effectively for safety, agriculture, and disaster preparedness purposes. There is a need to determine the optimal spatial distribution of the meteorological stations network to accurately monitor weather conditions and provide timely forecasts for the region [7]. To do this, it is necessary to follow guidelines set by the World Meteorological Organization (WMO) for planning a meteorological station network to achieve cost-effective and sustainable operation and maintenance of the stations [8].

Among the known methods for designing an optimal meteorological station network is utilizing the Geographic Information System tool [9]. GIS technology allows for the integration and analysis of various spatial data sources [10,11], including maps and satellite information, which are essential for modeling complex natural systems [12]. When determining suitable locations for meteorological stations, GIS can factor in multiple criteria [13]. GIS can combine various layers of information to assess the optimal positioning of weather stations [14].

In addition, the capacity to process and visualize spatial data makes GIS a fundamental decision-making tool in augmenting meteorological networks for better service to agriculture, industry, and wider society, especially in the context of climate change and meteorological hazards [15]. Thus, this paper determines the optimal spatial distribution of the meteorological stations' network in Northern and Central Luzon based on the guidelines set by the World Meteorological Organization (WMO). Specifically, it aims to generate a geographical location map of all existing synoptic and agrometeorological stations, determine the sites suitable for additional agrometeorological stations using the guidelines set by WMO, and identify the possible collaborating agencies in establishing the proposed stations in Northern and Central Luzon. The results of this study can be a basis for selecting sites suitable for establishing additional meteorological stations in Northern and Central Luzon.

2. MATERIALS AND METHODS

2.1 Study Area

The Northern and Central Luzon comprise Regions 1, 2, 3, and CAR, covering 22 provinces. This region is located between 119°28'E - 122°23'E and 14°00'N -

22˚55’N geographical coordinates (Fig. 1). Based on the list provided in the PAGASA website, the total number of existing meteorological stations is 19 (4 agrometeorological stations and 15 synoptic stations), situated within a total area of 86413.28 km^2. While other sources of climate information, such as Automatic Weather Station (AWS), are present in the area, these stations were not included in the analysis. This is to give more emphasis to the establishment of agrometeorological stations that are designed for more comprehensive data for certain applications as compared to AWS. The regions experience distinct wet and dry seasons, with the wet season typically running from May to October due to the southwest monsoon, also known as Habagat, bringing in moist air and precipitation. The dry season occurs from November to April, influenced by the northeast monsoon, or Amihan, which generally brings cooler and drier air.

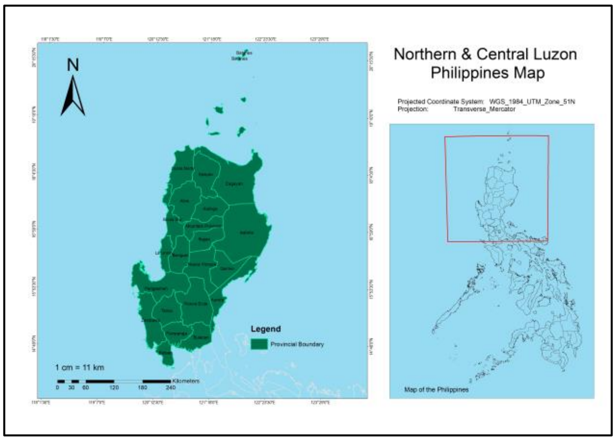

Fig. 1. Location map of the study area.

2.2 Methods

2.2.1 Identification of the Geographical Locations of existing PAGASA’s Synoptic and Agrometeorological Stations in the Area

The list of all existing synoptic and agrometeorological stations in Northern Luzon was obtained from the Philippines Atmospheric Geophysical and Astronomical Service Administration (PAGASA) website [16]. The radius of influence of these existing stations was not included in the suitability analysis. Their geographical locations were obtained using Google Earth by entering the latitude and longitude provided in the PAGASA website. Other weather stations not listed on the PAGASA website, i.e., Automatic Weather Stations (PAGASA and Bureau of Soils and Water Management-BSWM), were not included in the analysis.

