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# Tree Species Composition and Diversity in a Secondary Forest along the Sierra Madre Mountain Range in Central Luzon, Philippines: Implications for the Conservation of Endemic, Native, and Threatened Plants

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**Abstract:** The Sierra Madre Mountain Range (SMMR) is the backbone of the Luzon Islands that contains a high concentration of highly important ecological resources distributed among the 68 protected areas therewith. The present study aimed to assess the composition and diversity of tree species in a secondary forest within the SMMR. A 2.25 km transect with 10 900-m$^2$ plots were established to record tree species with a diameter at breast height of at least 10 cm. The findings revealed 148 individuals of trees from 38 morphospecies, 28 genera, and 20 families. Importance values unveiled the Aurora endemic *Macaranga stonei* Whitmore as the most important species in terms of the relative values of its abundance, frequency, and dominance. The area was also found to be home to 33 natives, 12 endemics, five IUCN threatened species, and nine Philippine threatened trees. Furthermore, the study site was also found to have considerably high diversity, with a Shannon–Weiner Index value of 3.269 and a relatively even distribution of individuals among species, as supported by the Simpson's Evenness index value of 0.9453. Significant correlational relationships were also found among species richness, Shannon–Weiner index, and Simpson's Evenness index, with correlation coefficients ranging from 0.881 to 0.934, with all significant at $p < 0.001$. Lastly, the study was able to produce a distribution map, which is necessary for implementing targeted conservation strategies. These findings provided valuable implications for future research and implementation of targeted and participatory biodiversity conservation and protection strategies.

**Keywords:** biodiversity; biodiversity hotspot; correlation analysis; distribution maps; Shannon–Weiner index; Simpson's Evenness index

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## 1. Introduction

The Philippines, an archipelagic country known for its rich biodiversity, stands proudly as one of the 18 megadiverse nations on Earth [1]. This designation signifies that it harbors over two-thirds of the world's biodiversity resources, which play a crucial role in supporting human well-being and survival while maintaining ecosystem stability [2,3]. Biodiversity generously provides us with essential resources like food, water, raw materials, and clean air. Moreover, it diligently regulates climate and protects us from natural disasters [4]. Ecologically speaking, biodiversity enables vital processes such as pollination, nutrient cycling, water filtration, and soil stabilization and erosion control—all working together to create balanced ecosystems and desirable environmental conditions [5–7].

Unfortunately, biodiversity has long been facing numerous threats that jeopardize its existence and the critical services it provides. Climate change, along with many undesirable human activities such as deforestation, habitat destruction, land use change, and overexploitation, primarily drive biodiversity loss globally [8]. Due to these, scientists were able to identify biodiversity hotspots that contain very high rates of endemism and drastic loss of vegetation and habitat that threatens various key biodiversity species [9]. At present, there are already 36 biodiversity hotspots, including the Philippines [10]. This signifies the need for immediate planning and implementation of strategies to prevent total biodiversity loss.

In the Philippines, various conservation and rehabilitation efforts are continuously implemented. The establishment and monitoring of protected zones under the National Integrated Protected Areas Systems (NIPAS) Act is considered one of the most important tools in conserving the country's key biodiversity resources, as recommended by the Convention on Biological Diversity [11]. Other conservation and rehabilitation programs, such as the National Greening program under Executive Order No. 26 [12], community-based forest management under Executive Order No. 263 [13], and sustainable ecotourism [14], among others, are recognized as greatly contributing to biodiversity conservation while educating people about its values and services.

However, there were critical issues in some rehabilitation and conservation programs. One of these is the unsuitable choice of plant species to rehabilitate a degraded or disturbed area. Several efforts in the past used exotic and invasive species such as *Gmelina arborea* Roxb. And *Swietenia macrophylla* King [15] in many greening activities. Some used native species, but there was a lack of pre-assessment of the site–species relationships thus introducing the natives to inappropriate habitats and hindering their successful growth and survival [16]. This is where the importance of plant inventory and assessments comes in. The data and findings yielded by these studies provide essential information on the population structure, composition, and ecology of an area and its resources that are beneficial in recovery planning, such as biodiversity conservation and habitat rehabilitation [17].

This current study aims to contribute to the conservation of Philippine biodiversity by assessing tree diversity in the municipality of San Luis in the province of Aurora. The province is a part of the Sierra Madre Mountain Range, the longest mountain range in the country, which is considered a highly important area in terms of valuable ecological resources distributed among its 68 protected areas [18,19]. Furthermore, there are very few studies about the plant composition and diversity in the province, which only cover the tree species in the municipalities of Baler [20] and Dipaculao [21], as well as the diversity of ferns in the municipalities of Maria Aurora [22] and Baler [23]. Hence, this study will pioneer the assessment of plants in the municipality of San Luis, which is beneficial in identifying the area's key biodiversity resources, such as the endemic, native, and threatened species, which is a crucial step in biodiversity conservation. Specifically, the study aimed to determine the tree species composition, including ecological classifications (i.e., indigeneity, endemism, and conservation status), calculate the importance values and diversity indices and explore the underlying relationships among diversity parameters and ecological variables (i.e., elevation).

## 2. Materials and Methods

### *2.1. Study Site*

The study was conducted in April 2023 in Barangay L. Pimentel in the municipality of San Luis, province of Aurora, situated approximately 15°41′2.94″ N and 121°30′1.23″ E (Figure 1). The barangay is composed of residential, agricultural, and mountainous forest lands. Specifically, the survey was carried out in mountainous forest lands, which is a portion of the Sierra Madre Mountain Range, the backbone of Luzon Island, that serves as a protector and barrier from typhoons coming from the Pacific Ocean [24]. The survey area had a moderately steep topography, with elevations ranging from 273 to 581 masl. Climate-wise, the municipality has average monthly temperatures ranging from 26 °C to 30 °C (high temperature) and 22 °C to 25 °C (low temperature), and average monthly rainfall ranging from 118.3 mm (March: average of 7 rainfall days) to 416.9 mm (October: average of 17 rainfall days) in 2023. In the past 10 years, the average annual temperatures have usually ranged from 26 °C to 28 °C, while rainfall has been 100.23 mm to 624.86 mm. During the study period, the area had an average temperature of 28 °C during daytime and

24 °C during nighttime and there were 8 rainy days, with precipitation of around 300 mm during the month of April [25].

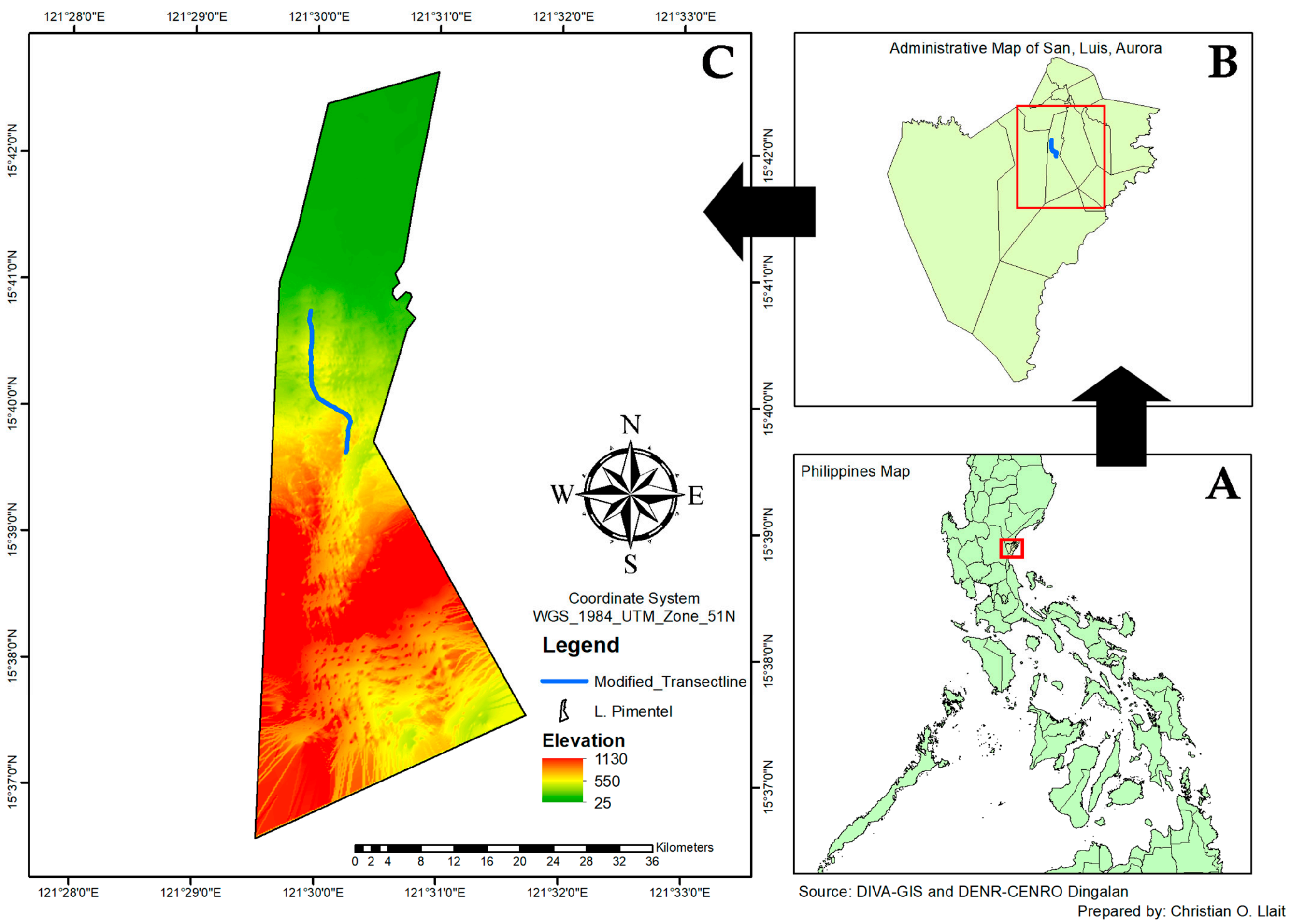


**Figure 1.** Location map of the study site in San Luis, Aurora: (**A**) study site pointed in the Philippine map, (**B**) location of the site pointed in the map of San Luis, Aurora, (**C**) elevation map of Barangay L. Pimentel showing the location of modified transect.

### *2.2. Survey and Mapping of Tree Species*

The inventory of tree species was carried out along a 2.25 km transect line with 10 30 by 30 m quadrats established at every 250 m point (Figure 2). The transect line was established following the trail while the quadrats were positioned alternately at the left and right of the transect line, with an approximate distance of 5 m away from the trail. The total coverage of all the quadrats was 9000 $m^2$. The use of transect in conducting this plant inventory was used to ensure that the quadrats were evenly distributed throughout the forest stand [26].

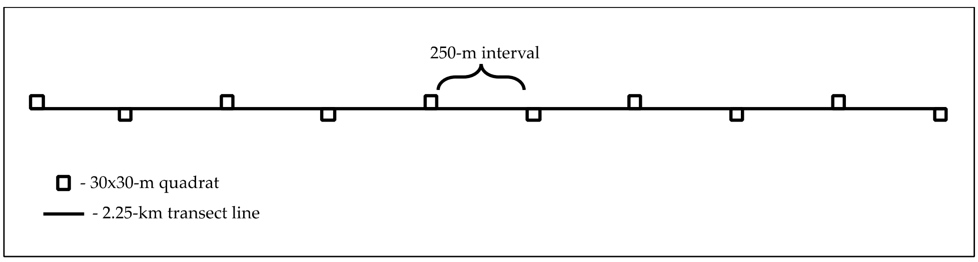


**Figure 2.** Arrangement of quadrats along the transect line.

After the establishment of the transect and quadrats, the plant survey was carried out. Trees with a diameter at breast height (DBH) of at least 10 cm were included in the study, following the DBH cut-off of many tree species inventories undertaken in the Philippines [27,28]. Plant identities were determined in the field using morphological characteristics. For individuals that were not identified in the field, photos were taken for further verification. References and databases such as Co's Digital Flora of the Philippines [29] and Revised Lexicon of Philippine Trees [30] were used to verify plant identities. Finally, the accepted scientific names of plants were determined using the Plants of the World Online database of the Kew Royal Botanic Gardens [31]. Significant ecological statuses (i.e., indigeneity, endemism, and conservation status) of all species were also assessed. Indigeneity and endemism were obtained from the Co's Digital Flora of the Philippines [29]. Meanwhile, conservation statuses were determined using the IUCN Red List of Threatened Species [32] for the global scale and DAO 2017-11 or the Updated National Checklist of Threatened Plants and their Categories [33] for the national scale.

Mapping was also carried out to visually present the location of each individual tree, which will also serve as the basis for the future implementation of targeted biodiversity conservation and management measures. Initially, the Locus map (a mobile outdoor navigation application) was used to record the location of the transect line and quadrats. Then, the geographic coordinates of each tree were recorded and encoded in Microsoft Excel. Geographic coordinates in decimal degree format were then converted into the Universal Transverse Mercator (UTM) format using the ArcGeek Coordinate Conversion Tool [34] before feeding it to ArcGIS software (v. 10.4). After that, the locations of all trees were plotted on the map. Lastly, final editing was undertaken to produce the final copy of the map in .jpeg format.

### *2.3. Data Analysis and Interpretation*

#### 2.3.1. Species Richness, Abundance, and Importance Values

Species richness, abundance, and importance values were either counted or calculated to discover the species composition in the area. Species abundance refers to the number of individuals of a species in an area [35], while species richness is the number of species or taxa present [36]. Hence, the number of species and its individuals were counted to determine the species richness and abundance. Lastly, importance values (IVs) serve as an index to measure how dominant a certain species is in a forest area through the relative values of its abundance, frequency, and dominance [37]. Thus, IVs were computed using the following equations [38]:

$$Density = \frac{number\ of\ individuals\ of\ a\ species}{total\ area\ sampled} \tag{1}$$

$$Relative\ Density = \frac{density\ of\ a\ species}{total\ density\ of\ all\ species} \tag{2}$$

$$Frequency = \frac{number\ of\ plots\ in\ which\ a\ species\ occur}{total\ number\ of\ plots\ sampled} \tag{3}$$

$$Relative\ Frequency = \frac{frequency\ of\ a\ species}{total\ frequency\ of\ all\ species} \tag{4}$$

$$Basal\ Area = 0.7854\left(DBH\ of\ a\ species^2\right) \tag{5}$$

$$Dominance = \frac{basal\ area\ of\ a\ species}{total\ area\ sampled} \tag{6}$$

$$Relative\ Dominance = \frac{dominance\ of\ a\ species}{total\ dominance\ of\ all\ species} \tag{7}$$

$$Importance\ Value = Relative\ Density + Relative\ Frequency + Relative\ Dominance \tag{8}$$

2.3.2. Diversity Indices

Biological diversity can be quantified using mathematical functions known as the diversity indices [39]. In this study, the widely accepted Shannon–Weiner (H′) and Simpson's Evenness (E) were employed as the species diversity indices and computed through Paleontological Statistics (PAST v 3.18) software. The choice of these indices aligns with the standards set by previous biodiversity studies undertaken in the country and uses the Fernando Biodiversity Scale, which has been widely adopted in diverse ecological investigations in the Philippines to effectively facilitate the interpretation of computed values [40,41] (Table 1).

**Table 1.** Fernando Biodiversity Scale.

| Interpretation | Shannon–Weiner | Simpson's Evenness |
|---|---|---|
| Very high | 3.5 and above | 0.75–100 |
| High | 3.0–3.49 | 0.5–0.74 |
| Moderate | 2.5–2.99 | 0.25–0.49 |
| Low | 2.0–2.49 | 0.15–0.24 |
| Very Low | 1.9 and below | 0.05–0.14 |

2.3.3. Correlation Analysis

Exploring intricate relationships among key variables is essential in deeply understanding the dynamics of forest ecosystems. Therefore, Pearson correlation analysis was used to explore the underlying relationship (i.e., monotonic association) among important variables, namely, elevation, species richness, abundance, Shannon–Weiner, and Simpson's Evenness. This was computed at a significance level of $p < 0.05$ through JASP v. 0.16.1, an open-source statistical software package. The results were interpreted using the computed correlation coefficient values ($r$-values) and their associated $p$-values, as well as the conventional approach in interpreting $r$-values, contextualized as a direct or inverse relationship [42] (Table 2).

**Table 2.** Conventional approach in interpreting correlation coefficient [42].

| Absolute Value of *r* | Interpretation |
|---|---|
| 0–0.09 | Negligible correlation |
| 0.10–0.39 | Weak correlation |
| 0.40–0.69 | Moderate correlation |
| 0.70–0.89 | Strong correlation |
| 0.90–1.0 | Very strong correlation |

## 3. Results and Discussion

### *3.1. Tree Species Composition*

The study recorded a total of 148 individuals of 38 morphospecies of trees from 20 families and 28 genera. In terms of the families, Dipterocarpaceae and Moraceae were the most speciose with seven and five species, respectively. The most abundant families were Euphorbiaceae, Dipterocarpaceae, and Moraceae, with 29, 28, and 21 individuals, respectively. These families are abundant in the Philippines, especially in tropical lowland evergreen forests that are dominated by dipterocarps [43]. Sadly, dipterocarps are among the most threatened plant species in the Philippines and in Southeast Asia due to deforestation, and their timbers have been massively exported in the past [44,45]. Species-wise, *Macaranga stonei* Whitmore was the most abundant, followed by *Parashorea malaanonan* (Blanco) Merr., with 24 and 9 individuals, respectively. Given that the study plots covered 9000 $m^2$, which is 9/10 of a hectare, it is estimated that these species, *M. stonei* and *P. malaanonan,* had 26 and 10 individuals in a hectare of the study area, respectively.

The importance values computation also revealed significant findings in terms of the species composition. Eleven (11) species had individual IVs of more than 10 (Figure 3). In total, these 11 species contributed 55.50% of the total IV of all species in the area. Among them, *M. stonei* had the highest IV of 30.35, which is equivalent to 10.11% of the total IV of all the species recorded, followed by *Parashorea malaanonan* (Blanco) Merr, with 21.63 (7.21%). *M. stonei*'s high IV was related to its high abundance of 24, its occurrence in six plots out of all ten plots, and a total basal area of 136.73 m$^2$. *M. stonei* is Aurora province-endemic and a critically endangered plant species belonging to the family Euphorbiaceae [29,32]. This keystone species lacks focus in terms of research, thus dictating the need to study this species more and include it as one of the top priorities for conservation due to it being a species restricted to the province of Aurora.

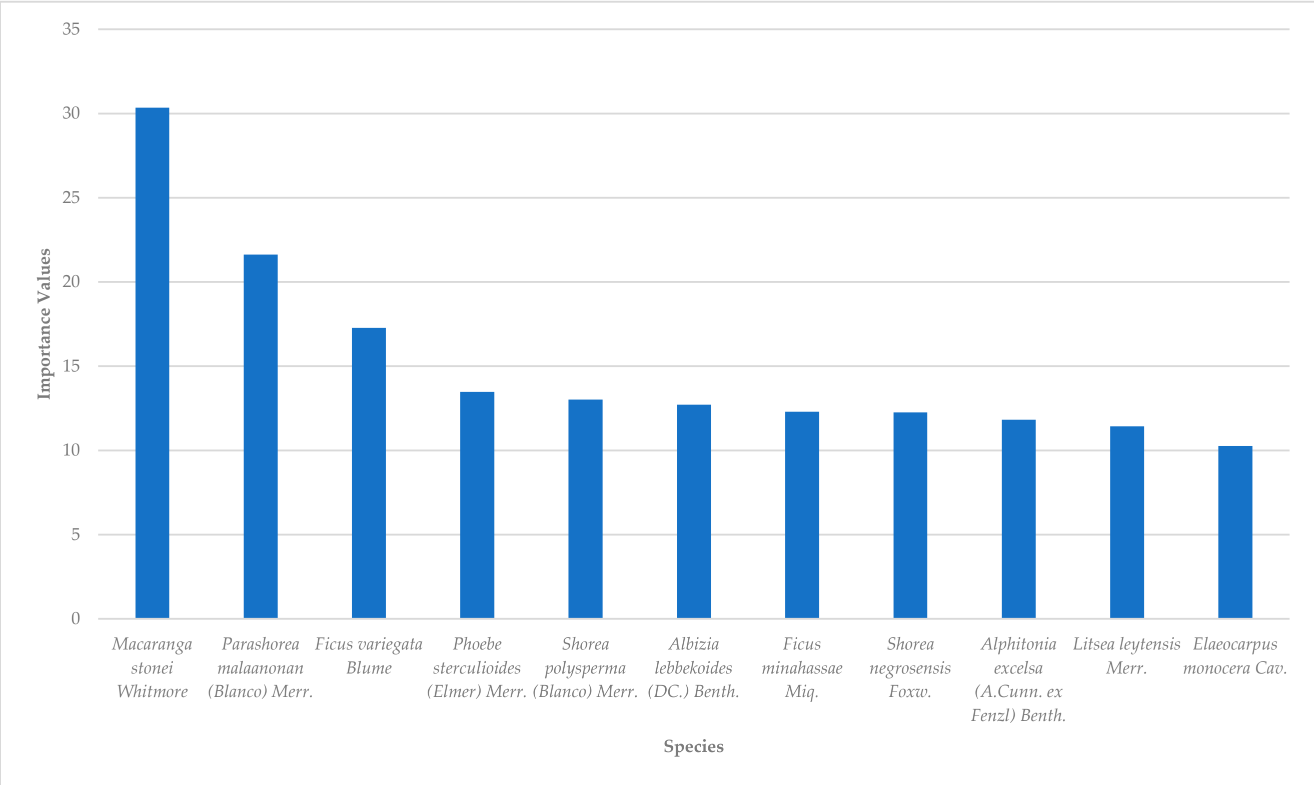


**Figure 3.** Top eleven species with highest importance values (IVs).

The surveyed forest was also found to be home to ecologically important species, namely, native, endemic, and threatened species (Table 3). Out of the 38 species found, 33 (86.84%) were natives, while five were exotics (with one invasive *Gmelina arborea* Roxb. ex Sm.). The native species were composed of 12 endemics, five IUCN threatened species, and 9 Philippine nationally threatened species. Specifically, there were one critically endangered, two endangered, and two vulnerable species found in the IUCN. Furthermore, there were two endangered, six vulnerable, and one other threatened species found in DAO 2017-11 or the Philippine Red List. The most notable among the Philippine endemic species were the IUCN critically endangered *M. stonei* and the IUCN vulnerable and DAO 2017-11 endangered *Hopea acuminata* Merr, and the IUCN endangered and DAO 2017-11 vulnerable Philippine national tree *Pterocarpus indicus* Willd. The presence of critically important plants in the area dictates the need for immediate action to conserve, protect, and even spread their population. It is emphasized that these species, particularly the endemics, have higher probabilities of extinction because of their narrow and restricted habitat than widespread species [46]. The native and endemic plant species also provide suitable habitats and enough food sources for native and endemic fauna species [47]. In fact, we were able to witness a couple of the Philippine endemic Luzon Rufous Hornbill (*Buceros hydrocorax* Linnaeus) during the survey. However, the presence of invasive species like the *G. arborea* adds pressure to the survival and propagation of the native and endemic flora and fauna species due to the aggressive nature of most invasive plants [48]. Actual representative photos of some critically important plant species in the area and an image of *B. hydrocorax* individuals are shown in Figure 4.

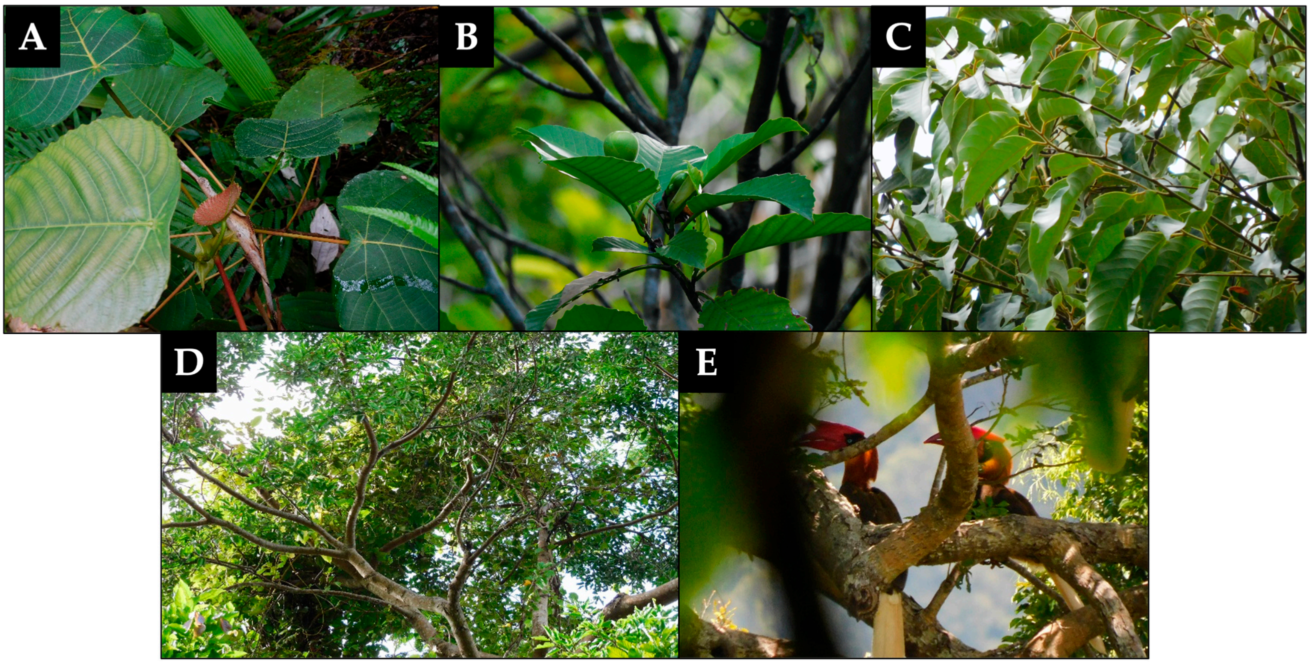


**Figure 4.** Representative photos of critically important species in the area. (**A**) *Macaranga stonei* Whitmore (endemic, IUCN critically endangered), (**B**) *Dillenia philippinensis* Rolfe (endemic, IUCN near threatened), (**C**) *Shorea polysperma* (Blanco) Merr. (endemic, DAO 2017-11 vulnerable), (**D**) *Shorea contorta* Vidal (endemic, DAO 2017-11 vulnerable), (**E**) a couple of *Buceros hydrocorax* Linnaeus (endemic, IUCN vulnerable, Philippine Red List endangered).

**Table 3.** Taxonomic list of native species recorded with their corresponding endemism and conservation statuses.

| Family | Species | Endemism [1] | Conservation Status [2] | |
|---|---|---|---|---|
| | | | IUCN Red List | DAO 2017-11 |
| Anacardiaceae | *Koordersiodendron pinnatum* (Blanco) Merr. | NE | ND | OTS |
| Brownlowiaceae | *Diplodiscus paniculatus* Turcz. | PE | LC | ND |
| Cannabaceae | *Celtis philippensis* Blanco | NE | LC | ND |
| Dilleniaceae | *Dillenia philippinensis* Rolfe | PE | NT | ND |
| Dilleniaceae | *Tetracera scandens* (Linn.) Merr. | NE | ND | ND |
| Dipterocarpaceae | *Dipterocarpus grandiflorus* (Blanco) | NE | EN | VU |
| Dipterocarpaceae | *Hopea acuminata* Merr. | PE | VU | EN |
| Dipterocarpaceae | *Parashorea malaanonan* (Blanco) Merr. | NE | LC | ND |
| Dipterocarpaceae | *Shorea contorta* Vidal | PE | LC | VU |
| Dipterocarpaceae | *Shorea negrosensis* Foxw. | PE | LC | VU |
| Dipterocarpaceae | *Shorea polysperma* (Blanco) Merr. | PE | LC | VU |
| Dipterocarpaceae | *Shorea squamata* (Turcz.) Benth. & Hook. | PE | LC | ND |
| Elaeocarpaceae | *Elaeocarpus cumingii* Turcz. | NE | LC | ND |
| Elaeocarpaceae | *Elaeocarpus monocera* Cav. | PE | ND | ND |
| Euphorbiaceae | *Macaranga grandifolia* (Blanco) Merr. | NE | VU | ND |
| Euphorbiaceae | *Macaranga stonei* Whitmore | PE | CR | ND |
| Euphorbiaceae | *Macaranga tanarius* (L.) Muell. Arg. | NE | LC | ND |
| Euphorbiaceae | *Mallotus paniculatus* (Lam.) Müll. Arg. | NE | LC | ND |

**Table 3.** *Cont.*

| Family | Species | Endemism [1] | Conservation Status [2] | |
|---|---|---|---|---|
| | | | IUCN Red List | DAO 2017-11 |
| Fabaceae | *Albizia lebbekoides* (DC.) Benth. | NE | LC | ND |
| Fabaceae | *Pterocarpus indicus* Willd. | NE | EN | VU |
| Hypericaceae | *Cratoxylum sumatranum* Blume | NE | LC | ND |
| Lauraceae | *Litsea leytensis* Merr. | PE | NT | EN |
| Lauraceae | *Phoebe sterculioides* (Elmer) Merr. | PE | LC | ND |
| Meliaceae | *Aglaia luzoniensis* (Vidal) Merr. & Rolfe | NE | NT | ND |
| Moraceae | *Artocarpus blancoi* (Elmer) Merr. | PE | LC | ND |
| Moraceae | *Ficus minahassae* Miq. | NE | LC | ND |
| Moraceae | *Ficus nota* (Blanco) Merr. | NE | LC | ND |
| Moraceae | *Ficus variegata* Blume | NE | LC | ND |
| Myrtaceae | *Syzygium nitidum* Benth. | NE | ND | VU |
| Myrtaceae | *Syzygium tripinnatum* (Blanco) Merr. | NE | ND | ND |
| Rhamnaceae | *Alphitonia excelsa* (A.Cunn. ex Fenzl) Benth. | NE | LC | ND |
| Sterculiaceae | *Sterculia ceramica* R.Br. | NE | ND | ND |
| Urticaceae | *Leucosyke capitellata* (Poir.) Wedd. | NE | LC | ND |

[1] Endemism classifications: PE—Philippine endemic; NE—Not endemic. [2] Conservation status classifications: CR—Critically endangered; EN—Endangered; Vu—Vulnerable; OTS—Other Threatened Species; NT—Near threatened; LC—Least concern; ND—No data.

### *3.2. Tree Species Diversity*

The diversity indices of the secondary forest in San Luis are presented in Figure 5. The Shannon–Weiner index values per quadrat ranged from 1.626 to 2.3384 and were interpreted as very low to low based on the Fernando Biodiversity Scale. In terms of Simpson's Evenness, the values ranged from 0.8182 to 0.9619, which were interpreted as very high. Quadrat 2 had the highest diversity ($H' = 2.384$ and $E = 0.9619$). Overall, the study area had a high Shannon–Weiner index ($H' = 3.269$) and a very high Simpson's Evenness index ($E = 0.9453$), which means that the trees in the area were relatively diverse and had a considerably even distribution of individuals among species. In most ecological studies in the Philippines, $H'$ values generally range from 1.5 to 3.5, wherein higher values dictate higher species diversity [49]. The overall $H'$ value of the present study falls within this range and was interpreted as high, which can possibly be attributed to the variety of native and endemic species that still thrive therewith. This is comparable with some studies undertaken in the Philippines, such as in a lowland forest in Agusan del Sur ($H' = 3.32$, $E = 0.52$) [50], in a secondary forest in Benguet ($H' = 2.40$) [49], and in a secondary forest in Pampanga ($H' = 2.2807$, $E = 0.8549$) [51], which were all categorized as having low to moderate diversity based on the Shannon–Weiner index. Similarly, these study sites were either under the management of upland communities or near their residential or agricultural sites. In contrast, the values are lower than the studies in a private mountainous forest in Baler, Aurora ($H' = 4.096$; $E = 0.9735$) [18], in the Quezon Protected Landscape ($H' = 3.90$, $E = 0.81$) [52], and in the Mt. Makiling Forest Reserve ($H' = 3.50$, $E = 0.91$) [53]. The common characteristics that possibly caused these high values were their classifications as private property, with strict monitoring and considerably high protection for the site in the first study and being classified as protected areas under the law of the second and third study sites, relating to the monitoring and protection activities of the government.

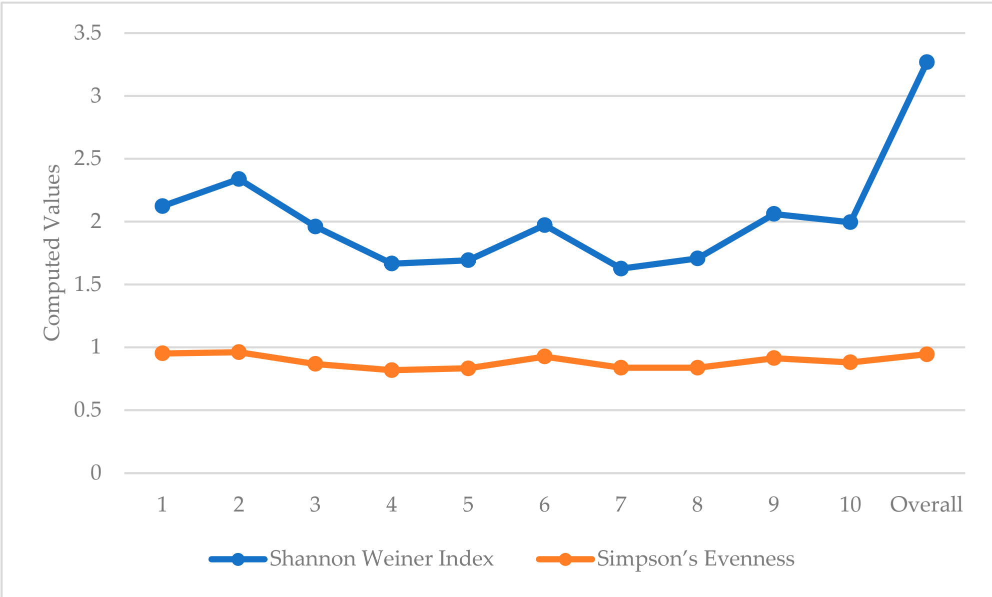


**Figure 5.** Computed diversity indices per quadrat and for the entire survey area.

### *3.3. Correlation among Parameters*

This study also tested the correlations among elevation, species richness, abundance, Shannon–Weiner, and Simpson's Evenness values. As a result, significant correlational relationships were only observed for the following: (a) Species Richness and Shannon–Weiner ($r$ = 0.881, $p < 0.001$); (b) Species Richness and Simpson's Evenness ($r$ = 0.885, $p < 0.001$); and (c) Simpson's Evenness and Shannon–Weiner ($r$ = 0.934, $p < 0.001$) (Figure 6). Based on the $r$-values, there was a strong positive correlation between species richness and Shannon–Weiner index as well as between species richness and Simpson's Evenness, as supported by a very high significance value of $p$ that is less than 0.001. This relationship suggests that as species richness increases, the values of the Shannon–Weiner and Simpson's Evenness indices also tend to increase. Thus, this observation indicates that having a greater variety of species can lead to a higher diversity, as measured by using the mentioned indices. Furthermore, there was a very strong positive correlation found between the Simpson's Evenness index and Shannon–Weiner index based on the obtained $r$-value, which is backed up by a very high statistical significance with $p < 0.001$. This indicates that as the value of Shannon–Weiner index increases, the value of Simpson's Evenness also tends to increase. The findings are corroborated by the study of DeJong, which also found a very strong correlation among species richness, Shannon–Weiner index, and Simpson's Evenness index, with correlation coefficients of more than 0.96 [54]. However, no significant correlational relationships were found between the following: (a) elevation and other variables, and (b) abundance and other variables. A similar finding was found in a study at a mountain range in Southern Mindano, suggesting that elevation did not greatly affect biodiversity parameters such as the diversity indices [55]. In essence, these results are beneficial in understanding the dynamics of an ecosystem, which can be the foundation for implementing management and rehabilitation strategies in different areas within the study site with the goal of improving biodiversity.

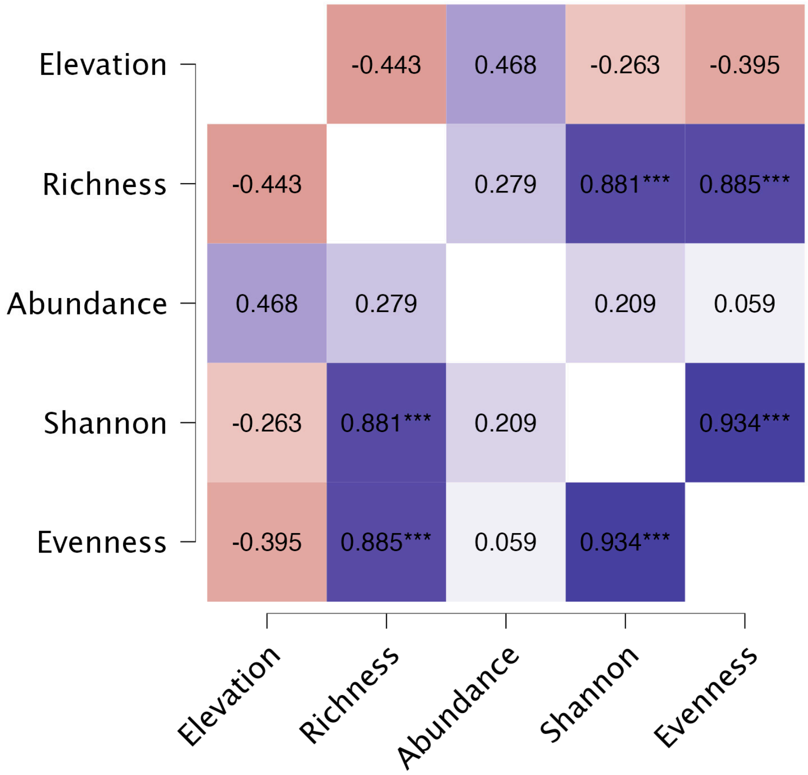


**Figure 6.** Heatmap of Pearson's *r* correlation among elevation and biodiversity parameters (*** $p < 0.001$).

### *3.4. Spatial Distribution of Trees*

Figure 7 shows the spatial distribution of trees across the sampling plots in the secondary forest of San Luis in Aurora, Philippines. This map shows the position of the transect line and the approximate location of each individual tree, represented by colored dots (legend placed on the right-hand side), based on the recorded coordinates. As observed in the map, the plots were zoomed in to show the locations of the trees more clearly. We can also see in the background of the zoomed image of the plots the actual image of the forest cover in the area, as reflected in the base map used. Mapping the spatial distribution of trees is a crucial element in devising strategies for the sustainable management and conservation of natural resources [56]. For instance, locating the trees can help us identify areas with possible sources of mother trees of the targeted species that we aim to propagate [57]. For example, if we are looking for a source of planting materials for a high-priority species such as *M. stonei*, which is a very important species in the area due to the fact that it is an endemic and critically endangered species, we can refer to the map and see that it can be seen in plots 3, 5, 7, 8, 9, and 10. Furthermore, distribution maps can visually present areas needing attention and immediate measures, such as in the case of our study, the presence of invasive *G. arborea* that poses a threat to the native biodiversity. Knowing the location of its recorded individuals (present in plots 2 and 3) will allow the forest managers to perform targeted measures in managing specific portions of the area where invasion issues arise [48]. Lastly, we can identify micro-biodiversity hotspots among the sampling plots in the study area by determining the number of critically important species [58].

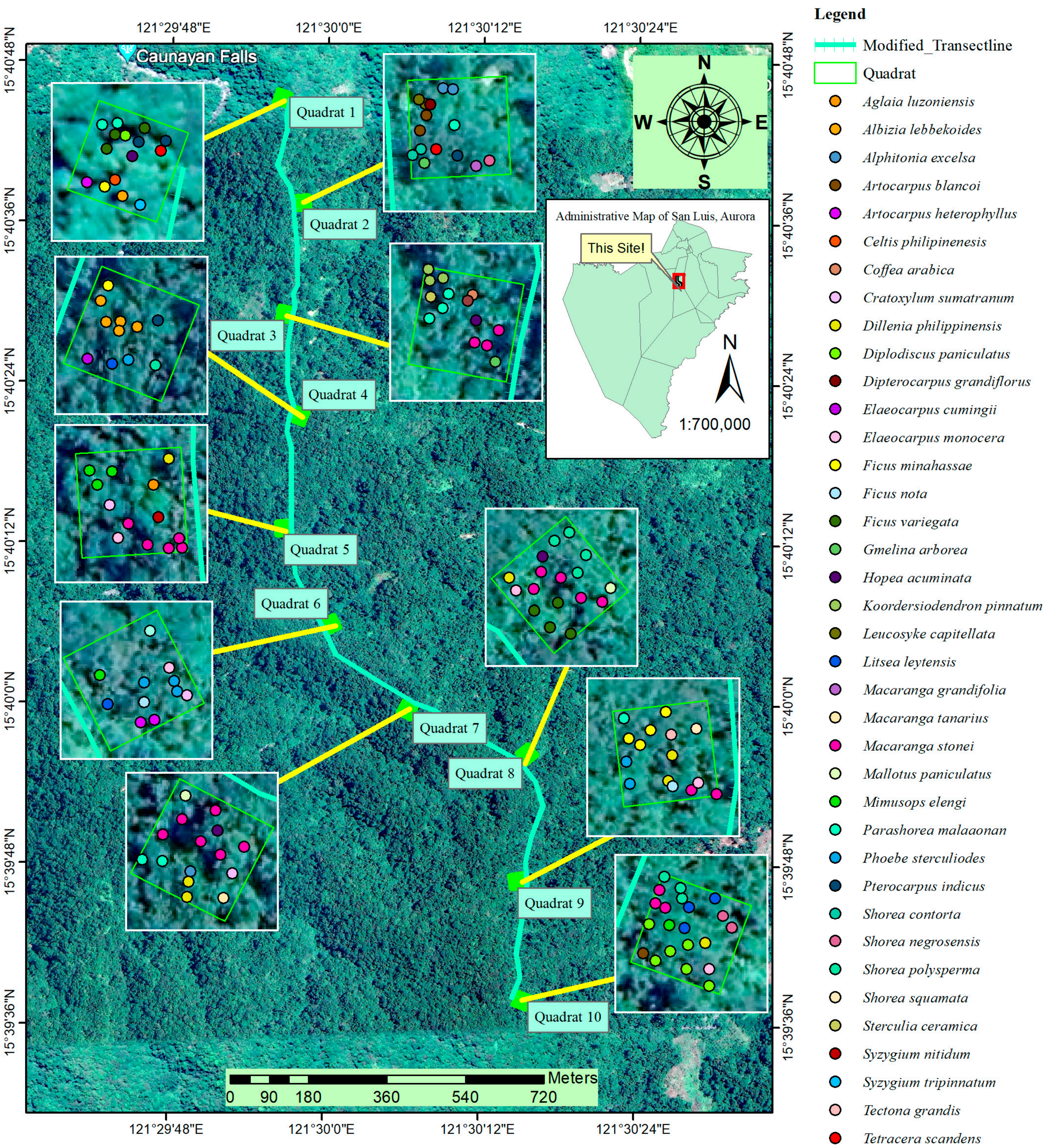


**Figure 7.** Distribution map of all trees across sampling plots in the secondary forests of San Luis, Aurora.

### 3.5. Research Limitations

This study provides valuable insights into the composition and diversity of tree species in the San Luis area of the SMMR. However, certain limitations were acknowledged. The research scope was limited to a short duration, and only a specific portion of the secondary forests of San Luis, Aurora, were covered by the transect, where variations in topography, exposure, and elevations, as well as forest dynamics, were not fully explored. Thus, these issues limit the generalizability of the findings in terms of larger ecosystems and dictate the need for long-term monitoring and the eventual establishment of a protected area. Furthermore, tree species were the only life forms included in the study, opening the door for a more comprehensive assessment of other biodiversity components, such as understorey and ground vegetation, wildlife, and soil characteristics, which were beyond the scope of this study. These limitations are crucial in interpreting the results to guide future research directions and in planning a holistic and more effective biodiversity management and conservation.

## 4. Conclusions and Implications

This study yielded valuable findings and insights regarding the species composition and diversity of a secondary forest in San Luis, Aurora. Overall, the area had a relatively high diversity and significant conservation, as signified by the recorded 148 individuals of 38 morphospecies belonging to 20 families and 28 genera, with 33 natives, 12 endemics, five IUCN threatened, and nine Philippine threatened species. Furthermore, diversity was found to be high in terms of the Shannon–Weiner index ($H' = 3.269$) and very high in terms of the Simpson's Evenness index ($E = 0.9453$). Significant correlational relationships were also found among species richness, Shannon–Weiner index, and Simpson's Evenness index. Lastly, individual trees were mapped to serve as a guide for targeted conservation measures. These findings are critical in the following applications for the conservation of native, endemic, and threatened species:

1. The presence of many native, endemic, and threatened species underscores the immediate need to prioritize the conservation of these species through the aid of the map produced in locating the micro-biodiversity hotspots in the area. Furthermore, many endemic species lack scientific studies, highlighting the need to conduct focused studies to explore the ecology and distribution of these critically important species. Furthermore, this can serve as a basis for the Department of Environment and Natural Resources to include the forest as one of the high conservation priorities or to expand protected areas to cover the area surveyed.
2. The relatively high diversity values and even distribution of plants calculated for the area somehow indicate a relatively healthy ecosystem. Thus, this underscores the need for intensified law enforcement to protect the remaining forests that serve as habitats for native and endemic wildlife, such as *Buceros hydrocorax* Linnaeus.
3. The presence of introduced and invasive species such as *Gmelina arborea* Roxb. poses a very significant threat to local native biodiversity. Targeted and participatory invasive species management is needed to control and eventually eradicate the impact of invasive plants in the ecosystem.
4. All the implications and conservation strategies discussed above will need the participation of locals and other stakeholders due to the fact that the area is adjacent to residential communities. Thus, information and educational campaigns, as well as a participatory approach in implementing conservation strategies, are ideal tools to ensure more effective biodiversity conservation and protection.

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## References


1. Vidallon, S.L.; Arriola, A.H. A preliminary checklist of Rubiaceae in Mt. Mariveles, Bataan, Philippines. *Biodiversity* **2023**, *24*, 1–10. [CrossRef]
2. Davids, S.; Mavumengwana, Z. Stocktaking SA's natural treasures. *Veld Flora* **2020**, *106*, 34–37.
3. Li, F.; Altermatt, F.; Yang, J.; An, S.; Li, A.; Zhang, X. Human activities' fingerprint on multitrophic biodiversity and ecosystem functions across a major river catchment in China. *Glob. Change Biol.* **2020**, *26*, 6867–6879. [CrossRef] [PubMed]
4. Ansari, N.A.; Agus, C.; Nunoo, E.K. Foundations of 'SDG15–LIFE on Land': Earth, Forests and Biodiversity. In *SDG15–Life on Land: Towards Effective Biodiversity Management*; Emerald Publishing Limited: Bingley, UK, 2021; pp. 7–48.
5. Sahu, D.; Sahu, J.K.; Kumar, V.; Gupta, P. Role of Floriculture in Promoting Biodiversity and Enhancing Ecosystems: A Comprehensive Review. *Int. J. Environ. Clim. Change* **2023**, *13*, 2077–2084. [CrossRef]
6. Keybondori, S.; Abdi, E.; Deljouei, A.; Lázaro-Lobo, A.; Ervin, G.N.; Shakeri, Z.; Etemad, V.; Borz, S.A. Effect of forest roadside on vegetation characteristics in the Hyrcanian temperate forest. *Eur. J. For. Res.* **2023**, *142*, 455–473. [CrossRef]
7. Sefidi, K.; Copenheaver, C.A.; Sadeghi, S.M.M. Anthropogenic pressures decrease structural complexity in Caucasian forests of Iran. *Écoscience* **2022**, *29*, 199–209. [CrossRef]
8. Caro, T.; Rowe, Z.; Berger, J.; Wholey, P.; Dobson, A. An inconvenient misconception: Climate change is not the principal driver of biodiversity loss. *Conserv. Lett.* **2022**, *15*, e12868. [CrossRef]
9. Jepson, P.; Canney, S. Biodiversity hotspots: Hot for what? *Glob. Ecol. Biogeogr.* **2001**, *10*, 225–227. [CrossRef]
10. Cunningham, C.; Beazley, K.F. Changes in human population density and protected areas in terrestrial global biodiversity hotspots, 1995–2015. *Land* **2018**, *7*, 136. [CrossRef]
11. Hind, E.J.; Hiponia, M.C.; Gray, T.S. From community-based to centralised national management—A wrong turning for the governance of the marine protected area in Apo Island, Philippines? *Mar. Policy* **2010**, *34*, 54–62. [CrossRef]
12. Gregorio, N.; Herbohn, J.; Harrison, S.; Pasa, A.; Ferraren, A. Regulating the quality of seedlings for forest restoration: Lessons from the National Greening Program in the Philippines. *Small-Scale For.* **2017**, *16*, 83–102. [CrossRef]
13. Lasco, R.D.; Pulhin, J.M. Environmental impacts of community-based forest management in the Philippines. *Int. J. Environ. Sustain. Dev.* **2006**, *5*, 46–56. [CrossRef]
14. Catibog-Sinha, C. Biodiversity conservation and sustainable tourism: Philippine initiatives. *J. Herit. Tour.* **2010**, *5*, 297–309. [CrossRef]
15. Mangaoang, E.O.; Pasa, A.E. Preferred native tree species for smallholder forestry in Leyte. *Ann. Trop. Res.* **2003**, *25*, 25–30.
16. Navarrete, I.A.; Peque, D.P.; Macabuhay, M.D. Soil information as a reforestation decision-making tool and its implication for forest management in the Philippines. In *Environmental Resources Use and Challenges in Contemporary Southeast Asia: Tropical Ecosystems in Transition*; Springer: Berlin/Heidelberg, Germany, 2018; pp. 97–116.
17. Appiah, M. Tree population inventory, diversity and degradation analysis of a tropical dry deciduous forest in Afram Plains, Ghana. *For. Ecol. Manag.* **2013**, *295*, 145–154. [CrossRef]
18. Coracero, E.E.; Malabrigo, P., Jr. Carbon storage potential of the tree species along the ultramafic forest in Sitio Dicasalarin, Barangay Zabali, Baler, Aurora, Philippines. *AIMS Environ. Sci.* **2020**, *7*, 589–601. [CrossRef]
19. Forest Foundation Philippines. Sierra Madre Mountain Range: Backbone of Luzon. 2022. Available online: https://www.forestfoundation.ph/wp-content/uploads/2022/04/Sierra-Madre-Mountain-Range_Landscape-Profile.pdf (accessed on 2 July 2023).
20. Coracero, E.E.; Malabrigo, P.L., Jr. Diversity Assessment of Tree Species in Sitio Dicasalarin, Barangay Zabali, Baler, Aurora, Philippines. *Open J. Ecol.* **2020**, *10*, 717–728. [CrossRef]
21. Bambalan, J.M.; Palapal, I.K.S.; Guleng, R.V.; Coracero, E.E.; Gallego, R.J.; Suniega, M.J.S. Tree diversity and carbon stock in North Poblacion and South Poblacion (Dipaculao, Aurora, Philippines). *Theor. Appl. Ecol.* **2022**, *2*, 198–208. [CrossRef]
22. Balberona, A.N.; Noveno, J.J.; Angeles, M.G.B.; Santos, R.I.; Cachin, E.J.D.J.; Cruz, K.G.J. Ethnomedicinal plants utilized by the ilongot-eģongot community of Bayanihan, Maria Aurora, Aurora, Philippines. *Int. J. Agric. Technol.* **2018**, *14*, 145–159.
23. Barrogo, K.N.; Delos Santos, M.P.; Montes, A.A.T.; Quiben, A.D.; Rotaquio, E.L., Jr.; Valete, E.J.P. Fern and fern allies as non-timber forest product in Baler, Aurora, Philippines. *Int. J. Agric. Technol.* **2021**, *17*, 423–432.
24. Coracero, E.E.; Malabrigo, P.J.L.; Bambalan, J.M.; Palapal, I.K.S.; Guleng, R.V.; Gallego, R.J.; Suniega, M.J.A. Diversity, Species Composition, and Carbon Stock Assessment of Trees in Aurora, Philippines: Variations between Preserved and Developed Ecosystems. *Environ. Sci. Proc.* **2022**, *22*, 29.
25. World Weather Online. San Luis Annual Weather Averages. 2023. Available online: https://www.worldweatheronline.com/san-luis-weather-averages/aurora/ph.aspx (accessed on 5 July 2023).
26. USDA. *Multiparty Monitoring and Assessment Guidelines for Community Based Forest Restoration in Southwestern Ponderosa Pine Forests*; US Department of Agriculture, Forest Service, Southwestern Region: Washington, DC, USA, 2003; 94p.