2.2.2 Criteria

Based on the WMO guidelines in siting additional stations, the agrometeorological station should have the following conditions:

- Topography – fairly level (avoided that are on or near steeply sloping ground, or near lakes, swamps, or areas with frequent sprinkling or flooding)
- Well-represented crop production
- Accessible
- Within an agricultural-based institution
- With at least 60m2 area
- No obstruction
- Away from bodies of water

These were summarized by Alejo, L.A. [13] as depicted in Table 1 which was employed in this study.

Table 1. Suitability criteria for weather stations [13].

Factor	Suitability Criteria	Data Needed	Data Source
Slope	0-3 %	Digital Elevation Model (DEM)	Isabela State University
Land Use	Cultivated, production areas, grasslands	Landuse/ Landcover (LULC)	Geoportal Philippines
Accessibility	At least 500 meters from the road buffer	Road Network	DIVA GIS Portal
Location of existing stations (Synoptic and agrometeorological)	Areas outside its 9 kilometers radius of influence (based on the WMO set density, 100-300km2)	Existing Weather Stations	PAGASA website
Water bodies (Rivers, Lakes & Coastline)	Outside 10 km buffer (Coastline) Waterbodies (1:50,000), LULC & Coastline	Coastline and Waterbodies	NAMRIA, Geoportal Philippines

2.2.3 GIS Application

The methodological framework for using GIS is depicted in Fig. 2. The datasets and corresponding extracted layer were depicted, as well as the method at identifying the suitable site. Various geoprocessing tools were utilized such as buffer, clip, intersection and difference. The significant procedure is intersecting all the layers after reclassifying the datasets based on the WMO guidelines. GIS is a fundamental tool in optimizing the meteohydrological network as mentioned by Turab et al. [17].

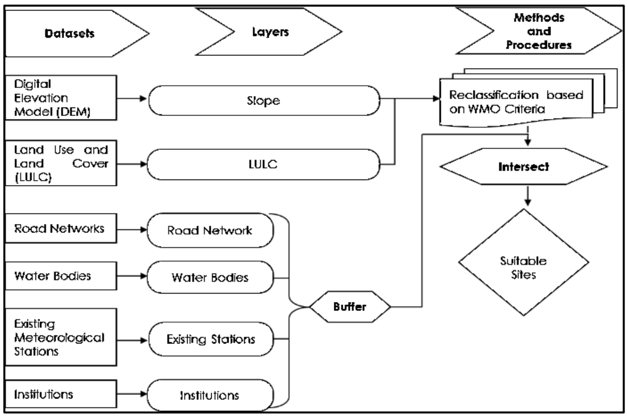

Fig. 2. Methodological GIS Framework.

2.2.4 Density of Station per Climate Type

The density of meteorological stations in each climate type in the study area was determined by dividing the number of stations by the area covered by the climate type.

3. RESULTS AND DISCUSSION

3.1 Location of existing synoptic and agrometeorological stations

A total of 19 meteorological stations were identified in Northern and Central Luzon and 4 of which are agrometeorological stations, and 15 are synoptic stations (Fig. 3). The 4 agromet stations are situated within the SUCs compound namely, Isabela State University (Region II), Nueva Vizcaya State University (Region II), Benguet State University (CAR), and Mariano Marcos State University (Region I). The radius of influence (9 km) of the existing meteorological stations, i.e. synoptic and agrometeorological stations, is not included in the analysis of suitable locations.

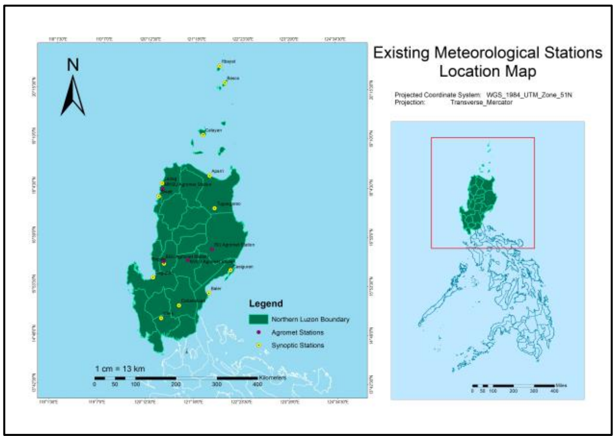

Fig. 3. Location map of the existing meteorological stations in Northern and Central Luzon Philippines.