27. Coritico, F.P.; Lagunday, N.E.; Galindon, J.M.M.; Tandang, D.N.; Amoroso, V.B. Diversity of trees and structure of forest habitat types in Mt. Tago Range, Mindanao, Philippines. *Philipp. J. Syst. Biol.* **2020**, *14*, 1–11.
28. Malabrigo, P.; Tobias, A.; Eduarte, G.; Terbio, L.; Hernandez, J.; Umali, A.G. Tree diversity and stand structure of a 2-hectare Permanent Biodiversity Monitoring Area (PBMA) in Mts. Iglit-Baco National Park, Mindoro Island, Philippines. *Ecosyst. Dev. J.* **2022**, *12*, 83–94.
29. Pelser, P.B.; Barcelona, J.F.; Nickrent, D.L. Co's Digital Flora of the Philippines. (2011 Onwards). Available online: http://www.Philippineplants.org (accessed on 1 May 2023).
30. Rojo, J.P. *Revised Lexicon of Philippine Trees*; Forest Products Research and Development Institute, Department of Science and Technology: Laguna, Philippines, 1999.
31. POWO. Plants of the World Online. 2023. Available online: https://powo.science.kew.org/ (accessed on 2 July 2023).
32. IUCN. The IUCN Red List of Threatened Species. 2023. Available online: https://www.iucnredlist.org (accessed on 2 July 2023).
33. DENR. *DAO 2017-11*; Department of Environment and Natural Resources: Quezon City, Philippines, 2017.
34. Fox, S.; Stefánsson, H.; Peternell, M.; Zlotskiy, E.; Ásbjörnsson, E.J.; Sturkell, E.; Wanner, P.; Konrad-Schmolke, M. Physical characteristics of microplastic particles and potential for global atmospheric transport: A meta-analysis. *Environ. Pollut.* **2023**, *342*, 122938. [CrossRef] [PubMed]
35. He, F.; Gaston, K.J. Estimating species abundance from occurrence. *Am. Nat.* **2000**, *156*, 553–559. [CrossRef]
36. Chao, A.; Chiu, C.H. Species richness: Estimation and comparison. *Wiley StatsRef Stat. Ref. Online* **2016**, *1*, 26.
37. Ismail, M.H.; Zaki, P.H.; Fuad, M.F.A.; Jemali, N.J.N. Analysis of importance value index of unlogged and logged peat swamp forest in Nenasi Forest Reserve, Peninsular Malaysia. *Int. J. Bonorowo Wetl.* **2017**, *7*, 74–78. [CrossRef]
38. Hernandez, J.; Umali, A.G.; Malabrigo, P. Floristic diversity assessment of Caramoan National Park, Camarines Sur, Philippines. *Ecosyst. Dev. J.* **2021**, *11*, 73–81.
39. Daly, A.J.; Baetens, J.M.; De Baets, B. Ecological diversity: Measuring the unmeasurable. *Mathematics* **2018**, *6*, 119. [CrossRef]
40. Pampolina, N.M.; Coracero, E.E.; Eco, K.O.; Tingson, K.N. Floristic Composition, Diversity, and Ecology for Conservation of Lower Agno Watershed Forest Reserve, Mountain Province, Philippines. *Asian J. Biodivers.* **2022**, *13*, 1–23.
41. De Villa, K.R.; Lagat, R.D. Species Diversity and Habitat Association of Ferns and Lycophytes in Mts. Palay-Palay Mataas na Gulod Protected Landscape. In *Plant Diversity in Biocultural Landscapes*; Springer Nature Singapore: Singapore, 2023; pp. 135–161.
42. Schober, P.; Boer, C.; Schwarte, L.A. Correlation coefficients: Appropriate use and interpretation. *Anesth. Analg.* **2018**, *126*, 1763–1768. [CrossRef] [PubMed]
43. Salvaña, F.R.P.; Lopez, C.K.C.; Mangaoang, C.C.; Bretaña, B.L.P. Diversity and community structure of trees in two forest types in Mt. Apo Natural Park (MANP), Philippines. *Biodivers. J. Biol. Divers.* **2019**, *20*, 1794–1801. [CrossRef]
44. Langenberger, G. Habitat distribution of dipterocarp species in the Leyte Cordillera: An indicator for species—Site suitability in local reforestation programs. *Ann. For. Sci.* **2006**, *63*, 149–156. [CrossRef]
45. Pang, S.E.; De Alban, J.D.T.; Webb, E.L. Effects of climate change and land cover on the distributions of a critical tree family in the Philippines. *Sci. Rep.* **2021**, *11*, 276. [CrossRef] [PubMed]
46. Volis, S.; Belolipov, I.V.; Asatulloev, T.; Turgunov, M. Role of endemism and other factors in determining the introduction success of rare and threatened species in Tashkent Botanical Garden. *J. Zool. Bot. Gard.* **2023**, *4*, 325–334. [CrossRef]
47. Manchester, S.J.; Bullock, J.M. The impacts of non-native species on UK biodiversity and the effectiveness of control. *J. Appl. Ecol.* **2000**, *37*, 845–864. [CrossRef]
48. Coracero, E.E. Distribution and Management of the Invasive Swietenia macrophylla King (Meliaceae) at the Foot of a Protected Area in Luzon Island, Philippines. *J. Zool. Bot. Gard.* **2023**, *4*, 637–647. [CrossRef]
49. Batani, R.S.; Basbas, A.V., Jr.; Loncio, R.S.; Napaldet, J.T. Floral diversity in a secondary forest managed by indigenous community: The case of Mt. Kili-kili in Benguet, Cordillera Central Range, Northern Philippines. *Biodiversity* **2023**, *24*, 212–230. [CrossRef]
50. Lleno, J.V.; Ligalig, R.J.; Sarmiento, R.T.; Along, A.A. Tree diversity, composition, and stand structure of lowland tropical forest in Prosperidad, Agusan del Sur, Philippines. *J. Surv. Fish. Sci.* **2023**, *10*, 4810–4830.
51. Mancera, J.P.; Ragragio, E.M.; Su, G.L.S.; Rubite, R.R. Plant community structure of a secondary forest at Barangay Camias, Porac, Pampanga, The Philippines. *Philipp. J. Sci.* **2013**, *142*, 135–143.
52. Carig, E.T.; Manuel, R.P. Tree Diversity and Timber Resources Assessment in Secondary Forests of Quirino Forest Landscape Project, Philippines. *Asian J. Biodivers.* **2021**, *12*, 36–54. [CrossRef]
53. Castillo, M.L.; Castillo, L.A.; Canceran, M.S.; Gonzalvo, K.J.P.; Barua, L.D.; Alegre, A.C.; Barredo-Parducho, V.O.; Gestiada, E.; Breva, R.; Bantayan, N.C. Distribution, diversity and spatial analysis of tree species in a long-term ecological research plot in Molawin-Dampalit Watershed, Mount Makiling Forest Reserve. *Asian J. Biodivers.* **2018**, *9*, 12–36. [CrossRef]
54. DeJong, T.M. A comparison of three diversity indices based on their components of richness and evenness. *Oikos* **1975**, *26*, 222–227. [CrossRef]
55. Gevaña, D.; Pollisco, J.P.; Pampolina, N.; Kim, D.; Im, S. Plant diversity and aboveground carbon stock along altitudinal gradients in Quezon Mountain Range in Southern Mindanao, Philippines. *J. Environ. Sci. Manag.* **2013**, *16*, 20–28. [CrossRef]
56. Pu, R. Mapping tree species using advanced remote sensing technologies: A state-of-the-art review and perspective. *J. Remote Sens.* **2021**, *2021*, 9812624. [CrossRef]

57. Engay-Gutierrez, K.; Dimailig, E.; Yacon, J. Plus and Mother Trees in Mt. Banahaw de Lucban, Quezon, Philippines. *J. Environ. Sci. Manag.* **2022**, *25*, 33–48. [CrossRef]
58. Harris, G.M.; Jenkins, C.N.; Pimm, S.L. Refining biodiversity conservation priorities. *Conserv. Biol.* **2005**, *19*, 1957–1968. [CrossRef]

# Development and Assessment of Outdated Computers: A Technology Waste for Alternative using Parallel Clustering

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**Abstract.** Technology is constantly evolving to the point that computers that are purchased then are inevitably outmoded in terms of speed and their ability to process new applications. The study aims to provide procedure and measurement in viewing the process of the parallel clustered computers via graphical representation. The idea of the development procedure has been conceptualized by the author to elevate obsolete computer for alternative use. Likert scale was used (experts and users) in assessing the system. It was found out that the development has a promising result as evident in the assessment of experts on the system's reliability (availability and stability) and the users' assessment of the system's accessibility (ease of use and flexibility). It is also noted that obsolete computers have alternative disposal technique of e-wastes. With this, the development of clustering (using the interconnectivity of a master node and slave nodes) that is reliable, accessible and with a minimal cost was conceptualized as an alternative for managing e-waste and addressing the demand of new technology in the public sectors.

**Keywords:** Parallel clustering, processing power, alternatives & e-waste.

## 1 Introduction

Nowadays, technology has become an essential part of our lives. New technology has paved the way for smartphones, faster and more powerful computers, more compact televisions and so much more. Technology has made our lives simpler, quicker, safer and more enjoyable.

Technology has truly revolutionized the way we live and the way we work. It has provided opportunities for productivity and development. It has made working more effective and efficient in general as companies continue to invest in cuttingedge technologies.

With all the promising outcomes of technology, companies have embraced it and enjoy all the profits it could give. It has played a crucial role in companies that technology is no longer seen as cost but more of an investment. At present, various companies and industries have strategically advanced their technologies to cope with the ever-changing world.

However, as technology progresses, there were also setbacks created by them. So much of the wastes from various industries come from the technologies that are utilized in their gateways. E-wastes, or the electronic products nearing the end of their "useful life" such as computers, televisions, copiers, and fax machines are some of the challenges in the fast-paced technology development.

E-waste, also known as "a wide and growing range of electronic devices ranging from large household appliances such as refrigerators, air conditioning, cell phones, personal stereos and consumer electronics to computers that have been discarded by their users" [1], has a major effect as technology progresses. Technology has developed and progressed so fast. Rapid application development has become challenging for developers to adapt, although some are searching for alternatives that will potentially help urbanized communities develop those technology.

As we live in a world that is geographically complex and unpredictable, new business forces are generated by the rush of mega-trends, including dramatic shifts in globalization and advances in technology. For any organization to survive and prosper in such an environment, innovation is imperative.

However, innovation is no longer just for creating value to benefit individuals, organizations, or societies. Innovation's overall goal can be far more far-reaching, helping to build a smart world where people can achieve the highest possible quality of life [2].

Over the past decade, technical advances have accelerated the exponential use of multimedia tools by learners of all ages. These global trends also include the constant progression of the e-learning assessment. Evaluation is the practice of clarifying what needs to be done and relating it to what needs to be done, in order to promote the evaluation of performance and how it should be achieved [3]. In terms of speed and their ability to process new applications, computers which are then bought are ultimately outdated. When this happens, outdated computers are considered to be redundant. This also happens in sectors where computation plays a crucial role in development and achievement. As necessity dictates, there is a need to find a way in which these devices, considered redundant and worthless, can be useful in constructing computers that can meet the demands of whatever endeavours.

A cluster consists of a series of interconnected stand-alone computers operating together as a single consolidated computing resource and is a type of parallel or distributed computer system [4]. Clustering is commonly used in a network to reduce the energy consumption and thus increase the network longevity [5]. In other terms, cluster is a series of separate and inexpensive computers, used together to provide a solution as a supercomputer.

Cluster computing provides a single general approach for designing and implementing high-performance parallel systems independent of individual hardware manufacturers and their product preferences [6]. A typical application of cluster parallel computing is to load and disperse the demand for processes by the master node to the slave nodes. The information is transmitted from the source to its respective cluster head and then to the base station in order for the selected head to bear all of the information that needs to be transmitted and route it to the intended target [7]. A commodity cluster is an array of entirely autonomous computer systems that are interconnected by an off-the-shelf networking network of commodity interconnections [8] and play a major role in redefining the supercomputing concept. As a result, high-performance high-throughput, and high-availability computing has arisen as parallel and distributed standard platforms.

With this, the development of clustering (using the interconnectivity of a master node and slave nodes) that is reliable, accessible and with a minimal cost was conceptualized as an alternative for managing e-waste in the public.

## 2 Build and Architecture

### 2.1 The parallel clustered uniform set-up

After the selection of obsolete system attachments on peripherals, cluster computers must be built.

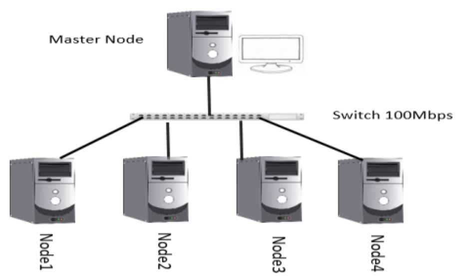


**Fig. 1.** Indicates the cluster clustering connectivity. The development was based on computer architecture clustered in parallel.

### 2.2 Production Instruments

The design of the clustered computers was based on the hardware and software needed to meet the demand of cluster computers are (a) personal computers consist of the same basic components: a CPU, memory, circuit board, storage, and input/output devices [9] (b)fast ethernet switch [10] (c)straight cable (T568A – T5668A) [11] and (d) Ubuntu ABC GNU/Linux [12].

### 2.2 Setup Clustering

Homogeneous computing is used to interconnect identical processor cores or units to create a high-performance device in order to use a homogeneous parallel clustering mechanism [13]. The nodes 1-4 and the master node all come in the same "Boot to Network" BIOS (basic input output system) configuration connected via T568A using Cat-5E UTP cable.

### 2.3 Installation (Software)

The next move is to install the program after the computers have been assembled. ABC GNU Linux (Ubuntu 9.04) [10] was used with the default kernel as a basis. Upon the installation of ABC GNU Linux (Ubuntu 9.04), gathered the information about the hardware specifications.

### 2.4 Specification and checking of device

Step 1: Upon determining the master node and slave node this will be the basis of hetorogenousity of the system as the specification be Processor: Intel Celeron M CPU with a CPU Speed: 2266 MHz

Step 2: Setting up of ABC GNU Linux kernel ISOLINUX3.63 Debian to the master node. Boot from the CD-ROM then choose an install mode, press enter then follow the directions on the screen. The default language of the distro is Spanish. Changing to your preference language is necessary. After which select use entire disk to partition the hard disk, then create username and password and lastly install ABC GNU (Ubuntu 9.04)

Step 3: Setting up the slave nodes, first enter the configuration or setup of CMOS, choose halt on ALL ERROR, and finally set-up to boot from the network.

Step 4: This procedure will check the master node via Command Line Interface (CLI), master@master-desktop:~$ cat clusterhosts 192.168.0.1. Upon checking proceed to connectivity check this will test the network connectivity of Master Node, Node1, Node 2, Node 3, and Node 4, master@master-desktop:~$ cat clusterhosts 192.168.0.1 192.168.0.13 192.168.0.3 192.168.0.10 192.168.0.8.

## 3 Monitoring

### 3.1 Cluster interpretation of GANGLIA monitoring tool (GUI) [14]

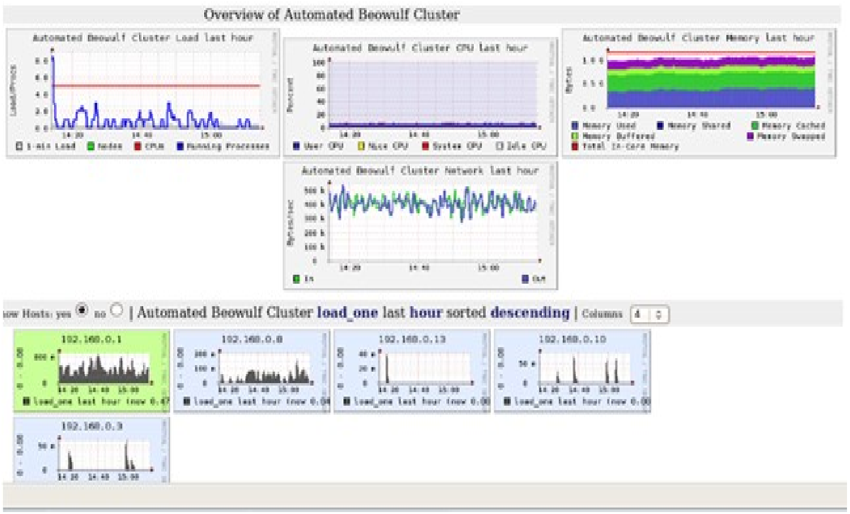


**Fig 2.** Overview of Automated Beowulf Cluster using Ganglia

Fig 2. Shows the device view of the cluster. A series of small graphs display the master node, and processes are used for nodes 1-4. It also indicates that the master node and nodes 1-4 work with various processes.

### 3.2 Performance differences of machine loaded

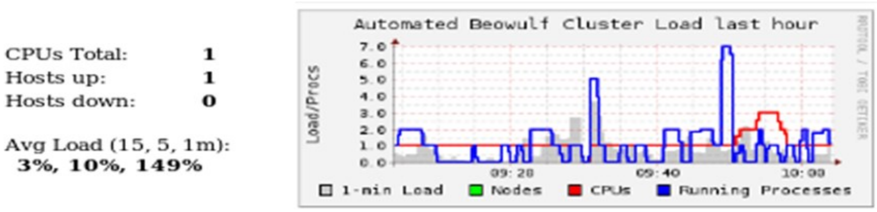


**Fig 3.** Performnace of Total hosts (1 CPU)

Fig 3. Displays performance representation from 1 host. It showed that the average capacity of a single CPU was 3%, 10% and 149%, showing that it is hard for a single host to process.

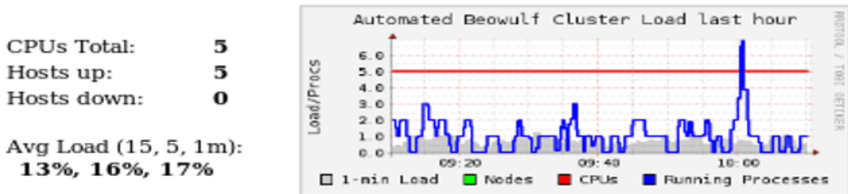


**Fig 4.** Performnace of Total hosts (5 CPU)

Fig 4. Shows the performance of 5 host computer. It indicates that the average load of performance is 13% , 16% and 17% which reveal that a multiple hosts process smoothly.

### 3.3 Network flow by graph (Master Node and Node 1)

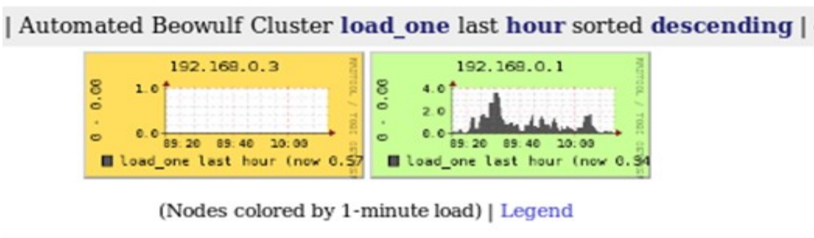


**Fig 5.** Master Node and Node 1

Fig 3. Reveals the master node and node 1. It ensures that the Master Node process and Node 1 process are distinct from one another. This also shows how process efficiency and relation identification are calculated.

### 3.4 Network movement process by graphs (Master Node and Node 1-4)

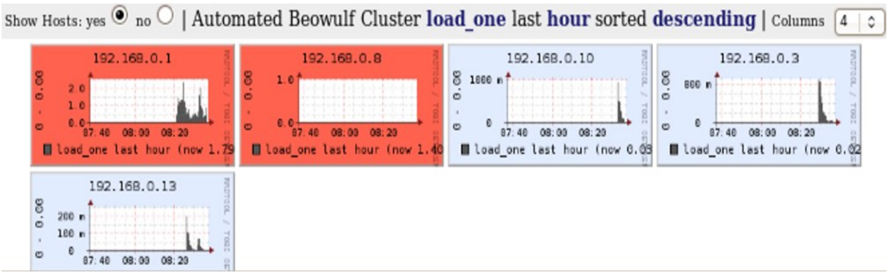


**Fig 6.** Process Identification of Nodes

Fig 6. Shows that the use of the CPU is 100%, it also shows that the Master Node and Node 1 used their processing power in the process distribution. It also reveals that different nodes have distinct processes.

### 3.5 Network movement process by graphs in Shutting down of Nodes

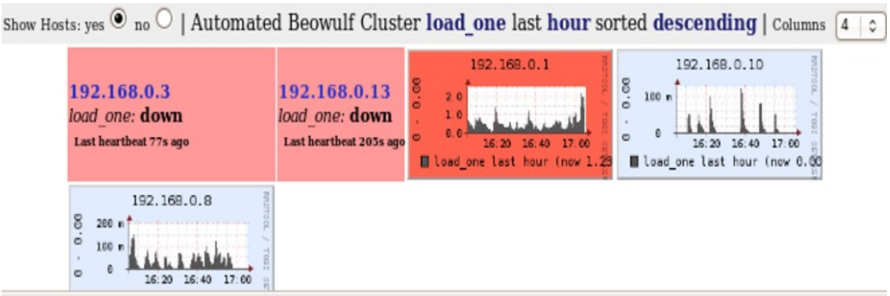


**Fig 7.** Node Process in Shutting Down

Fig 7. Indicates the Nodes have been successfully shut down. In the image and graph, the master node and the remaining nodes used that homogeneous parallel clustering processes are established and used.

## 4 Evaluation and Results

Two approaches are applied to test the homogeneous parallel clustering of alternatives for success acceptance and creation: by IT experts and by the users. The IT experts assessed the system as to Reliability with system availability and system stability [15] while the users rated the system as to accessibility with ease of use and flexibility of the system [16]. The questionnaire was based on the

Likert scale suggested by ISO 9126 [17] and used to analyze the results from scales 4.01-5.0 as excellent, 3.01-4.0 as very good, 2.01-3.0 as good, 1.01-2.0 as fair and 0-1.0 as poor with the following informative equivalents.