3.2 Suitable Locations for the Proposed Meteorological Stations

Based on the guidelines of WMO for Planning a Meteorological Network (WMO, 2010), given that Northern and Central Luzon requires the densest network of stations due to its very variable weather, the optimal number of stations that should be available in the study area is 346 stations. This is estimated assuming the whole area is flat and the area of influence of each station is 100-300km^2.

3.2.1 Slope Suitability

Slope suitability is a critical variable that can significantly affect the accuracy and reliability of meteorological data collected. The suitable slope of the area for the sitting of the agrometeorological station is 0 to 3% as stipulated in the WMO guidelines.

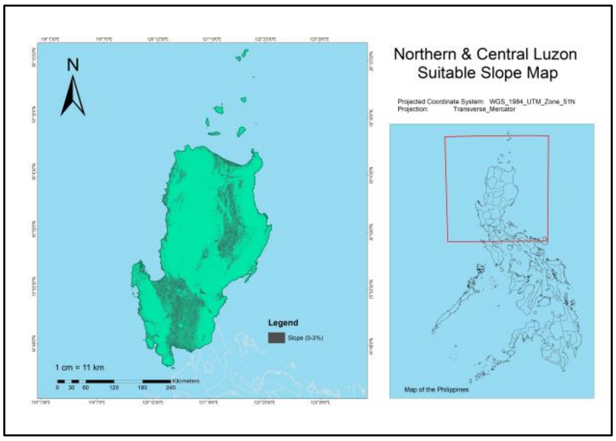

Fig. 4. Suitable Slope (0-3%) Map

This is generated using a 10m x 10m DEM obtained from the research department of Isabela State University. The slope suitability map (Fig. 4) shows that 12.52% of the total area of Northern Luzon is suitable for an agrometeorological station, which is equivalent to 10,819.49 km^2 compared to 86413.28 km^2 total area.

3.2.2 LULC Suitability

One of the criteria for agrometeorological siting, as set by the WMO, is to station in areas free of obstruction and disturbances (WMO, 2012). In addition, the agrometeorological station aims to provide climate data for agriculture production. Consequently, the LULC type is essential in sitting for additional agrometeorological stations. The latest LULC available on the NAMRIA's website (Geoportal Philippines) is in the year 2020 having 24 different classes. Following the WMO guidelines, all other LULC types aside from types associated with agriculture areas having minimum obstruction will be removed from the suitability analysis. From 24 classes, the LULC was trimmed down to 4 classes having a total area of 52,632.34km^2 (Table 2) and this accounted for 60.91% of the total study area.

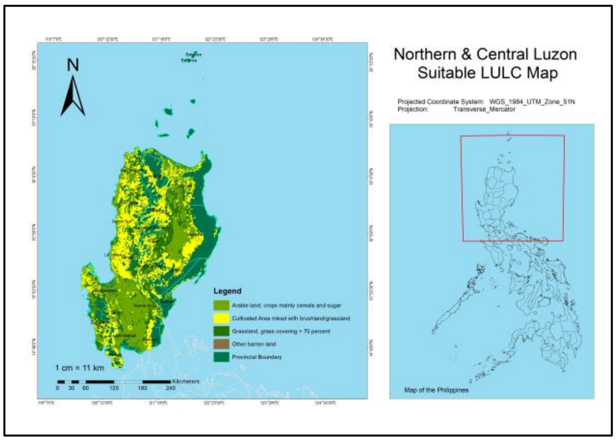

Fig. 5. Map of the Suitable LULC Types.

Table 2. Area of the Suitable LULC Type.

Description	Area (km^2)
Arable land, crops mainly cereals and sugar	19009.77
Cultivated Area mixed with brushland/grassland	23323.31
Grassland, grass covering >70%	10219.34
Other barren land	79.92
Total	52,632.34

3.2.3 Accessibility

Another important criterion when planning to augment existing agrometeorological networks is accessibility. According to WMO guidelines, it should be located in areas where it attracts local observers. Since sitting an agrometeorological station is about 0.5 km from an existing road, the suitable area is dramatically reduced to 9552.088 km^2. The density of road network is presented in Fig. 6. This can be considered as one of the limitations in choosing the appropriate area for an agrometeorological station. Additional costs in constructing roads will be incurred in areas with no access to roads.

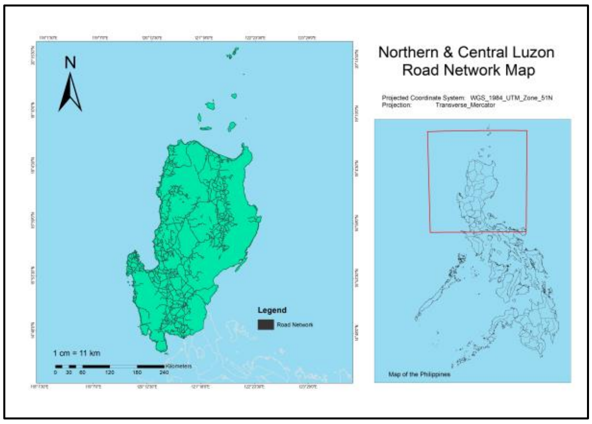

Fig. 6. Road Network in the Northern and Central Luzon.

3.2.4 Coast Lines and Inland Water Bodies

In this study, the criteria for the selection of suitable sites for the agrometeorological stations over Northern and Central Luzon is a 10 km distance from the coastlines. This is to avoid the possible effects of strong winds from the east coast as mentioned by Alejo (2018). The study area is bounded by the ocean in the north, east, and west areas. Having a 10-km distance from the coastline leads to no feasible site for agrometeorological stations, particularly in the Type 2 climate. It can also be noted that Northern and Central Luzon are dominated by river networks. Hence, areas within 10-km from the left and right banks were considered unsuitable for agrometeorological stations. High elevated areas were considered in choosing suitable sites in floodplain areas like Lallo, Cagayan to avoid the destruction that may be caused by floods.

3.2.5 Availability of Host Institution

There are 89 State Universities and Colleges (SUCs) and 4 Department of Agriculture Regional Field Offices (DA-RFOs) situated in the study area.

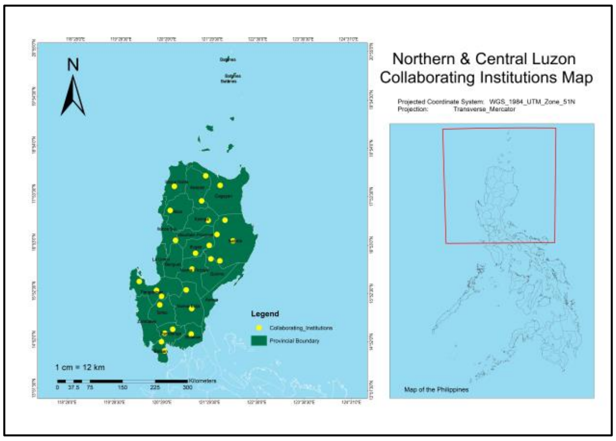

Fig. 7. Map of the Selected Collaborating Agency.

In consideration of the other factors in selecting a suitable site for a weather station, the number of collaborating agencies is reduced from 93 to 26 SUCs (Fig. 7).

3.2.6 Density of Meteorological Network per Climate Type

Based on the Modified Corona Classification, the study area has 3 climate types. The density of the network per climate was determined by calculating the area of each climate type and the number of stations per climate type, which includes both existing and proposed stations. As shown in Table 3, the density of meteorological stations in Climate Type I is 1 station in every 1512 km^2, 3488 km^2 for Climate Type II, and 1720 km^2 for Climate Type III. This is far from the desired density of 200-300 km^2 per station as stipulated in the WMO guidelines. Fig. 8 shows the location of the existing and proposed stations per climate type.