### 4.1 IT Experts

**Table 1.** Assessment of the System by IT Experts

| Assessment Criteria | Mean | Descriptive Rating |
|---|---|---|
| ***Realiability (Composite Mean: 4.08)*** | | |
| System Availability | 4.50 | Excellent |
| System Stability | 3.67 | Very Good |

Table 1 shows the results of the evaluation based on the reliability of the system. It obtained a composite mean of 4.08.

The IT Experts evaluated the reliability of the system based on the system availability with a 4.50 mean with a descriptive rating of Excellent and system stability with a 3.67 mean with a descriptive rating of Very Good.

### 4.2 Assessment of Users

**Table 2.** Assessment of the System by Users

| Assessment Criteria | Mean | Descriptive Rating |
|---|---|---|
| ***Accessibility (Composite Mean: 4.69*** | | |
| Ease of Use | 4.67 | Excellent |
| Flexebility of the System | 4.72 | Excellent |

Table 2 shows the results of users' assessment using a homogeneous parallel cluster. The users of the system were the students, IT faculty, and employees of Tarlac Agricultural University. To obtain the reliability of the evaluation, there were sixty (60) users who evaluated the system.

They evaluated the system accessibility based on ease of use with 4.67 as excellent and flexibility of the system with 4.72 as excellent. The system accessibility obtained a composite mean of 4.69 with a descriptive rating of excellent. The result indicate the uncomplicatedness of the system's operation.

## 5 Conclusion

The study found that the development and assessment result of the homogeneous parallel process clustering as alternatives is significant. Over the course of the review and testing, the performance of the machine was not damaged. Hence, the achievement of serviceable machines with low development costs has been established and guaranteed. Moreover, based on expert opinion and review, the use of a homogeneous parallel clustering method is strongly appropriate. The functionality of the framework was based on the efficiency of parallel clustering, and it also notes that operating is the master process and the nodes. Finally, because of the ease of service, the system's assessment is strongly appropriate to consumers in terms of usability.

In addition, the study findings have been established and could be introduced to other universities and schools in the area which will be used as an alternative computer to run application in today's technology demands. This will assist faculty, teachers and staff in researching other technical development and device efficiency.

Nevertheless, with the use of clustering strategies and encouraging e-waste management, universities and schools to alternatively develop outdated computers.
A future collection of machines with changed architectures will be selected for future work to enhance the analysis, in order to observe the effect of heterogeneity on the efficiency and growth of the clustering technique.

Lastly, to increase device reliability, an implementation can require additional measures, configurations, and performance review. Additional testing methods are also recommended to determine the efficiency of the device being built.

## References

1. D. Sinha-Khetriwal, The management of electronic waste: a comparative study on India and Switzerland, M.S.
2. M Sang M.Leea & SilvanaTrimi (2016). Innovation for creating a smart future, Journal of Innovation & Knowledge, ISSN: 2444-569X, Vol: 3, Issue: 1, Page: 1-8ay
3. D.D. Williams, C.R. Graham, in International Encyclopedia of Education (Third Edition), 2010
4. Yeo C.S., Buyya R., Pourreza H., Eskicioglu R., Graham P., Sommers F. (2006) Cluster Computing: High-Performance, High-Availability, and High-Throughput Processing on a Network of Computers. In: Zomaya A.Y. (eds) Handbook of Nature-Inspired and Innovative Computing. Springer, Boston, MA. 2006.
5. Mugunthan, S. R. "Novel Cluster Rotating and Routing Strategy for software defined Wireless Sensor Networks." Journal of ISMAC 2, no. 02 (2020): 140-146.

6. Thomas Sterling, in Encyclopedia of Physical Science and Technology (Third Edition), 2003
7. Raj, Jennifer S. "Machine Learning Based Resourceful Clustering With Load Optimization for Wireless Sensor Networks." Journal of Ubiquitous Computing and Communication Technologies (UCCT) 2, no. 01 (2020): 29-38.
8. Thomas Sterling, ... Maciej Brodowicz, in High Performance Computing, 2018
9. Casey, J. (2015). Computer Hardware: Hardware Components and Internal PC Connections. Guide for undergraduate students. Technological University Dublin
10. Sachidananda Kangovi, in Peering Carrier Ethernet Networks, 2017
11. Naomi J. Alpern, Robert J. Shimonski, in Eleventh Hour Network+, 2010
12. Castaos, I & Garrido, Izaskun & Garrido, Aitor & Sevillano, M. (2009). Design and implementation of an easy-to-use automated system to build Beowulf parallel computing clusters. 1 - 6. 10.1109/ICAT.2009.5348420.
13. Van Steen, M., & Tanenbaum, A. S. (2016). A brief introduction to distributed systems. Computing, 98(10), 967–1009. doi:10.1007/s00607-016-0508-7
14. Matthew L. Massie, Brent N. Chun, and David E. Culler. 2004. The ganglia distributed monitoring system: design, implementation, and experience. Parallel Comput. 30, 7 (2004), 817--840.
15. O'Connor, D.T., and A. Kleyner. 2012. ''Practical Reliability Engineering'', 5th Edition. Chichester, UK: J. Wiley & Sons, Ltd.
16. Petrie, Helen & Bevan, Nigel. (2009). The Evaluation of Accessibility, Usability, and User Experience. C Stepanidis. 10.1201/9781420064995-c20.
17. ISO/IEC 9126, Software Engineering - Product quality, Parts 1-4, 1999-2004.

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# CURRENT STATUS ON THE HEALTHCARE WASTE MANAGEMENT OF SELECTED HOSPITALS IN THE PHILIPPINES: AN ASSESSMENT

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**Abstract**

Healthcare waste management has been more critical during the outbreak of the Covid-19 pandemic. Healthcare waste (HCW) not only poses serious environmental and human health risks, but it can also cause death. The problem of how to manage HCW is extremely important to prevent widespread disease transmission and environmental degradation. A descriptive survey study assessing the implementation of the healthcare waste management on storage, pre-treatment, collection and disposal of all private and public hospitals in the Municipality of Camiling, Tarlac, Philippines was determined. A mixed method research was adopted by conducting semi-structured interviews with the Head of the Waste Management Division, Pollution Control Officers, Sanitary Inspector, and other employees involved in waste disposal in private and public hospitals, clinics, and rural health units. A survey was used as a quantitative tool for data collection from respondents involved in healthcare waste management. Data were gathered using questionnaires and interviews with respondents and key informants, respectively. Data were analyzed and interpreted using frequency count and percentage. Findings revealed that 80% of the respondents used a color coding scheme while 20% used labeling as means of waste segregation. It also showed that 60% of both private and public hospitals has conformed to the waste management standards set by the Department of Health (DOH), Republic Act 9003, and World Health Organization 2009. Moreover, a clinic has conformed only to the DOH standards in terms of segregation, pre-treatment, storage, and disposal of wastes generated. However, the rural healthcare unit used labeling in segregating its wastes instead of a color coding scheme. In addition, segregation of waste was done only in its T and B DOTS and Laboratory. Further, hospital wastes were mixed with municipal wastes and disposed of in a dumpsite. Treated hazardous and infectious wastes were disposed of using burial method. The system of handling, storage, treatment, and disposal of the hazardous wastes of the healthcare units was different from each other.

**Keywords:** Hospital waste, waste segregation, healthcare waste management, solid and hazardous waste, waste disposal and treatment

## INTRODUCTION

The management of hospitals and healthcare units has the responsibility of ensuring that hospital wastes have no adverse health and environmental consequences in their handling, storage, treatment, and disposal. Improper management of healthcare waste aids in the transmission of diseases even the Covid-19 virus. Hospital wastes or biomedical wastes consist of solid, liquid, sharps, genotoxic, pharmaceutical, infectious, chemical, risk, and non-risk. and laboratory wastes that are potentially infectious and dangerous to health care, sanitation workers, patients who are regularly exposed to these wastes, the people who will also be exposed to it, and the environment (soil, air, water) when improperly handled (Das et al., 2021, Gassemi et al., 2016. Hossain et al., 2011, and Patway et al., 2011, and Rao, 2008). These wastes have to be properly managed to protect public health otherwise they can pose serious risks of disease transmission to waste pickers, waste workers, patients, and the public in general upon exposure to infectious agents (Das, et al., 2021). Moreover, its causing disease is not only

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the problem but if it contains hazardous wastes or radioactive wastes, it cannot be mixed with other non-hazardous solid wastes in the sanitary landfill. Proper waste management practices, safety measures for waste workers, and sanitation are crucial strategies for combating further spread of infectious diseases and landfill issues (Das et al., 2021).

On the other hand, not all hospital wastes are dangerous because there are wastes generated from its offices, cafeteria, and patient cares which does not pose a threat to landfills and public health.

With this environmental concern, government agencies such as DOH and DENR have set quality standards as well as regulations and programs so that occupational hazards of the health care workers will be avoided; the use of toxic chemicals and mixtures will be regulated; and solid and hazardous waste disposal will be managed from generation to final disposal.

The waste management programs of both public and private hospitals, clinics, and rural health units in Camiling Tarlac were determined to validate if they are conforming to the standard rules set by DOH in terms of waste management and the RA 9003 or the Ecological Solid Waste Management Act of 2000. Following the rules set indicates their ability and active responsiveness in ensuring the health and welfare of the community as well as performing their social responsibility in preserving the integrity of the environment. Some of the problems identified were mostly due to non – segregation processes, unsecured dumpsites, and landfill. Moreover, the poor implementation of some healthcare institutions regarding waste management systems was observed. This will most likely result in land degradation and a threat to human health.

On the other hand, some of the most common problems identified are inadequate waste management, lack of awareness about health hazards, insufficient financial and human resources, and poor control of waste disposal. To be able to minimize these consequences, proper implementation of rules and policies should be practiced by the management of hospitals and health care units. A framework for healthcare waste management should always consider health and occupational safety. Hence, this study on assessing the implementation of waste management in the healthcare sectors was conducted to determine the practices and conformity to ambient standards of public and private hospitals and other healthcare units in the Municipality of Camiling from generation, segregation, handling, storage, treatment, and disposal of their wastes. Moreover, the solid and hazardous wastes generated by the hospitals, clinics, and health care units were identified. The waste management programs implemented were described and further assessed on their level of conformity to the guidelines set out by the Department of Health.

The data generated from this study can be used for policy formulation of the Local Government Unit in reviewing the prevailing policies, mechanisms, programs, and facilities on segregating, storing, handling, disposing, and treating hazardous and infectious hospital wastes. Findings can also provide salient information to the local concerned authority to identify numerous issues in healthcare waste management and find opportunities to devise systems and the best solution to each.

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## METHODS AND PROCEDURES

This study was carried out in a descriptive survey research design to describe the waste management practices of the premier health care units in Camiling, Tarlac, Philippines. The Head of the Waste Management Division, Pollution Control Officers, Sanitary Inspector, and other employees involved in the waste disposal of 2 private hospitals, 1 private clinic, and 1 rural health unit. To protect the reputation of these premiere healthcare providers and ensure the confidentiality of the information divulged to the researchers, the identity name was not mentioned throughout the discussion. Instead, an alternative nomenclature was used namely: Private hospitals 1 and 2, public hospital, clinic, and health center.

Questionnaires were used to determine the waste management disposal practices of the private and public hospitals, clinics, and health care units while structured interview guides for the key informants to triangulate the information provided by the respondents. The premier private and public hospitals and health care units in Camiling, Tarlac were identified. Permission to administer the questionnaires and conduct interviews with employees involved in healthcare waste management from the Heads and/or owners of the healthcare units was secured. The questionnaire was given to each of the personnel of the said institution and they were further interviewed to validate the data gathered. The gathered data were analyzed through the use of quantitative analysis. The quantitative data were tabulated and analyzed using descriptive statistics such as frequency counts, mean, and percentages.

## RESULTS AND DISCUSSION

### Solid Infectious and Hazardous Hospital Wastes

Data on the healthcare solid and hazardous wastes generated by the hospitals and other health care providers in Camiling, Tarlac are shown in Table 1.

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**Table 1: Summary of solid infectious and hazardous wastes generated by the hospitals and health care units**

| Hospitals and Health Care Units | Solid Wastes Generated | Infectious or Hazardous Wastes Generated |
|---|---|---|
| **Clinic** | • Papers<br>• Cartons<br>• Plastics<br>• Cans<br>• Styropor containers | • Sharps<br>• Blood<br>• Chemical waste from the laboratory<br>• Cotton swabs<br>• Used facemasks<br>• Used bandages<br>• Used tubing IV<br>• Specimen container of blood and fluids |
| **Public Health Unit** | • Glass<br>• Slides<br>• Papers<br>• Cartoons<br>• Used cans<br>• Styropor | • Used syringes<br>• Blood<br>• Urinals<br>• Blood lancets<br>• Phlegm<br>• Cotton swabs<br>• Facemasks |
| **Private hospital 1** | • Empty medical bottles<br>• Empty tetra pack containers<br>• IVF container<br>• Plastics, can, soft drinks, straws, wrapper, styropor containers<br>• Waste from the offices | • Disposal materials<br>• Used for collection of body fluid<br>• Dressing bandages<br>• Used folly catheters<br>• Used cotton falls<br>• Used gloves<br>• Used facemasks |
| **Private hospital 2** | • Waste from the offices-paper, cans, cartoon styropor containers | • Empty vials<br>• Sharps<br>• Needles<br>• Used gloves<br>• Used cotton, pharmaceutical waste<br>• Facemask<br>• Radioactive waste |
| **Public hospital** | • Paper products<br>• bottles<br>• Packaging materials<br>• Waste from offices | • Pharmaceutical waste<br>• pathological waste<br>• radioactive waste<br>• sharps<br>• chemical waste<br>• used foley catheters<br>• used blood product bags or tubing<br>• used gloves<br>• specimen container of blood and fluids<br>• used suction tubes<br>• cotton applicator soaked with blood<br>• body fluids from dressing of infected wound and post operative cases<br>• waste from isolation room<br>• Facemask |

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Table 1 shows that the solid wastes in the three hospitals, one public healthcare center, and one clinic are mostly similar. Most solid wastes were generated from their offices. Hazardous wastes on the other hand are mostly similar among the healthcare providers except for the presence of radioactive wastes in private hospital 2 and public hospital. Its presence can be attributed to the great number of patients either as out-patients or in-patients in these two hospitals. Many patients may mean different medical cases that will be needing low-level to high-level radioactive wastes. The influx of patients in public hospital is high due to cheaper medical expenses. However, premier private hospitals are also preferred due to the availability of comfortable facilities, sensitive and state-of-the-art diagnostic tests, and updated and advanced medical equipment (Al-Balushi et al., 2017 Meddedu et al., 2020).

In the Philippines, the Department of Health has set a standard color coding scheme for the disposal of healthcare waste. This coding scheme will be used in the health care facility as follows: Black for non-infectious dry waste, Green for non-infectious wet waste, Yellow for infectious and pathological waste, Yellow with Black Band for chemical waste including heavy metals, Orange for radioactive waste, and red for sharps and pressurized containers (Joson, 2012). The use of a color coding scheme as means to segregate hospital wastes is depicted in the table below.

**Table 2: The use of color coding as a means of waste segregation of the health care units in the Municipality of Camiling**

| Use color coding scheme for waste segregation | Frequency (n=5) | Percentage (%) |
|---|---|---|
| Yes | 4 | 80 |
| No | 1 | 20 |

Table 2 shows that the majority (80%) of the respondents were using a color coding scheme for waste segregation. These are private hospitals 1 and 2, public hospital, and clinic. However, 20% (Health Care Center) was using labeling instead of the color coding scheme in waste segregation. This color coding of the containers of the hospital wastes was set by DOH that is aligned with the UNEP/WHO 2009).

The conformity of these health care units to the standard rules set by DOH and according to RA 9003 is shown in Table 3.

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**Table 3: Summary of color coding scheme as means of waste segregation of the Hospitals and Healthcare Units in compliance to the Department of Health and RA 9003**

| Color Code | DOH Standards | Hospitals and Health Care Units | | | | |
|---|---|---|---|---|---|---|
| | | Clinic | Public Health Center | Private Hospital 1 | Private Hospital 1 | Public Hospital |
| **For non-infectious dry waste or biodegradable waste** | | | --- | | | |
| Black | ✓ | ✓ | | ✓ | ✓ | ✓ |
| Green | | | | | | |
| Yellow | | | | | | |
| **For noninfectious wet waste or non-biodegradable waste** | | | --- | | | |
| Black | | | | | | |
| Green | ✓ | ✓ | | ✓ | ✓ | ✓ |
| Red | | | | | | |
| **For infectious waste and pathological waste** | | | | | | |
| Green | | | | | | |
| Yellow | ✓ | ✓ | x | ✓ | ✓ | ✓ |
| Blue | | | | | | |
| **For chemical waste including those with heavy metal** | | | | | | |
| Yellow with black band | ✓ | x | x | x | ✓ | ✓ |
| Red | | | | | | |
| Green | | | | | | |
| **For radioactive waste** | | | | | | |
| Green | | | | | | |
| Black | | | | | | |
| Orange | ✓ | x | x | ✓ | ✓ | ✓ |
| **For sharps and pressurized container** | | | | | | |
| Red (puncture proof container) | ✓ | ✓ | x | ✓ | ✓ | ✓ |
| Yellow | | | | | | |
| Black | | | | | | |

The result in Table 3 reveals that 80% of the health care units were using black color coding in segregating their non-infectious dry solid wastes or biodegradable wastes; green for non-infectious wet solid waste or non-biodegradable wastes; and yellow for infectious and pathological wastes. The public health center is the only unit that did not use color coding. However, in terms of segregating chemical waste including heavy metals, 60% (Private Hospital 2 and Public Hospital) were using black bands as indicators. For segregating radioactive wastes, 60% (Private Hospitals 1& 2 and Public Hospital) were using the orange indicator while 80% of the healthcare providers were using red puncture-proof containers.

The color coding scheme was set by DOH. Results show that 80% have conformed to DOH standards and RA 9003 in using a color coding scheme in segregating hospital infectious and non-infectious wastes. Only 20% had not used such a scheme because according to them, labeling is their means of waste segregation.

The provision of using a black band for chemical waste with heavy metals has not been followed by Private Hospital 2 and the Clinic (40%) because according to them they have not

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used heavy metals in their hospital/clinic. The provision for segregating wastes with radionuclides was not also followed by Dr. John Iglesia Clinic due to the non-usage of such chemicals

**Segregation**

**Table 4: Segregation system of hospital wastes of the five healthcare Units in Camiling, Tarlac**

| Health Care Units (Hospitals, Health Center and Clinic) | Waste Segregation System |
|---|---|
| Public Hospital | – The hospital was implementing RA 9003 in full and was using color coding |
| Private Hospital 1 | – The hospital was implementing RA 9003 in full and was using color coding |
| Private Hospital 2 | – The hospital was implementing RA 9003 in full and was using color coding |
| Public Healthcare Center | – The center was implementing RA 9003 in full and was using labeling instead of color coding<br>– Only Laboratory and the T and B DOTS sections were observing waste segregation<br>– Infectious and non-infectious wastes were separated |
| Clinic | – The clinic was implementing RA 9003 in full and was using color coding |

Data in Table 4 reveals how the 5 healthcare units segregate their wastes. All units except the Public Healthcare Center exercised full implementation of RA 9003 or known as the Ecological Solid Waste Management Act of 2000 and adhered to DOH standards in waste segregation.

Segregation of hospital wastes in Public Hospital is done by separating the different types of wastes and placed in corresponding bins. Containers are properly marked as compostable waste, non-compostable table waste, infectious waste, chemical waste, pharmaceutical waste, pathological waste, radioactive waste, sharp waste and pressurized waste.

The Private Hospitals 1 and 2 have the same way of segregating their wastes through color coding scheme. The black container is for non-infectious dry waste, green bag is for non-infectious wet waste, yellow bag is for infectious and pathological waste, orange container is for radioactive waste and red container is for the sharps and pressurized container. The green plastic lined bin is for the biodegradable waste which includes empty cartoons, empty medicine boxes, and kitchen waste, left over foods, newspapers, papers, and vegetable peelings and fruit skins. Black plastic lined bin is for inorganic waste. Each room has different containers for the various kinds of waste. The segregation of waste done at the Salvador General Hospital is in compliance to the DOH standards and RA 9003.

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The Public Health Center did not fully implement waste segregation. The laboratory room and the T and B DOTS are the only rooms that implement waste segregation. Waste segregation was through the labeling of the trash can. The infectious waste and general waste were separated.

Segregation of wastes in the Clinic is done through a color coding scheme. The color yellow container is for infectious waste, the black container was for non-infectious dry waste or inorganic waste, the red container is for sharp waste and the green container is for biodegradable waste. Each room has its trash can. The Clinic adhered the RA 9003. The institution used it as their guide in segregating waste.

**Storage**

On-site storage is the beginning of waste disposal because unkept waste or simple dumps are sources of nuisance, flies, smells, and other hazards (Takele, 2009). Infectious and pathological wastes however need to be treated while storing them before disposing of it properly.

**Table 5: Storage of hospital wastes of the five health care units in Camiling, Tarlac**

| Health Care Units (Hospitals, Health Center and Clinic) | Storage System |
|---|---|
| Public Hospital | – Had Health Care Waste Management System (HCWMS) |
| Private Hospital 1 | – Had Material Recovery Facility (MRF) for solid wastes<br>– Solid wastes were stored for not more than 2 days |
| Private Hospital 2 | – Had Material Recovery Facility for solid waste<br>– Had concrete vault for temporarily storing hazardous and infectious wastes |
| Public Healthcare Center | – Stored infectious wastes in the drum for 1 year before disposal<br>– Pre-treated hazardous and infectious wastes while reused and recycled solid wastes |
| Dr. John Iglesia Clinic | – Stored solid wastes for not more than 2 days and collected by Municipal truck every Tuesday<br>– Available and visible waste containers |

Table 5 shows that Public Hospital followed the Health Care Waste Management System (HCWM) of their institution. This is a systematic activity of the administration that provides policy on segregation at source, transport, storage, transfer, processing, treatment, and disposal of health care waste that does not harm the environment. This system is also in compliance with the DOH Standards.

Private Hospital 1 had its own Material Recovery Facility (MRF) which they use to temporarily store their waste – residual, recyclables and treated infectious waste. The wastes were stored

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for not more than 2 days before disposing to the dump site.

Private Hospital 2 had its own Material Recovery Facility which they use to temporarily store their waste for the proper segregation and inspection of solid waste. They also use concrete vaults to momentarily store the treated hazardous and infectious waste for the security of the people and the environment before finally disposing of it in San Clemente, Tarlac.

The infectious or hazardous wastes generated by Public Healthcare Center are stored in a big drum. These wastes underwent pre-treatment before storing. It takes a year before the drum is buried in Camiling cemetery. The drum should be full before they bury it.

**Pre-treatment**

**Table 6: Pre-treatment of hospital wastes of the five healthcare Units in Camiling, Tarlac**

| **Health Care Units (Hospitals, Health Center and Clinic)** | **Pre-treatment System** |
|---|---|
| Public Hospital | – The hospital was using autoclaving machine to disinfect infectious and hazardous wastes |
| Private Hospital 1 | – The hospital was using antiseptic reagents for infectious and hazardous wastes and soaked before burying<br>– The hospital was using septic tanks for infectious wastes |
| Private Hospital 2 | – The hospital was storing pathological wastes in a secured bottle and was using formalin to preserve it before placing it in concrete vault<br>– The hospital was using Lysol to disinfect hazardous wastes<br>– The hospital was using needle burner for needle and syringes |
| Public Healthcare Center | – The center was using safety box for used syringe before disposal to drums<br>– The center was using chlorine to disinfect |
| Clinic | – The clinic had no pre-treatment system |

Table 6 reveals that the Public Hospital pre-treated its infectious and hazardous wastes through autoclaving the infectious wastes.

The Private Hospital 1 however was using Chlorox and Syndex for the pre-treatment of infectious and hazardous wastes. These are soaked for 1 week before they bury it. They also were using autoclaves to disinfect the containers of these wastes before disposing of them. The laboratory room has a septic tank for hazardous and infectious waste. A needle destroyer is used before disposing of the syringes and needles. The pathological wastes of Private Hospital 2 are stored in a secured bottle with formalin to preserve them before they are put in a concrete vault and finally bury it. Infectious and hazardous wastes undergo different treatment processes before disposal. In disposing of blood and other pathological waste, they often use Lysol to disinfect or lessen and kill harmful bacteria while sharps like needles are burned in the needle burner. The Public Healthcare Center uses a safety box for the syringes which were chlorinated before disposing it to drum. All other infectious and hazardous wastes were pre-treated with chlorine before disposing of them. The clinic on the other hand had no pre-treatment system for its hazardous and infectious wastes.

**Collection and Disposal**

Collection is the removal of refuse from collection points to the final disposal site. It is the most expensive as compared with other operation and management procedures, because it demands special vehicles, experienced people to manage, more manpower, hand tools, and more funds for fuel, salary, maintenance, gathering or picking up of solid waste from the various sources, taking the collected wastes to the location where it is emptied, and unloading of the collection vehicle (Takele, 2009).

**Table 7: Collection and disposal of hospital wastes of the five health care units in Camiling, Tarlac**

| Health Care Units (Hospitals, Health Center and Clinic) | Collection and Disposal System |
|---|---|
| Public Hospital | – Solid wastes were collected daily<br>– Waste bags were labeled<br>– Residual wastes were hauled using PEO dump truck in landfills at Matubog dumpsite<br>– Infectious and hazardous wastes were transported using closed van |
| Private Hospital1 | – Solid wastes were collected every morning and disposed at the sanitary landfills at Matubog dumpsite<br>– Infectious wastes were disposed in burial pits |
| Private Hospital 2 | – Solid wastes were collected in black bag and disposed at the sanitary landfill in Matubog dumpsite every day<br>– Hazardous and infectious wastes underwent pre-treatment and collected using yellow bag; transported in a closed van and disposed in San Clemente, Tarlac. |
| Public Healthcare Center | – Solid wastes were collected everyday, collected by the municipal dump truck and disposed at Matubog dumpsite |
| Clinic | – Solid wastes were collected by on-site waste collectors and collected by municipal dump truck every Tuesday morning<br>– Infectious and hazardous waste were pre-treated and dump at the back of the clinic |

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Collection of waste in Public Hospital is done in a manner that prevents damage to the container. It is collected daily or as frequently as required. No bags are removed unless they are labeled with their point of production (hospital ward and department) and contents.

Collection of waste from the room is done every morning and afternoon. The solid wastes are collected by the municipal garbage collector truck. These are transported and disposed of in the Matubog dumpsite of Camiling while the infectious and hazardous wastes are disposed in burial pits.

Collection of waste in Private Hospital 2 is done using a black container for the general non-biodegradable waste which is collected every day at 8 am by the municipal garbage collector truck of Camiling and disposed it to Matubog dumpsite. The collection of garbage in each room in the hospital is made 3x a day or as needed. Yellow container or infectious and hazardous waste like body parts is collected every morning if ever the patient will not claim it. Their pathological wastes are stored in a secured bottle with formalin to preserve them before they are put in a concrete vault and finally bury it. A closed van is used to transport hazardous and infectious wastes in the disposal area at San Clemente, Tarlac. The municipal garbage collector truck of Camiling is used to transport all the solid wastes they generate in the Matubog dumpsite.

The general solid wastes in Public Healthcare Center are collected every morning by the municipal garbage truck. These are disposed of in Matubog dumpsite at Camiling, Tarlac.

The waste collector collects the waste in the room once a day every afternoon at the Clinic. The general wastes are collected by the municipal garbage truck every Tuesday morning. The syringes and other infectious and hazardous wastes are treated first before putting on a safety box (biohazard). All the hazardous and infectious wastes are buried behind the clinic.

**Reuse and Recycle**

Not all solid wastes are disposed. There are hospital wastes that are reused and recycled. The different ways of the health care units in Camiling are shown and described below.

**Table 8: Reuse and recycle of hospital wastes of the five health care units in Camiling, Tarlac**

| Health Care Units (Hospitals, Health Center and Clinic) | Reuse and Recycle System |
|---|---|
| Public Hospital | - Practiced recycling |
| Private Hospital 1 | - Practiced recycling<br>- Treated material before reusing it |
| Private Hospital 2 | - Did not practice recycling<br>- Treated material before reusing it |
| Public Healthcare Center | - Did not practice recycling<br>- Treated material before reusing it |
| Clinic | - Did not practice recycling<br>- Treated material before reusing it |

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The Public Hospital practiced recycling. Solid wastes like plastic and glass, syringes, cartons, and vials are cleaned and transformed into decorations.

Private Hospital 1 treats the materials before reusing them. Wastes that were reused are gloves with no punctures or tears; those that were strong enough to be autoclaved; bonnets used during surgeries; left-over sutures at the operating room or delivery room; breakable bottles used with CTT; rubber-tubing used with suction machines; and CTT drainage. The hospital also recycles materials such as newspapers, cartons, empty water bottles, and IV plastic bottles. These recyclable wastes are sold by the maintenance personnel to junkshops.

Supplies used by Private Hospital 2 are disposable for the safety of people around including patients except their medical instruments used. Medical instruments went through a process of treatment with the use of autoclave machines before they are reused. Recycling of waste is not practiced in Public Healthcare Center. Materials being reused are treated and autoclaved before reusing them. The Clinic did not practice recycling waste generated. Some of the materials were put into the autoclave for treatment before reusing it.

**Strategies in Implementing Waste Management Program**

The Public Hospital followed the Health Care Waste Management System or HCWM of its institution. This is the systematic administration of activities that provide for segregation at source, segregated transportation, storage, transfer, processing, treatment, and disposal of healthcare waste that do not harm the environment. This complies with the DOH Standards.

The Private Hospital 1 Waste Management Program focused on source reduction by proper waste segregation, recycling, treatment, and residual disposal. Health Care Waste Minimization centered on how to reduce waste. This was done through reduction at source, which involved complete elimination of waste or lessening the waste generated. Reuse, recycling, and segregation of waste using the color coding scheme were done. To reduce waste at source the hospital purchased/selected supplies that were less wasteful and less hazardous. They used less hazardous methods in cleaning. To make their waste management program effective, they launched a massive educational and communication program for their staff. Periodic monitoring and evaluation of the program is done.

No strategies or specific program in support of waste management program was provided by 60% of the healthcare provider (Private Hospital 2, Public Healthcare Center, and the Clinic. But their segregation, storage, collection, and disposal of their wastes show that they adhere to the RA 9003 and DOH standards.

## CONCLUSIONS

The adherence of the healthcare providers in Camiling, Tarlac to RA 9003 or the Ecological Solid Waste Management Act of 2000 and the DOH standards had fully prevented human health deterioration in the community but not land degradation. Their responsibility of ensuring that there is no adverse health in their management of healthcare wastes was because they consider first the health and occupational safety of the people.

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Proper collection and disposal of solid wastes in the health care units have greatly helped in the control of insects, rodents, and filth bone diseases and prevented fire-cause hazards by instantaneous combustion in the dumpsite. Proper treatment and disposal however of hazardous and infectious wastes have prevented the short and long-term irreversible health risks.

The off-site disposal of general residuals of the health care units in the Matubog dumpsite was along the stream of the household and commercial wastes of the Municipality. The infectious and hazardous wastes were treated and disposed of properly. However, burial as means of disposing of infectious wastes is not sustainable and the lack of a common disposal system of infectious and hazardous wastes was practiced by the hospitals.

Between private and public health care units, the private hospitals were more conscientious in implementing their waste management program. The limited resources, facilities, and manpower while catering to more number of patients may be the reasons for the poor implementation of public hospitals in private hospitals.

## RECOMMENDATIONS

Big or small institutions should have waste management written policies for the proper disposal of healthcare waste and strictly follow them. The Camiling Health Center should have concrete rules and regulations regarding healthcare waste management. Each unit should have a waste minimization written policy with specific goals, objectives, and timeliness to have a successful and sustainable waste management program.

The health care owners/administrators should not only consider burial ways of disposing of infectious wastes. Less permeable material should cover the burial pits to avoid seepage of liquid infectious wastes to the groundwater table and other run-offs. They should also consider other treatment methods such as radiation technology, encapsulation, inertization, etc. aside from the usual chlorination process that they employ to ensure the minimization of infection or widespread disease.

The Municipality of Camiling should allocate financial resources for the proper collection of hospital wastes. They have to ensure that hospital waste bags are properly labeled before collecting by their dump trucks. Healthcare wastes should be separately collected and disposed of from the residuals generated by the community. The Municipality should design and build a sanitary landfill, unlike the open dumping at Brgy. Matubog. Relocation of the dumpsite is worth reconsidering.

Government hospitals should allocate bigger funds for their waste management program. A stricter policy should be drafted and followed. It should also be part of their mission and goals. It should be a way of life for the healthcare providers. They have to be competitive with the private hospitals in implementing waste minimization programs.

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DOI 10.17605/OSF.IO/7GKA6

**References**

1. Al-Balushi S. and Khan F.R. (2017) Factors Influencing the Preference of Private Hospitals to Public Hospital in Oman. International Journal of Management, Innovation & Entrepreneurial Research EISSN: 2395-7662, Vol. 3. No. 2 pp. 67-78
2. Das, A.K., Islam, N., Billah, M., Sarker, A. (2021). Covid-19 pandemic and healthcare solid waste management strategy - A mini-review. Science of the the Total Environment Vol. 778, 146220
3. DOH Health Care Waste Management Manual 2020. 4th Edition. Wash in Health Care Facilities. https://www.washinhcf.org
4. Ghassemi, M.K. and Yussuf, R.B.M. (2016) Advantages and Disadvantages of healthcare waste treatment and disposal alternatives: Malaysian Scenario. Pol. J. Environ. Stud. Vol 25, No. 1 17-25
5. Hossain, M.S., Santhanam, A., Norulaina NAN, et al. (2011) Clinical solid waste management practices and its impact on human health and environment-A review. Waste Management 31: 754-766.
6. Mededdu, M., Pulina M., and Scuderi, R. (2020). Public and private healthcare services: What drives the choice? Socio-Economic Planning Sciences, Vol. 70
7. Patwary, M.A., O'Hare, W.T., Sarjer, M.H. (2011) Assessment of occupational and environmental safety associated with medical waste disposal in developing countries: A qualitative approach. Safety Science 49:1200-1207
8. Rao, P.H. **(**2008). Waste management & research: The journal of the international solid wastes and public cleansing association**.** Waste Management Research Journal. 2008 Jun; 26(3):297-303
9. Takele T. (2009). Lecture on solid and hazardous waste. University of Gondar in collaboration to the Ministry of Health, Ethiopia and USAID.

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AGRICULTURAL CHEMISTRY AND FERTILITY OF SOILS

# Delineation of Micronutrient Deficient Zones in Agricultural Soils of Santa Ignacia, Tarlac

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**Abstract**—Delineation of nutrient-limited zones in agricultural soils is delicate in achieving balanced fertilization and appropriate land management. Due to the lack of detailed information regarding micronutrient availability in Santa Ignacia, Tarlac, Central Luzon Philippines, a study was conducted to investigate the spatial distribution of Zn, Cu, Fe and Mn in the municipality. Soil test results were subjected to descriptive statistics and geo-analytical technique through best fit semivariogram based on highest coefficient of determination. Then, ordinary kriging was employed using the optimum model to generate spatial variability maps and eventually delineate nutrient limited areas. Micronutrient concentration in the area followed the order Fe > Mn > Cu > Zn with moderate to strong variability. Spatial dependence factors (SDf) were found to be moderate for Zn and Cu, while strong SDf were recorded for Fe and Mn. Zn deficient zones accounting to 2517 ha were delineated in the extreme northern and southern region of the municipality. Cu deficient zone covering 1893 ha was delineated at the east-central region of the study area. Meanwhile, no limited zones were delineated for Fe and Mn indicating the relative abundance of these nutrients in Santa Ignacia, Tarlac. Therefore, interventions to increase Zn and Cu availability in deficient zones are recommended to further improve crop yields in the municipality.

**Keywords:** kriging, micronutrient, semivariogram, spatial variability, Inceptisols

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## INTRODUCTION

Essential micronutrients primarily serve as catalyst in enzyme systems and are required in numerous metabolic functions [37]. Although they are needed in minute amounts, the deficiency or abundance of these elements directly affects crop nutrition and environmental pollution [4, 10]. Intensified crop production in past years have resulted in the decline of fertility and overall quality of soils in the Philippines. The Department of Agriculture and prior research have reported cases of micronutrient deficiency in agricultural soils, though its distribution has not been thoroughly analyzed and studied [24, 31]. The lack of micronutrient management system employed in farmlands coupled with indiscreet use of chemical inputs have caused the imbalance of soil nutrients [48]. These issues amplify the call to conduct investigation on the fertility status of soil resources in the country.

The interplay of weathering process, natural events and anthropogenic factors may generate levels of spatial variation among trace elements in different agroecosystems [17, 41]. Zonal delineation on the availability of soil nutrients is a key element of precise agriculture. The identification of nutrient limited and sufficient zones is required to formulate an appropriate and site specific nutrient management scheme [36]. Although fertility maps are available in the region, it is limited to some macronutrients namely, nitrogen, phosphorus and potassium. Characterization and distribution of trace elements in local soils are often neglected. Thus, there is an urgent need to precisely describe the spatial distribution of micronutrients in the study area.

In this regard, geostatistical techniques have become a standard in the analysis of spatial differentiation concerning soil nutrients. Integrating spatial information in geostatistical models can refine estimation and improve map accuracy [26]. Among the various geostatistical methods employed by the researchers for generating soil fertility maps, ordinary kriging remains to be the most commonly utilized interpolation technique [6, 36, 44]. It has the potential to provide the best unbiased linear predictions and generate information regarding estimation errors while reducing the local error variance [27]. It is proven to be fast, cost-efficient and reliable method of producing thematic maps that will serve as basis for appropriate land management. Therefore this study aims to (i) assess the level of micronutrient elements (Zn, Cu, Mn, Fe) in the study area and (ii) delineate micronutrient deficient zones using optimal semivariogram (ordinary kriging) models.

**Table 1.** Micronutrients rating based on soil test values, mg $kg^{-1}$

| Soil test | Deficient | Sufficient | | |
|---|---|---|---|---|
| | | moderate | high | extremely high |
| Zinc | <0.5 | 0.5–1.0 | 1.0–3.0 | >3.0 |
| Copper | <0.2 | 0.2–1.0 | 1.0–1.8 | >1.8 |
| Iron | <4.5 | – | – | – |
| Manganese | <5.0 | 5.0–15.0 | 15.0–30.0 | >30.0 |

## MATERIALS AND METHODS

**Site description.** The study was conducted in the Municipality of Santa Ignacia, Tarlac. It is within the Central Luzon region of the Philippines. The capital of the area is geographically located at 15.5841° N and 120.4688° E. It is bounded on the north by the town of Camiling, on the south by San Jose, on the west by Mayantoc and on the east by Gerona, Tarlac. The municipality has a relatively flat terrain in the central and eastern portion, while moderately hilly on the western side. The total land area is 14 189 ha, and most of it is involved in agriculture (Fig. 1). It produces a wide range of crops, including rice, fruits and vegetables. The dominant soil type in the area is fine loamy textured inceptisol characterized by isohyperthermic temperature regime with incipient development towards maturity but not fully developed diagnostic horizons. This soil has minimum complexity towards horizonation which is commonly found in areas with pronounced wet and dry seasons [5, 33]. Soil pH in the area ranges from extremely acidic to slightly alkaline while organic matter (OM) varies from low to medium levels. Finally, the levels of phosphorus (P) and potassium (K) range from low to high concentrations. Based on Corona Climate Classification, Santa Ignacia belongs to Climate Class I which has pronounced wet and dry periods. Annual average precipitation sits at 715 mm where maximum rainfall occurs in the months of July and August. Temperature in the area ranges from 22–31°C, maximum temperature occurs during April and May while minimum temperature is felt in the months of January and February.

**Soil sampling and analysis.** A total of 336 soil samples at a depth of 0–30 cm were randomly collected in the study area. The geographic location of each sampling point was recorded using a handheld GPS. Distribution of sampling points is shown in Fig. 1. Each soil sample was air dried while impurities were removed by hand before passing through a 2 mm mesh and eventually stored in a clean plastic container. Micronutrients including Fe, Cu, Zn and Mn were analyzed through diethylenetriaminepentaacetic acid extraction–atomic absorption spectrometry (DTPA-AAS) using of 1 : 2 soil:extractant ratio as described in FAO–Standard Operating Procedure for Soil Available Micronutrients and Heavy Metals [8, 18]. In addition, soil pH, organic matter and phosphorus were also analyzed using 1 : 1 soil and water suspension [12], Walkley and Black [45] and Olsen extractant method [30], respectively. Soil test values were interpreted and clustered based on micronutrient fertility standards of Philippine Council for Agriculture and Resources Research and other relevant literature [36, 48].

**Data processing and analysis.** Descriptive statistical analysis was executed using SPSS 20.0 software. Semivariance analyses and model fitting were conducted using GS + 9.0 software. Models with maximum coefficient of determination ($R^2$) were identified as optimal model parameters [16]. The best fit model was then used as basis for ordinary kriging interpolation using ArcGIS 10.4 (ESRI, Redlands, CA, USA). Semivariance is expressed as follows:

$$r(h) = \frac{1}{2N(h)}\sum_{i=1}^{n(h)}[z(Xi) - z(Xi + h]^2,$$

where $r(h)$ is the semivariogram, h is the separation distance, $N(h)$ is the pairwise number of data points separated by distance h, $Z(x)$ is the value of a regionalized variable at spatial position $x$, and $Z(x + h)$ is the value of a regionalized variable at position $x + h$. Nugget, sill and range are key parameters of semivariogram models to describe spatial structure. Furthermore, the nugget/sill ratio and spatial dependence factor (SDf) represents the spatial autocorrelation between variables. SDf < 25% indicates high spatial correlation, in which natural factors are the principal drivers; SDf = 25–75% represents moderate spatial correlation which might be affected by both natural and anthropogenic factors; and SDf > 75% indicates low spatial correlation, where the variation is attributed to random factors [36, 48].

## RESULTS AND DISCUSSION

**Statistical characteristics of soil micronutrients**. Descriptive statistics of the soil test values are presented in Table 2. The micronutrient concentration in the area followed the order Fe > Mn > Cu > Zn. The Zn level in the study area ranges from 0.06–21.16 mg $kg^{-1}$ with a mean value standing at 1.21 mg $kg^{-1}$. It means that Zn concentrations are qualitatively classified as deficient to extremely sufficient. The Cu concentration ranges from 0.02 to 41.09 mg $kg^{-1}$ with a mean value at

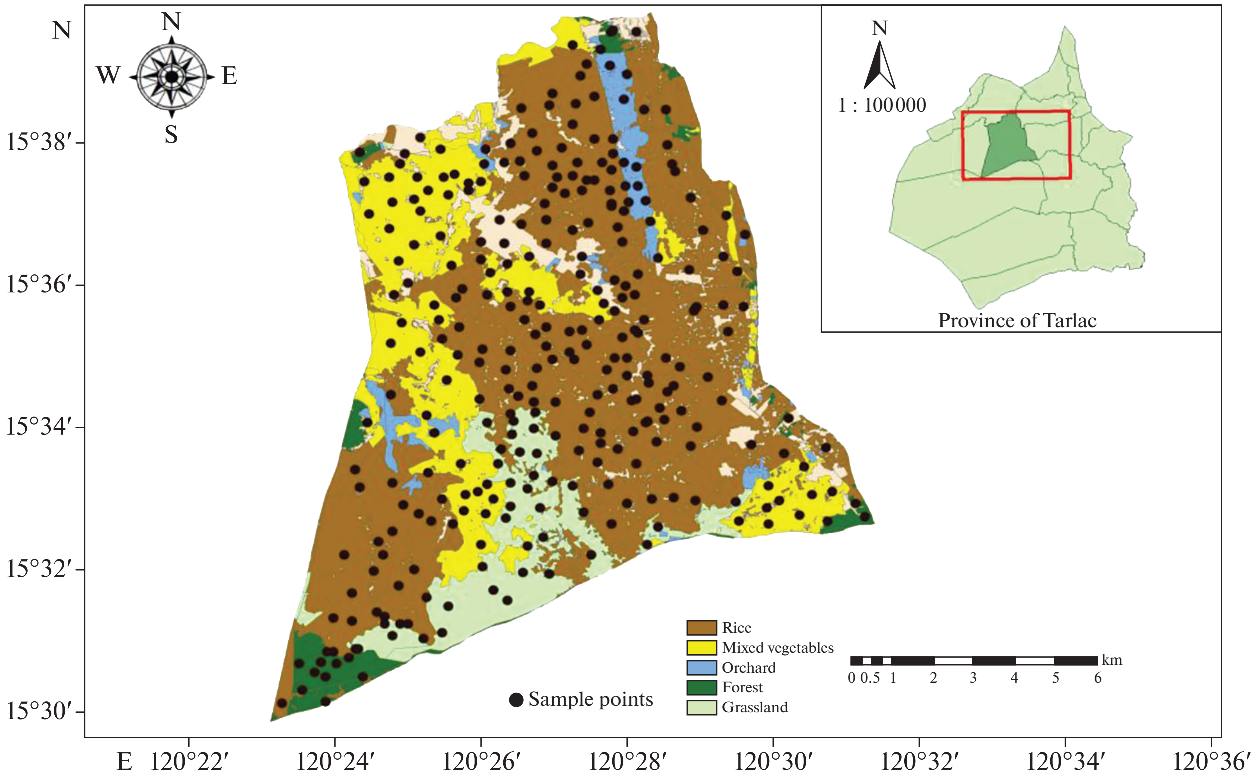


**Fig. 1.** Land use map and distribution of sampling points in the study area.

5.58 mg kg$^{-1}$. Likewise, clusters of soil test results are classified as Cu deficient to extremely sufficient. The levels of Fe and Mn ranges 13.97–237.28 and 15.95–246.97 mg kg$^{-1}$ respectively. These values are considered extremely sufficient, which indicates the relative abundance of Fe and Mn in the study area.

One of the very important statistical indices to reflect spatial variation is the CV. A CV of >1 is considered to be strong, while a CV of 0.1–1 and <0.1 is considered moderate and weak variation, respectively [25, 26, 31]. The CV of the subject elements is considered moderate to strong which ranges from 0.6 to 1.97. The order of variation among the nutrients is recorded as Zn > Cu > Mn > Fe. The considerable variation of micronutrients is a common finding especially in agriculture based ecosystems. Aside from parent materials, the nutrient variability in agricultural soils may be attributed to different land utilization types which requires varying fertilizer application, pest control, and other crop management systems [16, 46]. Taking into account the lack of micronutrient fertilization guide and indiscreet use of chemical inputs, it is not surprising to observe moderate to strong variability of soil nutrients in the study area.

Aside from soil micronutrients, different edaphic properties in the study area were also analyzed to determine their possible relationship. The correlation map of Zn, Cu, Fe, Mn, P, K, pH, and OM is summarized in Table 3. Cu concentration is correlated with pH and OM level. Cu concentrations vary with soil pH due to the dissolution of Cu insoluble composts or adsorption on the surfaces of Fe and Al oxides or precipitated in hydroxyl forms depending on the level of acidity [28]. Furthermore, OM has a dynamic relationship with the mobility of Cu in soils. The complex-

**Table 2.** Descriptive statistics of essential micronutrient elements, mg kg$^{-1}$

| Elements | Max | Min | Mean | Std. Dev. | Skewness | Kurtosis | CV |
|---|---|---|---|---|---|---|---|
| Zn | 21.16 | 0.06 | 1.21 | 2.39 | 7.18 | 58.71 | 1.97 |
| Cu | 41.09 | 0.02 | 5.85 | 7.24 | 2.38 | 7.15 | 1.23 |
| Fe | 237.28 | 13.97 | 89.11 | 53.13 | 0.87 | 0.13 | 0.60 |
| Mn | 246.97 | 15.95 | 60.39 | 43.58 | 1.61 | 3.32 | 0.72 |

Std. Dev, Standard Deviation; CV, Coefficient of Variation.

**Table 3.** Correlation matrix of soil trace elements

| Variables | pH | OM | P | K | Z | Cu | Mn | Fe |
|---|---|---|---|---|---|---|---|---|
| pH | **1** | **0.463** | –0.148 | 0.185 | 0.083 | **–0.421** | –0.195 | **–0.380** |
| OM | **0.463** | **1** | –0.114 | 0.119 | 0.095 | **0.337** | –0.100 | –0.091 |
| P | –0.148 | –0.114 | **1** | –0.015 | 0.133 | –0.094 | –0.196 | 0.142 |
| K | 0.185 | 0.119 | –0.015 | **1** | –0.045 | 0.081 | –0.056 | 0.036 |
| Z | 0.083 | 0.095 | 0.133 | –0.045 | **1** | **–0.216** | **–0.217** | –0.088 |
| Cu | **–0.421** | **0.337** | –0.094 | 0.081 | **–0.216** | **1** | 0.185 | –0.019 |
| Mn | –0.195 | –0.100 | –0.196 | –0.056 | **–0.217** | 0.185 | **1** | 0.062 |
| Fe | **–0.380** | –0.091 | 0.142 | 0.036 | –0.088 | –0.019 | 0.062 | **1** |

Values in bold are different from 0 with a significance level $\alpha = 0.05$.