Table 3. The density of the Meteorological Network for each Climate Type.

Climate Type	Area (km^2)	No. of Stations (Existing & Proposed)	Area per Station (km^2)	Optimum No. of Station
I	36294.75	24	1512	145
II	17442.23	5	3488	70
III	32676.29	19	1720	131
Total Area	86413.28	48	Total	346

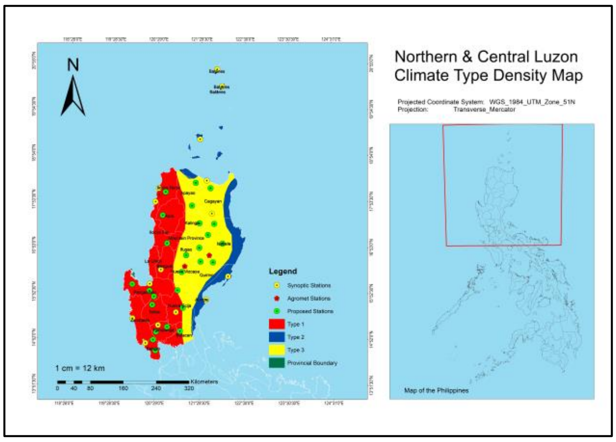

Fig. 8. Map of the Meteorological Station Density per Climate Type.

3.2.7 Proposed Suitable Sites for Additional Meteorological Stations

The map (Fig. 9) below shows the suitable sites for the additional agrometeorological stations in Northern and Central Luzon.

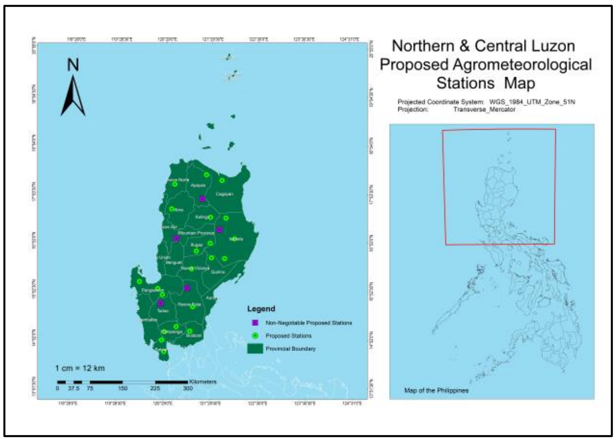

Fig. 9. Map of the Proposed Agrometeorological Station in Northern and Central Luzon.

There are 26 identified locations in order to augment the density of agrometeorological stations in the study area. This is further reduced to 5 stations by identifying the most priority areas such as large areas of agricultural production, proximity to nearest meteorological stations, and density of agrometeorological station per region. An additional 1 Agromet Station was for Regions I, II, and CAR while 2 stations were identified for region 3 because the 3 former regions exist while the latter has no agrometeorological stations. In addition, an augmented meteorological stations network map (Fig. 10) is created to present the spatial distribution of the existing and proposed stations.

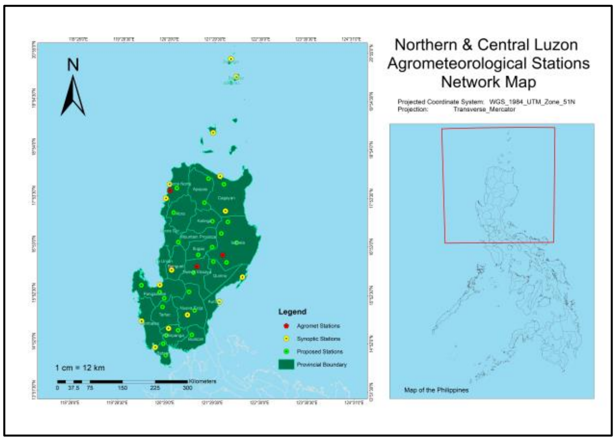

Fig. 10. Augmented Meteorological Stations Network Map (without AWS) in Northern and Central Luzon.