**Table 4.** Geostatistics of the fitted semivariogram models of micronutrients

| Elements | Model | Nugget | Sill | NSR | $R^2$ | SpD |
|---|---|---|---|---|---|---|
| Zinc | Spherical | 1.25 | 2.26 | 0.55 | 0.73 | 55.30 |
| Copper | Spherical | 1.19 | 1.92 | 0.62 | 0.69 | 61.90 |
| Iron | Exponential | 115 | 483 | 0.23 | 0.81 | 23.80 |
| Manganese | Exponential | 80 | 423 | 0.18 | 0.89 | 18.91 |

NSR—nugget to sill ratio; $R^2$—R-squared; SpD—spatial dependence factor.

ation of OM with Cu is an important mechanism in its retention and bio-availability [25]. Meanwhile, Fe is negatively correlated with pH. Fe is commonly affected by pH due to the latter's direct effect on the precipitation of soluble Fe into insoluble forms [13]. Interestingly, Zn has negative correlation to Cu and Mn, which suggests negative interactions among these nutrients. Alloway [2] reported that the relationships between Cu and Zn are often antagonistic because of their competitive adsorption on soil colloids and absorption sites of plant roots. Cu fertilization has been shown to alter Zn dynamics in soil or vice versa [20, 21]. Interestingly, Rahman et al. [35] reported that Cu and Zn were mostly speciated as carbonate phases under P-deficient condition. The complexation of these elements with carbonate and phyllosilicate minerals is likely the controlling factor of their bio-availability. In addition, Vasu et al. [43] identified antagonistic nutrient interaction as one of the primary drivers of the concentration and spatial characteristics of micronutrients under semi-arid tropical environment. Thus, co-fertilization trial of Cu and Zn may be explored to further characterize the antagonistic behavior of these nutrients in local soils of Santa Ignacia.

**Spatial structure and variability of micronutrients.** Spherical model was the optimum semivariogram function for Zn and Cu, while exponential model was optimum for Fe and Mn. The highest coefficient of determination ($R^2$) was observed for Mn at 0.89, and Cu has the least $R^2$ at 0.69. A strong spatial dependence factor was observed for Fe (23.80) and Mn (18.91). It indicates that spatial variation of Fe and Mn in the study area is primarily affected by soil forming factors, including parent material, terrain and other structural parameters. Same results were reported by Kavitha et al. [16], Shukla et al. [38] and Zou et al. [48] regarding strong spatial dependence of these nutrients. However, contrary results were reported by Odoi et al. [30] indicating weak SpD of Fe and Mn within the industrial zone of Ghana. They identified the discharge of industrial waste as main factor on the spatial structure of such nutrients. Thus, the absence of heavy industrialization and other similar activities in Santa Ignacia might have caused the dominance of structural factors on the spatial characteristics of Fe and Mn.

On the other hand, moderate spatial dependence factor (SpD) was observed for Zn (55.30) and Cu (61.90). Moderate SpD suggest that spatial variation of these nutrients is primarily affected by the simultaneous action of structural and random factors, including land use, crop management and anthropogenic pollution [48]. Moderate spatial dependence was also observed by Shukla et al. [38] and Liu et al. [19] for Cu and Zn respectively. They hypothesized that the spatial characteristics of these nutrients may be attributed to the imbalance utilization of heavy metal containing inputs in crop production. Furthermore, weak SpD for Zn and Cu was even observed in various crop producing areas which suggest the significant effect of farm management on the variability of these nutrients [34, 38]. Such findings on spatial autocorrelation indicate the need to conduct a deeper analysis on the specific causes of spatial variability of soil micronutrients in the study area.

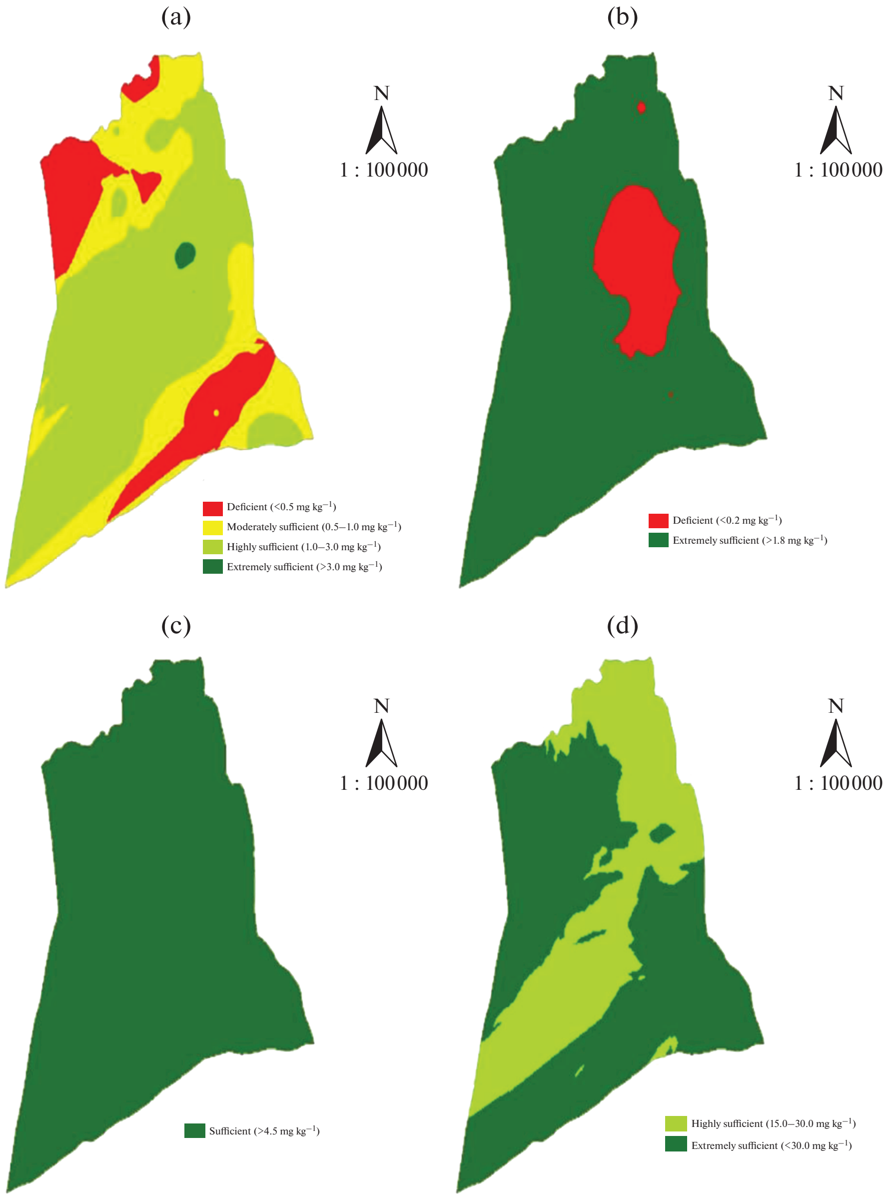


**Fig. 2.** Spatial variability map of micronutrients (a) zinc, (b) copper, (c) iron, (d) manganese.

The spatial variability of micronutrient concentration in the study area is displayed in Fig. 2. Zn deficient zones accounting to 2517 ha were delineated in the extreme northern and southern region of the municipality, while the remaining portion varies from highly to extremely sufficient. The application of zinc sulphate is recommended to correct the deficiency in the concerned areas. Under flooded conditions, zinc

**Table 5.** Distribution of micronutrient availability classes

| Fertility class | Zn | | Cu | | Fe | | Mn | |
|---|---|---|---|---|---|---|---|---|
| | area, ha | % | area, ha | % | area, ha | % | area, ha | % |
| Deficient | 2517 | 18 | 1893 | 13 | – | – | – | – |
| Moderate | 3469 | 24 | – | – | – | – | – | |
| High | 8061 | 57 | – | – | 14189 | 100 | 5788 | 41 |
| Extremely High | 142 | 1 | 12296 | 87 | – | – | 8401 | 59 |

solubility often decreases due to mechanisms associated with soil redox status [1, 3]. Since paddy rice is the dominant crop in the area, water management system to improve aeration and drainage may be employed to increase zinc solubility [13]. Other options, such as utilization of ammonium sulfate and applying organic fertilizer to further increase the availability of zinc may also be considered [11]. Cu deficient zone covering 1893 ha of the study area was delineated at the east-central region. The remaining portion of the area is classified as highly sufficient for Cu. The addition of CuO or $CuSO_4$ in deficient areas is recommended to balance Cu levels. The amendment of Cu-enriched foliar fertilizer and elemental sulfur is likewise recommended to increase Cu absorption by plants [11, 14]. Finally, no deficient zones were delineated for Fe and Mn. The levels of these nutrients are found to be highly sufficient in the study area.

The results of the study concur with prior research regarding micronutrient status of farmlands in the Philippines. Yoshida et al. [47] estimated around 500000 ha of Zn deficient rice areas alone. Katyal and Vlek [15] also reported Zn deficiency in some hydrosols and gleysols in the country. Mahagud et al. [22] likewise assessed widespread Zn deficiency especially in lowland areas. Furthermore, the Philippines was also included in a group of countries with serious Zn deficiency problem in their agricultural soils [2]. Meanwhile, Descalsota et al. [7] reported Cu deficiency in particular areas of Central Luzon including some parts of Muñoz, Llanera, and Zaragosa in Nueva Ecija; La Paz in Tarlac and Santa Cruz in Zambales. Finally, Mahagud et al. [23] reported high levels of Fe and Mn in agricultural areas of Central Luzon. Toxic accumulations of Fe and Mn (300 and 1000 mg $kg^{-1}$ respectively) are observed in rice plants evidencing the abundance of these elements in the area.

## CONCLUSIONS

The study provides the first micronutrient availability map of Santa Ignacia, Tarlac. Moderate to strong variability of micronutrients was observed in the area. Zn (18%) and Cu (13%) deficient zones have been delineated in multiple regions of the municipality. The employment of field measures to increase Zn and Cu availability in deficient areas is recommended to further increase crop yields in the municipality. Meanwhile, Fe and Mn are found to be entirely sufficient suggesting their relative abundance in the study area. Geo-statistical method is indeed a time and cost-effective tool in mapping various soil properties. Finally, the results of this study can be used to formulate site specific nutrient management and other relevant land policies in Santa Ignacia, Tarlac.

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## CONFLICT OF INTEREST

The authors declare no conflicts of interest in the conduct of this research.

## REFERENCES

1. A. S. Abdullah, "Zinc availability and dynamics in the transition from flooded to aerobic rice cultivation," J. Plant Biol. Soil Health **2** (1), 5 (2015).
2. B. J. Alloway, *Zinc in Soils and Crop Nutrition* (IZA and IFA, Brussels, Paris, 2008), pp. 92–109. https://www.topsoils.co.nz/wp-content/uploads/2014/09/Zinc-in-Soils-and-Crop-Nutrition-Brian-J.-Alloway.pdf.
3. M. A. Bunquin, S. Tandy, S. J. Beebout, and R. Schulin, "Influence of soil properties on zinc solubility dynamics under different redox conditions in non–calcareous soils," Pedosphere, 96–105 (2017). https://doi.org/10.1016/S1002-0160(17)60299-6
4. A. Chrysargyris, M. Höfte, N. Tzortzakis, S. A. Petropoulos, and F. Di Gioia, "Editorial: micronutrients: the borderline between their beneficial role and toxicity in plants," Front. Plant Sci. **13,** (2022). https://doi.org/10.3389/fpls.2022.840624
5. *Atlas of Soil-Based Agricultural Guide Maps V. 2. Luzon Island, Region III, IV-A, IV-B and V* (Department of Agriculture, Bureau of Soils and Water Management, 2019).
6. R. N. Desavathu, A. R. Nadipena, and J. R. Peddada, "Assessment of soil fertility status in Paderu Mandal, Visakhapatnam district of Andhra Pradesh through Geospatial techniques," Egypt. J. Remote Sens. Space Sci. **21** (1), 73–81 (2018). https://doi.org/10.1016/j.ejrs.2017.01.006
7. J. P. Descalsota, C. P. Mamaril, and G. O. San Valentin, "Fertility status of selected rice soils in the Philippines," Philipp. J. Crop Sci. **2** (2), 45–57 (2003). https://www.cabi.org/GARA/FullTextPDF/2009/20093019309.pdf.
8. *Standard Operating Procedure for Soil Available Micronutrients (Cu, Fe, Mn, Zn) and Heavy Metals (Ni, Pb, Cd), DTPA Extraction Method* (FAO, Rome, 2022). https://www.fao.org/3/cc0048en/cc0048en.pdf.
9. B. Hafeez, Y. M. Khanif, and M. Saleem, "Role of zinc in plant nutrition - a review," Am. J. Exp. Agric. **3** (2), 374–391 (2013).
10. Z. L. He, X. E. Yang, and P. J. Stoffella, "Trace elements in agroecosystems and impacts on the environment," J. Trace Elem. Med. Biol. **19** (2–3), 125–140 (2005). https://doi.org/10.1016/j.jtemb.2005.02.010
11. International Rice Research Institute, *Zinc Deficiency—IRRI Rice Knowledge Bank (N.D.).* http://www.knowl-

edgebank.irri.org/training/fact-sheets/nutrient-management/deficiencies-and-toxicities-fact-sheet/item/zinc-deficiency.

12. M. L. Jackson, *Soil Chemical Analysis*, 2nd Ed. (M. L. Jackson, Madison, 1973).
13. J. Jones, *Iron Availability and Management Considerations: A 4R Approach* (2020). https://acsess.onlinelibrary.wiley.com/doi/10.1002/crso.20019.
14. D. Kaiser and C. Rosen, *Copper for Crop Production* (2018). https://extension.umn.edu/micro-and-secondary-macronutrients/copper-crop-production.
15. J. C. Katyal and P. L. G. Vlek, "Micronutrient problems in tropical Asia," in *Micronutrients in Tropical Food Crop Production* (Springer Netherlands, Dordrecht, 1985), pp. 69–94. https://doi.org/10.1007/978-94-009-5055-9_3
16. C. Kavitha, M. P. Sujatha, and R. Tata, "Spatial variations in soil micronutrients as influenced by agro ecological conditions in a tropical humid region," Trop. Ecol. **60** (3), 362–378 (2019). https://doi.org/10.1007/s42965-019-00037-w
17. P. Kumar, P. Kumar, M. Sharma, A. Shuka, and N. Butail, "Spatial variability of soil nutrients in apple orchards and agricultural areas in Kinnaur region of cold desert, Trans-Himalaya, India," Environ. Monit. Assess. **194** (4), (2022). https://doi.org/10.1007/s10661-022-09936-3
18. W. L. Lindsay and W. A. Norvell, "Development of a DTPA soil test for zinc, iron, manganese, and copper," Soil Sci. Soc. Am. J. **42** (3), 421–428 (1978). https://doi.org/10.2136/sssaj1978.03615995004200030009x
19. Z. Liu, W. Zhou, J. Shen, P. He, Q. Lei, and G. Liang, "A simple assessment of spatial variability of rice yield and selected soil chemical properties of paddy felds in South China," Geoderma **235**, 39–47 (2014). https://doi.org/10.1016/j.geoderma.2014.06.027
20. J. F. Loneragan and M. J. Webb, "Interactions between zinc and other nutrients affecting the growth of plants," in *Zinc in Soils and Plants* (Springer Netherlands, Dordrecht, 1993), pp. 119–134. https://doi.org/10.1007/978-94-011-0878-2_9
21. Y. Luo and D. L. Rimmer, "Zinc-copper interaction affecting plant growth on a metal-contaminated soil," Environ. Pollut. **88** (1), 79–83 (1995). https://doi.org/10.1016/0269-7491(95)91050-u
22. J. C. Magahud, R. B. Badayos, P. B. Sanchez, and P. C. Sta. Cruz, "Levels and sources of potassium, calcium, sulfur, iron and manganese in major paddy soils of the Philippines," Int. J. Philipp. Sci. Technol. **8** (2), 1–8 (2015). https://doi.org/10.18191/2015-08-2-014
23. J. C. Magahud, R. B. Badayos, P. B. Sanchez, and P. C. Sta. Cruz, "Levels and potential sources of heavy metals in major irrigated rice areas of the Philippines," IAMURE Int. J. Ecol. Conserv. **15** (1), (2015). https://doi.org/10.7718/ijec.v15i1.1000
24. J. Manglapuz, Philippine Daily Inquirer (2023). https://newsinfo.inquirer.net/1731058/da-finds-micronutrient-deficiency-in-farmlands-across-ph.
25. L. Matijevic, D. Romic, and M. Romic, "Soil organic matter and salinity affect copper bioavailability in root zone and uptake by Vicia faba L. plants," Environ. Geochem. Health **36** (5), 883–896 (2014). Epub 2014 Apr 24. https://doi.org/10.1007/s10653-014-9606-7
26. T. G. Mueller and F. J. Pierce, "Soil carbon maps: enhancing spatial estimates with simple terrain attributes at multiple scales," Soil Sci. Soc. Am. J. **67** (1), 258–267 (2003). https://doi.org/10.2136/sssaj2003.2580
27. T. G. Mueller, N. B. Pusuluri, K. K. Mathias, P. L. Cornelius, R. I. Barnhisel, and S. A. Shearer, "Map quality for ordinary kriging and inverse distance weighted interpolation," Soil Sci. Soc. Am. J. **68** (6), 2042–2047 (2004). https://doi.org/10.2136/sssaj2004.2042
28. G. R. Nachtigall, R. C. Nogueirol, L. R. F. Alleoni, and M. A. Cambri, "Copper concentration of vineyard soils as a function of pH variation and addition of poultry litter," Braz. Arch. Biol. Technol. **50** (6), 941–948 (2007). https://doi.org/10.1590/s1516-89132007000700005
29. J. O. Odoi, F. A. Armah, and L. Luginaah, "Assessment of spatial variability of heavy metals in soils under the infuence of industrial soap and detergent waste water discharge," IJRRSA **9** (2), 322–329 (2011).
30. S. R. Olsen, C. V. Cole, F. S. Watanabe, and L. A. Dean, *Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate* (Circular, Washington DC, 1954), vol. 939.
31. D. Palanog, M. I. C. Calayugan, G. I. Descalsota-Empleo, A. Amparado, M. A. Inabangan-Asilo, E. C. Arocena, P. C. Sta. Cruz, T. H. Borromeo, A. Lalusin, J. E. Hernandez, C. Acuin, R. Reinke, and B. P. M. Swamy, "Zinc and iron nutrition status in the philippines population and local soils," Front. Nutr. **6**, (2019). https://doi.org/10.3389/fnut.2019.00081
32. Philippine Council for Agriculture and Resources Research, *Standard Methods of Analysis for Soil, Plant, Tissue, Water and Fertilizer* (1980).
33. Philippine Rice Research Institute, *PhilRice–Soils Information System* (2011). https://dbmp.philrice.gov.ph/soils/series.
34. H. B.Raghupathy and S. Srinivas, "Spatial variability studies in mango for identification of nutrient imbalance using GIS technique," in *ISRS Proceeding Papers of Sort Interactive Session (2014). ISPRS TC VIII International Symposium on "Operational Remote Sensing Applications: Opportunities, Progress and Challenges"* (Hyderabad), pp. 9–12.
35. N. Rahman, D. Peak, and J. Schoenau, "Antagonistic effect of copper and zinc in fertilization of spring wheat under low soil phosphorus conditions," Can. J. Soil Sci. **102** (3), 797–809 (2022). https://doi.org/10.1139/cjss-2021-0189
36. R. P. Sharma, S. Chattaraj, D. Vasu, K. Karthikeyan, P. Tiwary, R. K. Naitam, B. Dash, G. Tiwari, A. Jangir, A. Daripa, S. K. Singh, S. G. Anantwar, and A. M. Nimkar, "Spatial variability assessment of soil fertility in black soils of central India using geostatistical modeling," Arch. Agron. Soil Sci., 1–13 (2020). https://doi.org/10.1080/03650340.2020.1766678

37. A. Shenkin, "Micronutrients in health and disease," Postgrad. Med. J. **82** (971), 559–567 (2006). https://doi.org/10.1136/pgmj.2006.047670

38. K. Shukla, S. K. Behera, N. K. Lenka, P. K. Tiwari, C. Prakash, R. S. Malik, N. K. Sinha, V. K. Singhd, A. K. Patra, and S. K. Chaudhary, "Spatial variability of soil micronutrients in the intensively cultivated Trans-Gangetic Plains of India," Soil Tillage Res. **163**, 282–289 (2016). https://doi.org/10.1016/j.still.2016.07.004

39. F.-F. Song, M.-G. Xu, Y.-H. Duan, Z.-J. Cai, S.-L. Wen, X.-N. Chen, W.-Q. Shi, and G. Colinet, "Spatial variability of soil properties in red soil and its implications for site-specific fertilizer management," J. Integr. Agric. **19** (9), 2313–2325 (2020). https://doi.org/10.1016/s2095-3119(20)63221-x

40. X.-D. Song, D. J. Brus, F. Liu, D.-C. Li, Y.-G. Zhao, J.-L. Yang, and G.-L. Zhang, "Mapping soil organic carbon content by geographically weighted regression: a case study in the Heihe River Basin, China," Geoderma **261**, 11–22 (2016). https://doi.org/10.1016/j.geoderma.2015.06.024

41. G. S. Tagore, S. K. Sethy, P. S. Kulhare, and G. D. Sharma, "Characterization of spatial variability of micro nutrients in soils: classical vs. geo-statistical approach," Commun. Soil Sci. Plant Anal. **2022**, 1–16 (2022). https://doi.org/10.1080/00103624.2022.2118292

42. G. S. Tagore, G. D. Bairagi, R. Sharma, and P. K. Verma, "Spatial variability of soil nutrients using geospatial techniques: a case study in soils of sanwer tehsil of Indore district of Madhya Pradesh," in *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Symposium, ISPRS Technical Commission VIII* (Hyderabad, 2014).

43. D. Vasu, N. Sahu, P. Tiwary, and P. Chandran, "Modelling the spatial variability of soil micronutrients for site specific nutrient management in a semi-arid tropical environment," Model. Earth Syst. Environ. **7**, 1797–1812 (2021). https://doi.org/10.1007/s40808-020-00909-4

44. D. Vasu, S. K. Singh, N. Sahu, P. Tiwary, P. Chandran, V. P. Duraisami, V. Ramamurthy, M. Lalitha, and B. Kalaiselvi, "Assessment of spatial variability of soil properties using geospatial techniques for farm level nutrient management," Soil Tillage Res. **169**, 25–34 (2017). https://doi.org/10.1016/j.still.2017.01.006

45. A. Walkley and I. A. Black, "An examination of the degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method," Soil Sci. **37** (1), 29–38 (1934). https://doi.org/10.1097/00010694-193401000-00003

46. R. Wang, R. Zou, J. Liu, L. Liu, and Y. Hu, "Spatial distribution of soil nutrients in farmland in a hilly region of the Pearl River delta in China based on geostatistics and the inverse distance weighting method," Agriculture **11**(1), 50 (2021). https://doi.org/10.3390/agriculture11010050

47. S. Yoshida, J. S. Ahn, and D. A. Forno, "Occurrence, diagnosis, and correction of zinc deficiency of lowland rice," Soil Sci. Plant Nutr. **9** (2), 83–93 (1973). https://doi.org/10.1080/00380768.1973.10432522

48. R. Zou, Y. Zhang, Y. Hu, L. Wang, Y. Xie, L. Liu, H. Yang, and J. Liao, "Spatial variation and influencing factors of trace elements in farmland in a lateritic red soil region of China," Agronomy **12** (2), 478 (2022). https://doi.org/10.3390/agronomy12020478

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# Small Farm Reservoir Suitability Analysis in Tarlac Province, Philippines

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**Abstract** Small farm reservoir (SFR) suitability analysis is useful in water resources management and development assistance of government and non-government agencies for farmers and farmer-groups. The researcher utilizes the geographic information system to analyze the suitable areas for the construction and management of small water impounding to store and conserve rainwater in rainfed areas. The factors on rainfall, soil texture, slope, land use, irrigation status, groundwater availability and distance from river were considered for the suitability mapping of SFRs. The following factors have their corresponding weights which are derived from using the analytical hierarchy process (AHP) procedure. The testing of the model was done by determining the suitability value (S) of each sample SFR. The research findings showed the areas in the province potentially suitable for SFRs of the total land area of Tarlac: 47% are not suitable, 25% are marginally suitable, 13% are moderately suitable and 15% are highly suitable.

**Keywords** Suitability, Small Farm Reservoir, Geographic Information System, Rainfed Areas, AHP

## 1. Introduction

The Philippines has 41% total rainfed cropped area that mostly relies on rainfall; however its availability is lesser in dry season (Moya *et al.,* 1994). In addition, development of facilities for conventional irrigation is unlikely because of undulating topography, surface drainage and monetary constraints. Rainfed farmers suffer frequently from drought because of the inadequate water together with poor management practices of irrigation water. To mitigate the effect of drought in these areas, farmers with small farms are collecting rainfall and runoff and storing rainwater in small farm reservoir to be used for the wet and dry season crops (Guerra *et al*., 1994). Small farm reservoir (SFR) is an earth dam structure used to harvest and store rainfall and runoff for irrigation. It is the smallest version of small water impounding project with an embankment height of less than 4 meter (Ines *et al*, 2018). Studies showed that small farm reservoirs (SFRs) serve as an economically viable means for storing and conserving rainwater to lessen the effect of drought and cropping intensification in rainfed drought-prone areas. However, information about this technology is very limited making a hindrance to researchers, technical implementers and government agencies in utilizing its maximum potential in rainfed areas. Generating information system about SFRs with the aid of geographic information system (GIS) technology can be used as a basis for areas suited for SFRs as an effective water management scheme for individual farmer and farmer groups to improve crop production. Furthermore in the water resources development planning strategies of the government for the national, regional and local levels, as GIS has often used for the geographic concerns on agriculture. Thus, the objective of the study was to generate suitability maps for SFR construction in the province of Tarlac.