3.3 Identified Host Agencies

In consideration of the parameters set by WMO, the non-negotiable host institutions that may cater to the sitting of the proposed agrometeorological stations are listed in Table 4. The shortest and farthest distances from the host agency or institution are 0.1 km and 7.17 km, respectively. These locations shall be further validated on site to determine their capacity and acceptability as host institution.

Table 4. Suitable Agencies for the Siting of Additional Agrometeorological Stations.

No.	Region	Province	Municipality	Host Institution	Distance (km)
1	CAR	Apayao	Conner	Apayao State College - Conner	0.1
2	I	Ilocos Sur	Cervantes	Ilocos Sur Polytechnic State College - Cervantes	0.24
3	II	Isabela	Mallig	Isabela State University - Roxas	7.17
4	III	Tarlac	Santa Ignacia	Tarlac Agricultural College - Camiling	0.62
5	III	Nueva Ecija	Carranglan	Nueva Ecija University of Science and Technology - Caranglan	0.12

4. CONCLUSIONS

The objective of this study was to establish the most effective arrangement of an agrometeorological station network in Northern and Central Luzon, Philippines, utilizing GIS technology and following the WMO guidelines. The analysis took into account various factors, including slope, land use/land cover (LULC), accessibility, proximity to water bodies, and the availability of host institutions. This study was considered because of the significant contributions of agrometeorological stations to different sectors, particularly in agriculture. The data collected from the agro-meteorological stations will play a crucial role in informing decision-making processes and the formulation of effective management strategies. Through real-time monitoring and data analysis of weather conditions, agrometeorological stations offer precise weather forecasts and early warning information. This allows for adjustments in the timing of crop planting and fertilizer application, resulting in improved yields and crop quality. Additionally, it helps farmers avoid or minimize the impact of disasters on crops and agricultural production, ultimately enhancing their economic efficiency and quality of life.

Based on the result, there are 19 meteorological stations found in the study area, consisting of 4 agrometeorological and 15 synoptic stations. The study suggested the establishment of 26 new sites following the recommendations of the World Meteorological Organization (WMO). Out of the 26 proposed stations, 5 non-negotiable sites are identified considering agricultural production, proximity to nearest meteorological stations, and density of agrometeorological station per region. In addition, 26 potential host institutions for the proposed stations were identified which highlights the significance of partnering with educational and research institutions. The proposed network map provides a more extensive coverage of the region, especially in areas with different climate types.

These findings offer a valuable framework for the establishment of a stronger agrometeorological network in Northern and Central Luzon that aims to improve the weather monitoring and forecasting capabilities. This will impact agricultural practices, disaster preparedness, and food security in the region. However, there is a need to validate on site the reliability and accuracy of this analysis to provide a more significant and valuable information. This study only provides a preliminary investigation using secondary and open-source data obtained from various websites.

5. ACKNOWLEDGMENTS

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6. DATA AVAILABILITY

Most of the data used in this study can be accessed from online resources while other data are available from the author upon reasonable request.

7. REFERENCES

[1] Rahman, G., Ullah, S., Dawood, M., Ul Moazzam, M. F., & Lee, B. G. (2021). Spatio-temporal characteristics of meteorological drought in Khyber Pakhtunkhwa, Pakistan. PLOS ONE, 16(4), e0249718. https://doi.org/10.1371/journal.pone.0249718

[2] Sun, Y., Yang, Y., Zhang, L., & Wang, Z. (2014). The relative roles of climate variations and human activities in vegetation change in North China. Physics and Chemistry of the Earth, Parts A/B/C, 87-88, 67-78. https://doi.org/10.1016/j.pce.2015.09.017

[3] Felipe, A. J. B., G, M. J., & Abriol, M. P. (2024). Suitability Evaluation of Existing Agrometeorological Network in Luzon, Philippines Using GIS-based Analytical Hierarchy Process (AHP). Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES), 10, 48. https://doi.org/10.5109/7323241

[4] Bacci, M., Baoua, Y. O., & Tarchiani, V. (2020). Agrometeorological Forecast for Smallholder Farmers: A Powerful Tool for Weather-Informed Crops Management in the Sahel. Sustainability, 12(8), 3246. https://doi.org/10.3390/su12083246

[5] Navariti. (2024). Role of Weather Stations in Farming: Helps in Climate Smart Agriculture. https://www.linkedin.com/pulse/role-weather-stations-farming-helps-climate-smart-agriculture-cqljc

[6] Chattopadhyay, Nabansu & Ghosh, Kripan & Chandras, s.V.. (2016). Agrometeorological Advisory to assist the farmers in meeting the challenges of extreme weather events. Mausam. 67. 277-288. 10.54302/mausam.v67i1.1226.

[7] Arsenault, R. & Brisstte, F. 2013. Determining the Optimal Spatial Distribution of Weather Station Networks for Hydrological Modeling Purposes Using RCM Datasets: An Experimental Approach. Vol. 15, Issue 1. Journal of Hydrometeorology. 15 (1): 517-526. https://doi.org/10.1175/JHM-D-13-088.1

[8] World Meteorological Organization (WMO). 2010. Guide to Agricultural Meteorological Practices. WMO-No. 134. WMO, Geneva, Switzerland.

[9] Feloni, E., Karpouzos, D., & Baltas, E. (2018). Optimal Hydrometeorological Station Network Design Using GIS Techniques and Multicriteria Decision Analysis. Journal of Hazardous Toxic and Radioactive Waste, 22(3). https://doi.org/10.1061/(asce)hz.2153-5515.0000397

[10] Lamien, M. H. Y., & Farzaneh, H. (2024). Mapping Suitable Solar Farm Sites in Suez Governorate via Remote Sensing and GIS Techniques. Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES), 10, 359. https://doi.org/10.5109/7323286

[11] Reddy, G.P.O. (2018). Spatial Data Management, Analysis, and Modeling in GIS: Principles and Applications. In: Reddy, G., Singh, S. (eds) Geospatial Technologies in Land Resources Mapping, Monitoring and Management. Geotechnologies and the Environment, vol 21. Springer, Cham. https://doi.org/10.1007/978-3-319-78711-4_7

[12] Thakur, J.K., Singh, S.K. & Ekanthalu, V.S. Integrating remote sensing, geographic information systems and global positioning system techniques with hydrological modeling. Appl Water Sci 7, 1595–1608 (2017). https://doi.org/10.1007/s13201-016-0384-5

[13] Alejo, L. A., 2018. Suitability analysis for optimum network of agrometeorological stations: A case study of Visayas Region, Philippines. Vol. 20, No. Journal of Agrometeorology 20 (4): 269-274

[14] Rojas Briceño, N.B.; Salas López, R.; Silva López, J.O.; Oliva-Cruz, M.; Gómez Fernández, D.; Terrones Murga, R.E.; Iliquín Trigoso, D.; Barrena Gurbillón, M.; Barboza, E. Site Selection for a Network of Weather Stations Using AHP and Near Analysis in a GIS Environment in Amazonas, NW Peru. Climate 2021, 9, 169. https://doi.org/10.3390/cli9120169

[15] Raihan, A. 2024. A Systematic Review of Geographic Information Systems (GIS) in Agriculture for Evidence-Based Decision Making and Sustainability. Volume 3. Global Sustainability Research. 10.56556/gssr.v3i1.636.

[16] PAGASA. https://bagong.pagasa.dost.gov.ph. (Accessed: 21.05.24)

[17] Turab, N. T., Truc, P. T. T., Liem, N. D., & Loi, N. K. (2016). Optimal selection of number and location of meteo-hydrological monitoring networks on vu gia–thu bon river basin using GIS. International Journal on Advanced Science, Engineering and Information Technology, 6(3), 324-328.