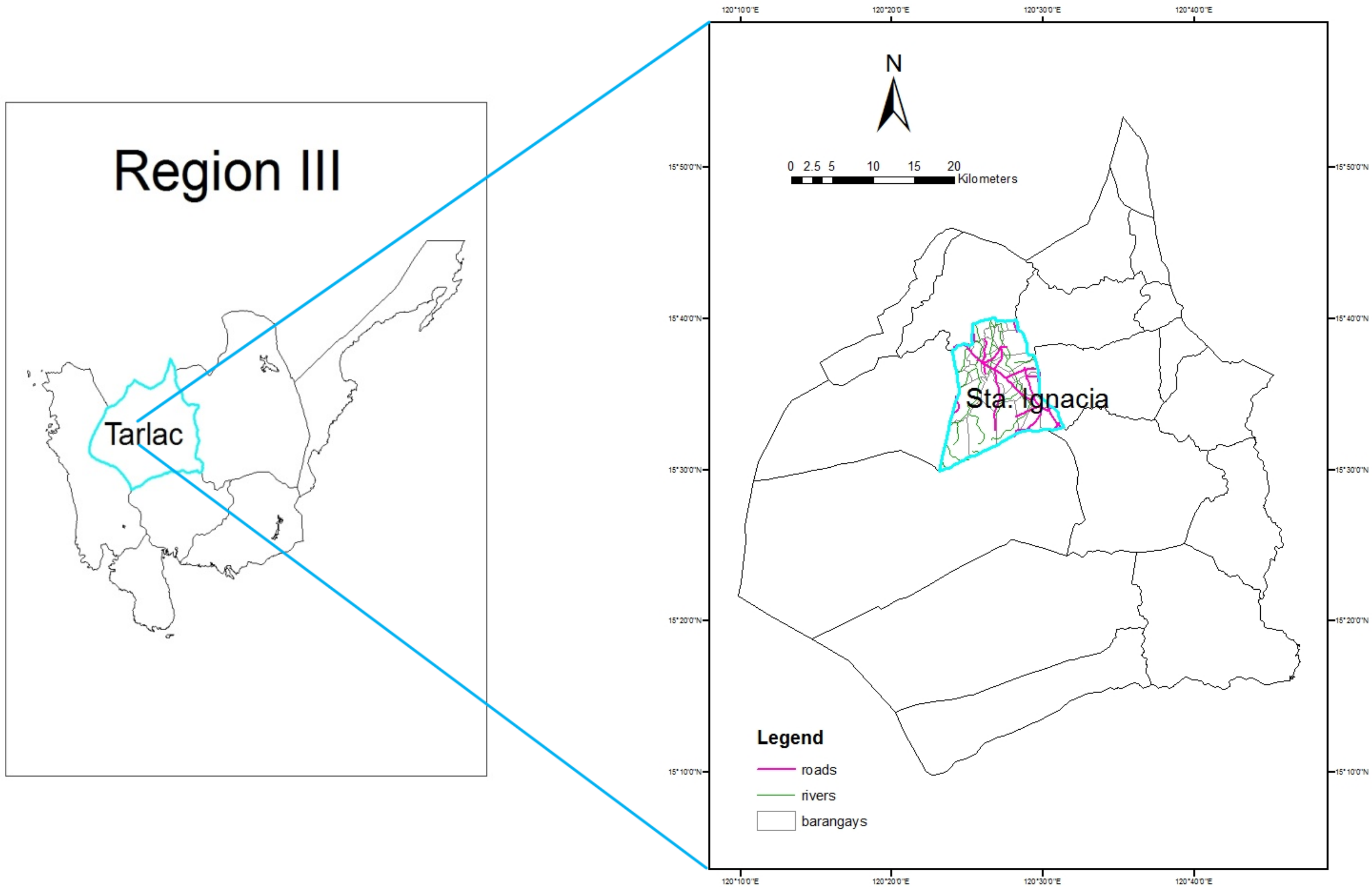



**Figure 1.** Map of Tarlac Province, Philippines

## 2. Materials and Methods

**Study Area**

The study was established in the province of Tarlac (Figure 1). The study covers an area of 273,660 hectares and is located between latitude 15º 10’15” N to 15º 52’52” N, longitude 120º 8’4” E to 120º 46’27” E. The study area has flat to undulating topography, with the eastern part of the province being plain and the western part to be hilly to mountainous. Tarlac has two distinct seasons, the wet and the dry seasons. It has unimodal rainfall pattern, having high monsoon rains in wet season (WS) and lesser amount of rainfall in dry season (DS). Recorded annual rainfall varies from 2,030 mm to 4,060 mm in the northwestern portion.

**Data Acquisition**

Rainfall map, soil texture map, slope map, land use map, irrigation status map, groundwater availability map and distance from river map were acquired from corresponding agencies namely in local agrometeorological station, Mines and Geosciences Bureau (MGB), National Mapping and Resource Information Authority (NAMRIA), National Irrigation Administration (NIA), National Water Resources Board (NWRB) and Department of Agriculture – Bureau of Agricultural Research (DA-BAR), respectively.

**Suitability Factors**

The data on rainfall, soil texture, slope, land use, irrigation status, groundwater availability and distance from river were used as the factors in the suitability mapping of SFRs. In the study of Cacayan *et.al* (2019), the factors considered are average annual rainfall, soil texture, slope and irrigation status while the past study of Galang *et.al* (1994), the criteria used at macrolevel are land use, slope, road network, municipal boundaries; however rainfall and soil type are excluded in the study. On the study of De Guzman (2013), the factors on rainfall, soil texture, slope, land use, irrigation status, groundwater availability and distance from river were used. The corresponding weights of these factors and its suitability ratings were determined. The factor maps derived from the seven thematic maps were integrated to the GIS (ArcGIS) software to develop a final suitability map to show the potential sites for SFRs construction. The methodology for identifying potential sites for SFRs is summarized in Figure 2.

**Suitability Model for Evaluation of the Potential SFR Sites**

Identification of the potential areas involves finding the areas that will satisfy a chosen set of criteria for establishment of SFR. Testing considers the impact of the system adoption.

The small farm reservoir suitability model (S) (equation 1) was derived from combining the factors with their corresponding weights for determining the potential areas for SFR in the final suitability map. Every location in the map had a suitability value. The formula below was used in calculating the suitability value of each grid cells:

$$S = [(\text{Rainfall x rf}) + (\text{Soil texture x stf}) + (\text{Groundwater availability x gf}) + (\text{Slope x sf}) + (\text{Land use x lf}) + (\text{Irrigation status x if}) (\text{Distance x af})] \quad (1)$$

where:

S = Suitability value for small farm reservoir
Rainfall = Rainfall factor map
Soil texture = Soil texture factor map
Slope = Slope factor map
Land use = Land use factor map
Irrigation status = Irrigation status factor map
Groundwater availability = Groundwater availability factor map
Distance = distance from river factor map
rf = rainfall weight
stf = soil texture weight
sf = slope weight
lf = land use weight
if = irrigation status weight
gf = groundwater availability weight
af = distance from river weight

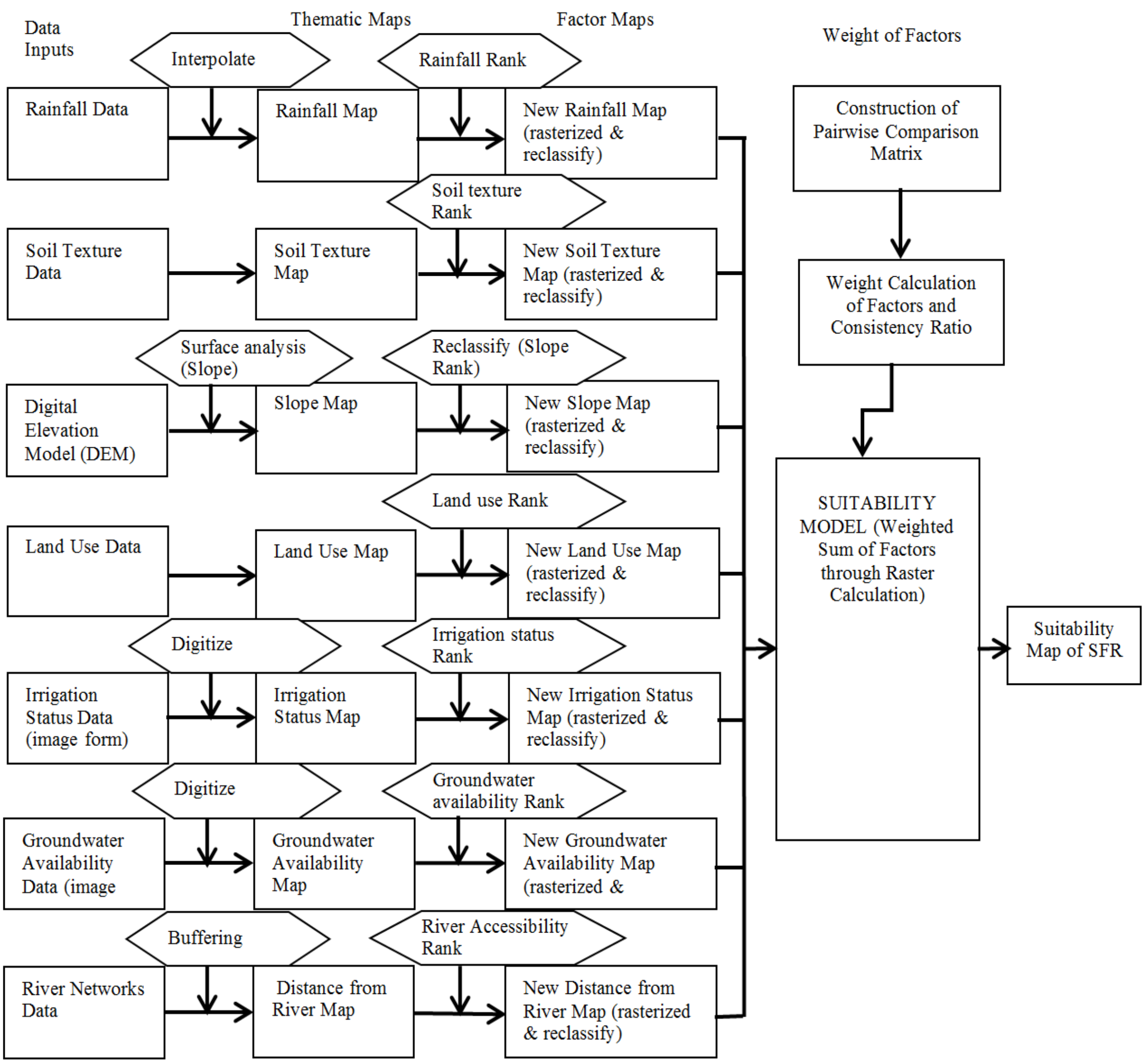



**Figure 2.** Methodology for identifying potential sites for SFRs

**Table 1.** Ranking of factors for SFRs

| Factors | Description | Suitability Scale |
|---|---|---|
| Rainfall [a] | <1000 mm | 1 |
| | 1000 - 1200 mm | 2 |
| | >1200 mm | 3 |
| Soil texture [b] | other class {sand, silt loam, silt, clay, Mountain soil (undifferentiated), Angeles soil (undifferentiated), Tarlac soils} | 0 |
| | sandy loam | 1 |
| | sandy clay loam | 2 |
| | clayloam & silty clayloam | 3 |
| Slope [c] | 3- 8% (gently sloping to undulating) | 3 |
| | 0 - 3% (level to nearly level) | 2 |
| | 8 - 18% (undulating to rolling) | 2 |
| | 18 - 30% (rolling to moderately steep) | 1 |
| | >30% (steep to very steep) | 0 |
| Land use | other land uses {built-up, closed forest, forest plantation, inland water, open forest, wooded lands} | 0 |
| | barren land | 1 |
| | Grassland | 1 |
| | cultivated land | 3 |
| Irrigation status | non-irrigated area | 3 |
| | irrigated area [d] | 0 |
| Groundwater availability [e] | deep well areas | 3 |
| | shallow well areas | 0 |
| | difficult areas [f] | 0 |
| Distance from river | > 200 m | 3 |
| | 100 - 200 m | 2 |
| | 50 -100 m | 1 |
| | 0 -50 m | 0 |

Note: [a] Rainfall description based from the category used by Galang et al. (1994)

[b] Soil texture description based from different soil types used by BSWM (1997) wherein only soil types under loamy soils is considered

[c] Slope class used by Galang et al. (1994) based from the slope category of DA-BAR

[d] Irrigated area of BBMP acquired from NIA-Tarlac

[e] Groundwater availability map acquired from NWRB

[f] Forested area with deep well areas that unsuitable for groundwater extraction

### Ranking of Factor

Each map layer has individual values in each class. To be able to perform arithmetic operation, values must be assigned from a numeric evaluation scale referred to as suitability scale or preference from best to worst. Each factor was ranked by how suitable it is and is done through the process of reclassifying.

Table 1 shows the ranking of the factors for potential areas of SFRs wherein suitability scale of 0-3 was used, 3 being the highest value. Ranking of factors was based from the following four suitability ratings: not suitable (0), marginally suitable (1), moderately suitable (2) and highly suitable (3).

### Weighting of Factor

Some factors are more important than the others in the suitability model. Therefore, percent influence or weight is assigned to each factor based from its importance. Calculating the weight of each factor was done using analytical hierarchy process (AHP). From the AHP procedures of Coyle (1989), the three steps used are as follows: (1) construction of a single pair-wise comparison matrix; (2) calculating the list of relative weights, importance, or value of the factors; and, (3) calculating and checking of the Consistency Ratio (CR).

The study of Al-Ruzouq *et al.* (2019) used the AHP in determining the importance of parameters such as precipitation, drainage stream density, geomorphology, geology, curve number, total dissolve solids, elevation, slope and major fracture Euclidean distance for dam site suitability mapping and analysis.

### Suitability Rating

Table 2 shows the suitability rating having its corresponding ranges of each class. The interpretation of suitability classes for each factor was classified on a scale from 0 to 3 as follows: not suitable, marginally suitable, moderately suitable, and highly suitable.

**Table 2.** Suitability rating

| Suitability Levels | Range |
|---|---|
| Not suitable | 0.0000 - 2.0000 |
| Marginally Suitable | 2.0001 - 2.5000 |
| Moderately suitable | 2.5001 - 2.7500 |
| Highly suitable | 2.7501 - 3.0000 |

### Testing of the Suitability Model

The selected SFRs locations in the study area were overlayed in the final suitability map for SFRs and the testing of the model (equation 1) was done by determining the suitability value (S) of each sample SFR. There are one hundred fifty (150) SFR samples that are randomly selected on the municipality of Sta. Ignacia, Tarlac. Locations of SFRs are done using global positioning system (GPS).

## 3. Results and Discussion

Finding the best location for SFRs was accomplished in the suitability mapping of SFR sites. Each factor map used was reclassified according to its suitability and these maps were combined with their corresponding percent influence to produce the final suitability map of SFRs. Suitability value of every location in the map was obtained after the creation of the final suitability map for SFRs.

### Thematic Maps

The thematic maps (rainfall, soil texture, slope, land use, irrigation status, groundwater availability and distance from river) used as the factors of the study that are essential for identifying the potential sites for SFR are presented in Figure 4. These are the preliminary maps used with their corresponding attributes.

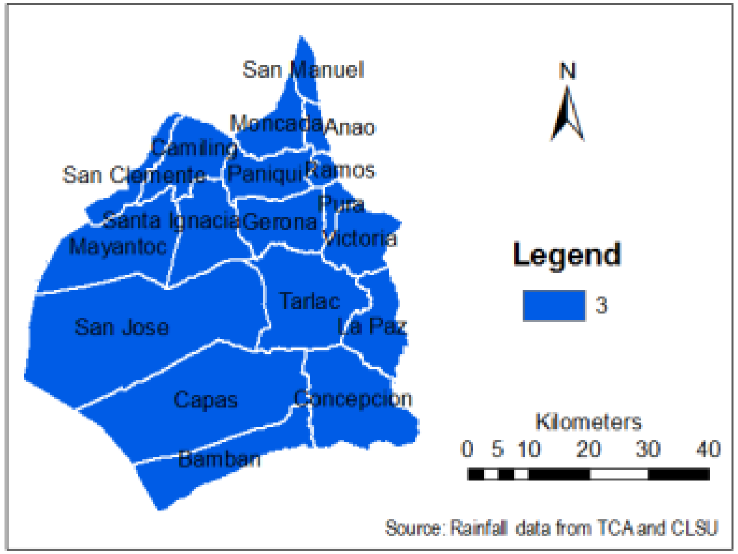
### Factor Maps

Each thematic map having individual values in each class was assigned a value from the numeric evaluation scale known as suitability scale or preferences, from best to worst, to be able to perform arithmetic operation in the suitability analysis. These thematic maps are ranked according to suitability through reclassification. Ranking of the factors was done by assigning a scale of 0 to 3, 3 being the highest value. The factor maps were the resulting maps after reclassification of the thematic maps shown in Figure 5.

### Determination of the Relative Important Weights of Factor

Assigning weights or percent influence to each factor was needed because of the fact that some factors are more important in the suitability model than others. This was done through analytical hierarchy process (AHP). If the factors are of equal importance then assign the same weight to each one.

In SFR adoption, the factor considered as most preferable is land use, and the next are rainfall, irrigation status and distance from river followed by soil texture and lastly, slope. Table 3 shows the pair-wise comparison matrix for assessing the relative important weights of each factor in creating the suitable areas for SFRs.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Source: Rainfall data from TCA and CLSU

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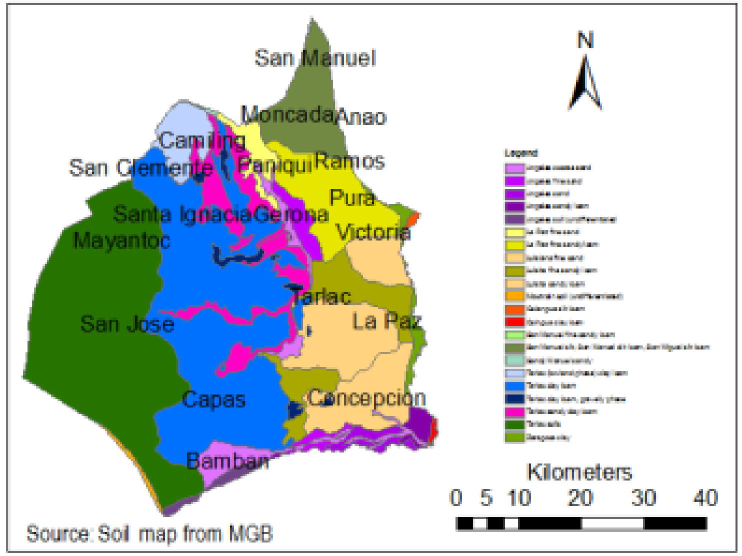
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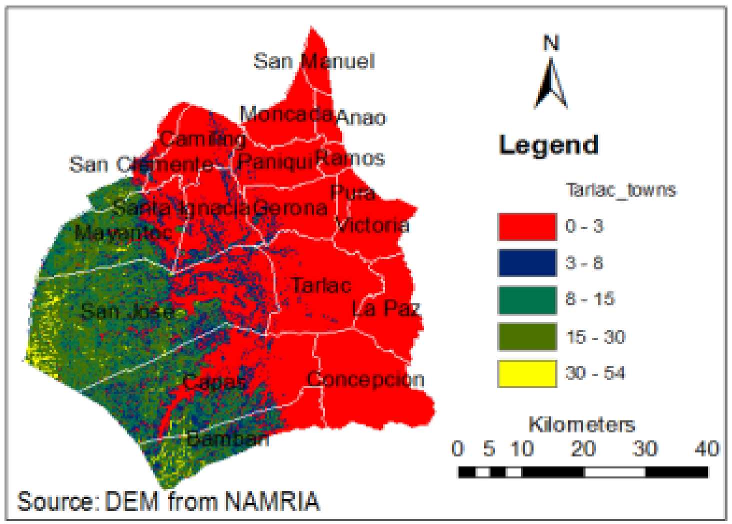
Source: Soil map from MGB

(b)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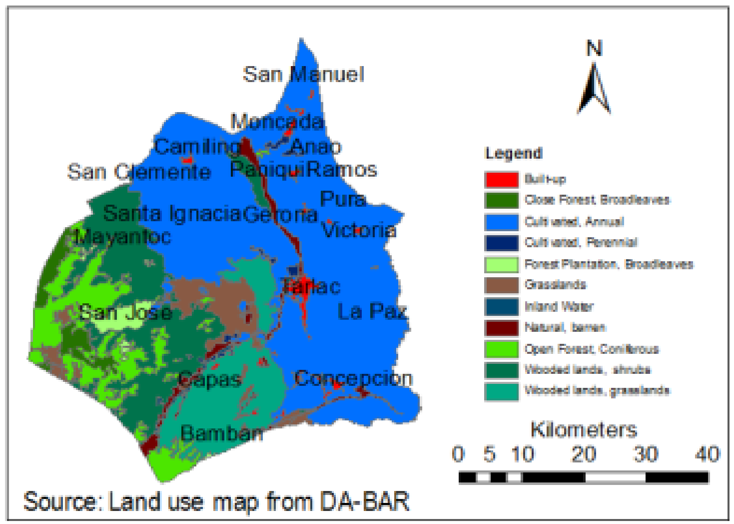
Source: DEM from NAMRIA

(c)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Built-up
Close Forest, Broadleaves
Cultivated, Annual
Cultivated, Perennial
Forest Plantation, Broadleaves
Grasslands
Inland Water
Natural, barren
Open Forest, Coniferous
Wooded lands, shrubs
Wooded lands, grasslands
Kilometers
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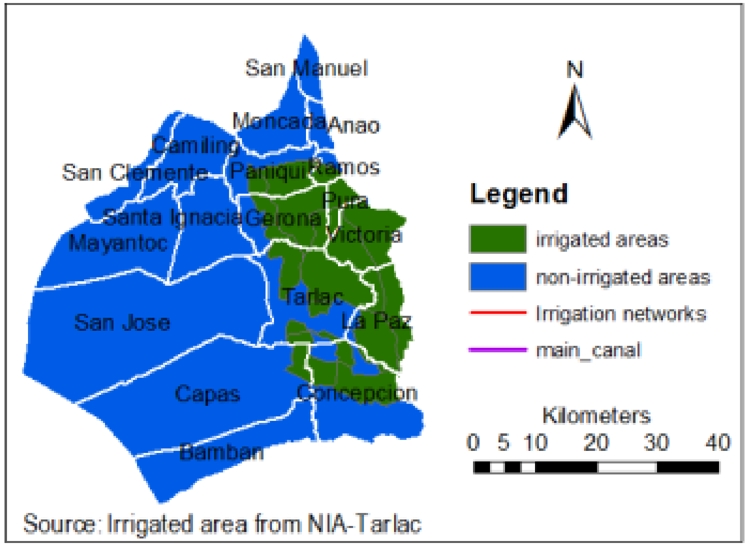
Source: Land use map from DA-BAR

(d)

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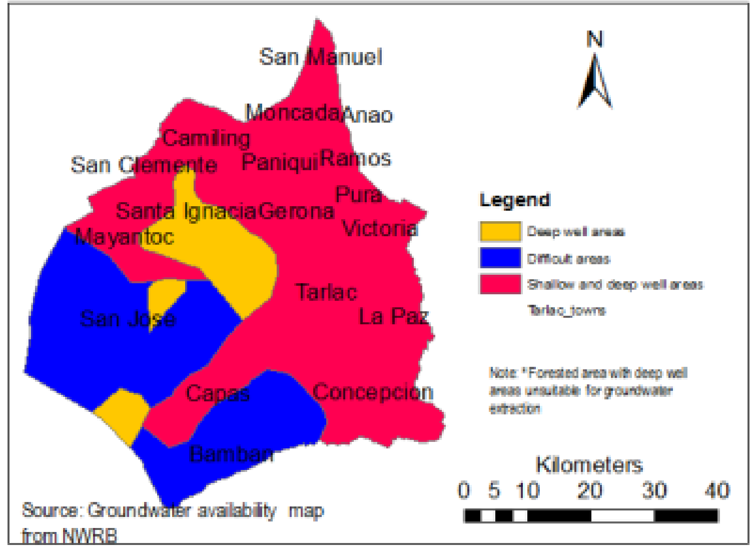


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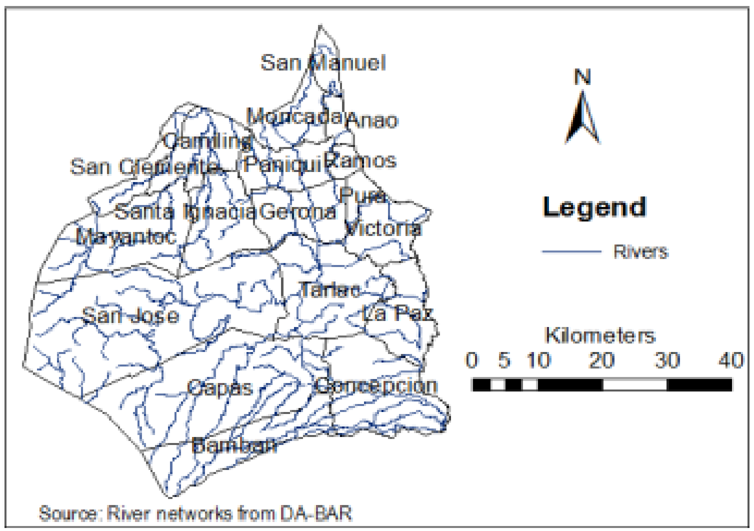
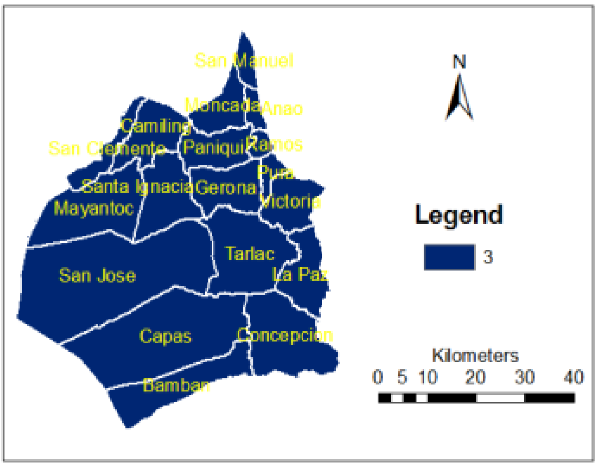



(g)

**Figure 4.** The thematic maps used in suitability mapping (a) Rainfall map (b) Soil texture map (c) Slope map (d) Land use map (e) Irrigation status map (f) Groundwater availability map and (g) River network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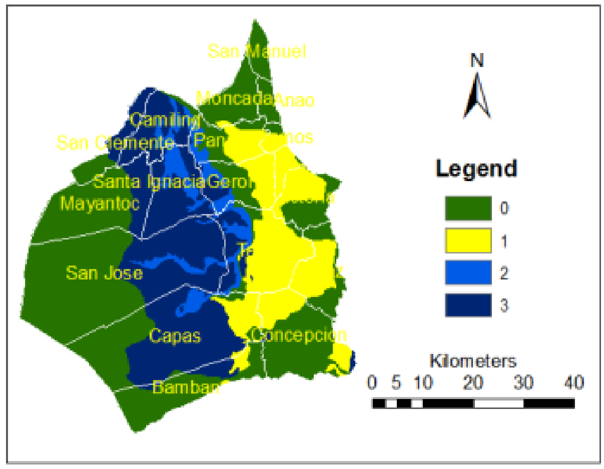
(a)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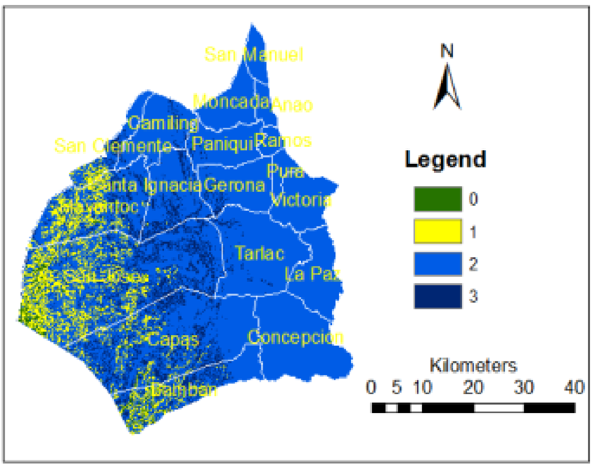
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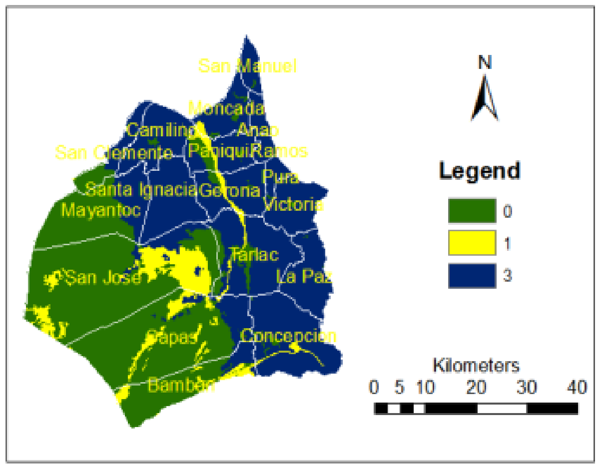
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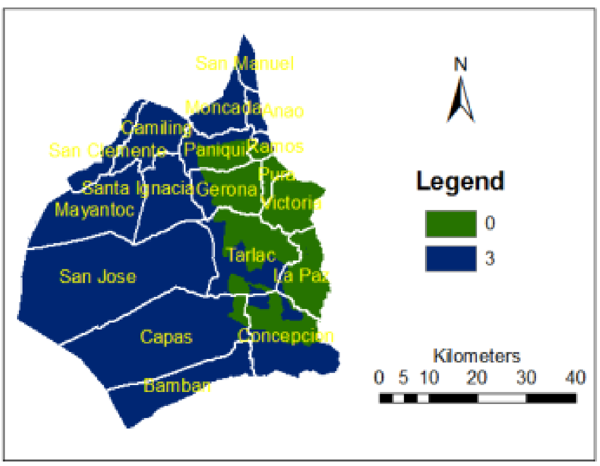
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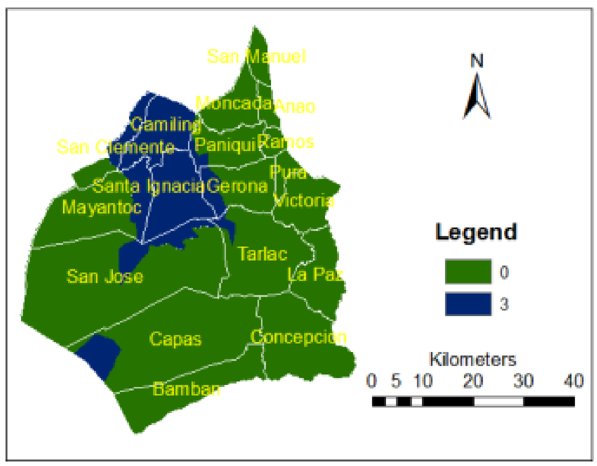
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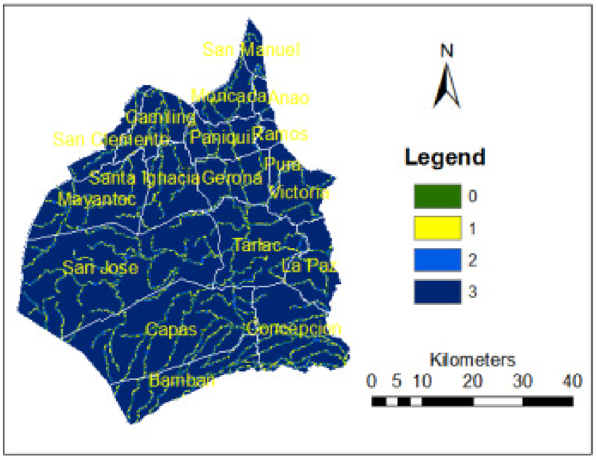


(g)

**Figure 5.** The different factor maps produced from the thematic maps (a) Rainfall factor map (b) Soil texture factor map (c) Slope factor map (d) Land use factor map (e) Irrigation status factor map (f) Groundwater availability factor map and (g) Distance from river factor map

**Table 3.** Pair-wise comparison matrix for assessing the relative weight of factors

| | Rainfall | Soil texture | Slope | Land use | Irrigation status | Groundwater availability | Distance from river | RIW |
|---|---|---|---|---|---|---|---|---|
| **Rainfall** | 1 | 5 | 7 | 1/3 | 1 | 3 | 1 | 0.167 |
| **Soil texture** | 1/5 | 1 | 3 | 1/7 | 1/5 | 1/3 | 1/5 | 0.038 |
| **Slope** | 1/7 | 1/3 | 1 | 1/9 | 1/7 | 1/5 | 1/7 | 0.022 |
| **Land use** | 3 | 7 | 9 | 1 | 3 | 5 | 3 | 0.366 |
| **Irrigation status** | 1 | 5 | 7 | 1/3 | 1 | 3 | 1 | 0.167 |
| **Groundwater availability** | 1/3 | 3 | 5 | 1/5 | 1/3 | 1 | 1/3 | 0.073 |
| **Distance from river** | 1 | 5 | 7 | 1/3 | 1 | 3 | 1 | 0.167 |

Consistency ratio (CR): 0.03

RIW = Relative Important Weight

## Final Suitability for SFRs

Overlaying of the different factor maps produced the suitable sites for SFRs. Combining these factor maps was done by the use of raster calculator from spatial analyst tool after reclassifying each map. Each factor maps was multiplied with its corresponding weights and added together to produce the final suitability map.

The formula in equation 2 used in the suitability model was substituted by the computed values of weights or percent influence to each factor as shown below:

S = [(rainfall factor x 0.167) + (soil texture x 0.038) + (slope x 0.022) + (land use x 0.366) + (irrigation status x 0.167) + (groundwater availability 0.073) + (distance x 0.167)]

Figure 6 shows the suitability map for SFR sites in Tarlac classified into four suitability classes; 0-not suitable, 1-marginally suitable, 2-moderately suitable and 3-highly suitable. Not suitable areas have the highest value of 142,353 hectare or 47% of the total land area of the province. Marginally suitable areas were 73,839 hectare or 25% of the total area of the province. Moderately suitable areas had the smallest area of 40,129 hectare or 13% of the total land area of the province. Highly suitable areas for SFRs got 44,813 hectare or 15% of the total land area of the province.

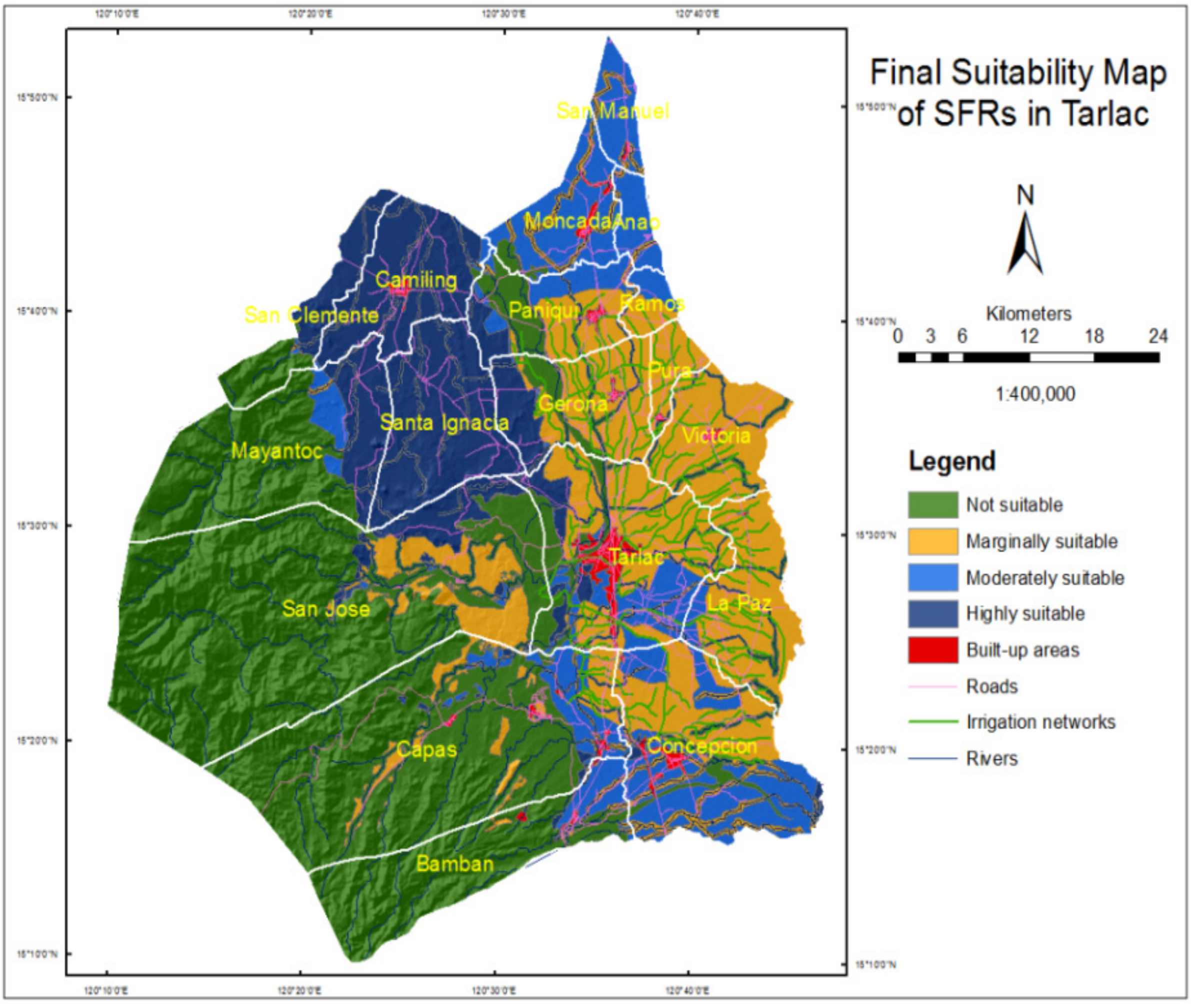


**Figure 6.** Final Suitability Map of SFRs in Tarlac

**Testing of the Suitability Model**

Testing of the suitability model was done by determining the suitability (S) value of each SFR overlay in the final suitability map. The summary of the suitability value of each SFR is shown in Table 4.

**Table 4.** Summary of the suitability (S) value of selected SFRs

| Suitability Class | Range of Suitability Value (S) | Frequency (n=150) | Percentage (%) |
|---|---|---|---|
| Not suitable | 0.0000 -2.0000 | 11 | 8 |
| Marginally suitable | 2.0001 -2.5000 | 0 | 0 |
| Moderately suitable | 2.5001 -2.7500 | 2 | 1 |
| Highly suitable | 2.7501 -3.0000 | 137 | 91 |

# 4. Conclusions

Based on the result, the usage of SFRs as a source of water for irrigation in wet and dry season intensifies cropping in drought-prone rainfed areas. The availability of information system on SFRs can be used by authorities or sectors responsible for water resources management and development.

GIS-aided decision support system for SFRs can be a viable means in determining the areas suited for SFR construction as well as the location of existing SFRs to maximize their full utilization.

# REFERENCES

[1] Al-Ruzouq, R. Shanableh A., Yilmaz A. G, Idris A., Mukherjee S., Khalil M. A, and Gibril MB. A. (2019).https://www.researchgate.net/publication/335727798_Dam_Site_Suitability_Mapping_and_Analysis_Using_an_Integrated_GIS_and_Machine_Learning_Approach/link/5d7803724585151ee4adee1d/download.

[2] Cacayan Jr., A. O. Apdohan, A. G., Bacobo, A. E., and Ruta, J. L. (2019). Identifying suitable areas for small farm reservoir in Agusan Del Norte using geographic information system. Available at: https://www.researchgate.net/publication/338134754_IDENTIFYING_SUITABLE_AREAS_FO

R_SMALL_FARM_RESERVOIR_IN_AGUSAN_DEL_NORTE_USING_GEOGRAPHIC_INFORMATION_SYSTEM.

[3] Coyle, R. (1989). Practical strategy. Open access material. AHP.

[4] De Guzman, E. M. (2013). A GIS-aided decision support system for small farm reservoir. Unpublished Masteral Thesis in Agricultural Engineering, Institute of Graduate Studies, Central Luzon State University, Nueva Ecija, Philippines.

[5] Galang, A., Bhuiyan, S. and Hunt, E. (1994). Identification of potential areas for use of the on-farm reservoir system for drought alleviation. In: Bhuiyan, S.I. (Ed.), On-farm Reservoir Systems for Rainfed Ricelands. International Rice Research Institute. Manila, Philippines. pp. 25–38. Available at: http://books.irri.org/9712200663_content.pdf.

[6] Guerra, L., Watson, P, and Bhuiyan, S. (1994). Hydrological characteristics of on-farm reservoirs (OFRs) in rainfed rice growing areas. Modified version of the paper originally published in Agricultural Water Management. In: Bhuiyan, S.I. (Ed.), On-farm Reservoir Systems for Rainfed Ricelands. International Rice Research Institute. Manila, Philippines, pp.12–24. Available at: http://books.irri.org/9712200663_content.pdf.

[7] Ines, R. L., Tuazon, J. B., Daag, M. N. (2018). Utilization of Small Farm Reservoir (SFR) for Upland Agriculture of Bataan, Philippines, (pp 1-6) International Journal of Applied Agricultural Sciences. Available at: https://www.semanticscholar.org/paper/Utilization-of-Small-Farm-Reservoir-(SFR)-for-of-Ines-Tuazon/aaec07e42d7a6a5ac729cb17e083f8b75c669827.

[8] Moya, T., Dela Vina, W. and Bhuiyan, S. (1994). Potential of on-farm reservoir use for increasing productivity of rainfed rice areas: the Philippine case. Modified version of the paper originally published in Agricultural Water Management. In: Bhuiyan, S.I. (Ed.), On-farm Reservoir Systems for Rainfed Ricelands. International Rice Research Institute. Manila, Philippines, pp.61–71. Available at: http://books.irri.org/9712200663_content.pdf.

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# Correlates of School Support and After School Activities to Academic Performance of the Tau Student Athletes SY 2018 - 2019

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**Abstract**

The purpose of this study is to propose a sports development program for the university by determining how school support and after school activities affect the student-athlete performance of Tarlac Agricultural University. This study aims determine the importance of school support and school activities of the student-athletes of Tarlac Agricultural University. The study used descriptive-correlational research design to find relationships of the variables involved. The salient findings of the study are as follows: That there were more male student-athletes than female, most of the student-athletes involve in ballgames as sports discipline and most of the student-athletes were middle performers. On the school support, the student-athletes of the university has training and clothing allowance. But claimed that they have no monthly allowances, athletes' insurance, and housing. It was also found out that most of the student-athletes were hooked up in social media platforms as their after school activities, rather than to work on their courses' requirement, training for improvement and hanging out with friends. On the relationships, it was found out that there is a significant relationship between the after school activities of student-athletes to their academic performance. With regards to the after school activities of student-athletes and to their athletic performance, it was found out that these two were significantly related based on the data gathered. It was also found out that there is a significant relationship between the athletic performance of the student-athletes to their academic performance.

**Keywords**— Student-athletes, school support, school activities, academic performance

## I. INTRODUCTION

Sports have become a major shift and attraction for students nowadays in the Philippines. The prints, radio, television and internet media have contributed much to the popularity of both professional and amateur sports in the country. Millions of pesos if not billions of pesos are spent on the upgrading of sports facilities and training of athletes. It is not surprising, that the popularity of sports has been reflected in the programs of every colleges and universities in the country. As reflected in Article 15, Section 19 of the 1987 Philippine Constitution that " the State shall promote physical education and encourage sports programs, league competitions, and amateur sports, including training for international competitions, to foster self-discipline, teamwork, and excellence for the development a healthy and alert citizentry." Also, under Section 6 of Republic Act 6847 mandates the Philippine Sports Commission (PSC) to set the priorities and direction of a national sports agenda, giving emphasis to grassroots participation.

Multiple times a year throughout the country, researchers, administrators, students, sports fans, and coaches gather at sport-related conferences to hear panels debate the most predominant issues and how they will affect the future landscape of sports in the country. Athletics versus academics has been at the forefront of sports in colleges and universities for many years and serves as the underlying questions for other issues as well.

In SCUAA student athletes must carry a load of at least 12 units per term and maintain a 60 percent passing mark. The rules are non-negotiable as they should be because no league will want a varsity athlete playing for a school without going to class or flunking his course. This means student athletes must know how much to sacrifice in academics for sports because if they forego studies completely, they jeopardize their athletic eligibility. On his column, Sporting Chance, Joaquin Henson of Philippine Star, cite the program of Ambassador Cojuangco which started on the year 2013 – 2014, for the La Salle basketball men team. The program started with career visioning for athletes which has career counseling and testing, the program also include orientation of parents of athletes to explain the concept of the program. Dr. Coscolluela of La Salle, who conducted the program said, “The faculty will be oriented on the goals, policies and procedures of the varsity sports program, the practice schedules, the peak varsity competition periods which may require adjusted class schedules and make-up classes,” she said. “The faculty will also be encouraged to use differentiated teaching strategies that enable students to find meaningful ways of learning that are attuned to their styles and domains of interest”. Perhaps, other schools may consider undertaking a similar program to prepare their athletes for life after school.

Similarly, it is possible that athletic communities in state universities and colleges have developed a negative reputation with respect to the performance in academics. After school programs have become a developmental for young people but the current social, political and economic climate continue to pose the following challenges: funding, program sustainability and expansion, quality improvement and maintenance and programming to meet the needs of an increasing diverse group of athletes, this is according to James Bartlett Presbrey, (2017) on his study entitled “The Development and Sustainability of Sports-Based Youth Development Programs as a Viable Options for After-School Programs”. Burns et. al. (2013), on their study “Academic Support Services and Career Decision-Making Self-Efficacy in Student Athletes”, found out that academic support services were positively related to levels of career decision-making self-efficacy of student athletes.

Recent research has begun to investigate the influence of school support and after school activities to student athletes. Recently, the NCAA has created metrics to examine the academic performance of student-athletes such as the Academic Progress Rate (APR) and the Graduation Success Rate (GSR).Previous investigations have provided insights into the recent focus on academic performance of student-athletes. Grimit (2014) stated that, when it comes to education of student-athletes, most research focuses on GPA and traditional educational views. She also found out that student athletes do better in school than their peers.The broad goal of the Commission on Higher Education, however, is to prepare individuals for the rest of their lives and develop productive members of the society. Research suggests that participation in athletics is motivating student-athletes in the classroom in terms of better time management and motivation to attend classes, Byrd and Ross (1991). School varsity athletics provides an opportunity for holistic education, yet little research has been done to understand the overall impact of athletics through investigating the school support and school activities and the well-being of the student-athletes.

School varsity athletics supporters counter that the time commitments create structure and routine that often support academic success and can help overcome risk factors. Athletics participation itself provides non-traditional education that aids in the overall development of young people, contributes to increased academic performance of student-athletes. This was proven in the study of Gayles& Hu (2009), with their research findings that engagement and sport participation of students had also motivated them to engage in educationally purposeful activities and the impact of their experiences on cognitive and affective outcomes.

As teachers, student advisers and coaches of student-athletes, the researchers noticed that there is not much research conducted in this area of endeavor, also the researchers observed that the factors involve in this study is not given priority in past researches conducted. This motivated the researchers to look into the importance of school support and after school activities of the student-athletes as to the relationship of their academic performance and athletic performance.

The purpose of this study is to propose a sports development program for the university by determining how school support and after school activities affect the student-athlete performance of Tarlac Agricultural University.

| **Sex** | | **Age** | | | **Athletic Involvement** | | | | | **Athletic Performance** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M | F | 16-18 | 19-21 | 22-25 | Ball Games | Athletics | Martial arts | Archery | Swimming | Champion | Middle Performer | losing |
| 30 | 25 | 20 | 30 | 5 | 24 | 15 | 8 | 6 | 2 | 2 | 45 | 8 |

***Objectives of the Study***

This study has the following objectives;

1. To describe the student-athletes of TAU in terms of the following;
   a. Sex;
   b. Age;
   c. Academic performance;
   d. Sports involvement; and
   e. Athletic performance.
2. to determine the school support given to student athletes.
3. to determine the after school activities of the student athletes.
4. to determine the relationship between after school activities and academic performance of the student-athletes.
5. to determine the relationship between after school activities and athletic performance of the student athletes.
6. to determine the relationship between athletic performance and academic performance of the student-athletes.

## II. METHODOLOGY

This chapter presents the methods of the study, namely the research design, locale of the study, data gathering instruments, data gathering procedures and statistical tools to be used.

***Research Design***

The study will make use of the descriptive-correlational research design to find relationships of the following variables; school support, after school activities, academic performance and athletic performance of the Tarlac Agricultural University student-athletes. The descriptive will be employed in determining the school support and after school activities of the student-athletes. Correlational because it will determine the extent to which the school support, after school activities, academic performance and athletic performance correlates each other.

The study used Questionnaire Checklist to answer the specific problems of the study. It was be subjected to validation by experts and the suggestions and their suggestions were considered in the finalization of the checklist.

## III. RESULTS AND DISCUSSIONS

This chapter presents the findings of the study which aimed to determine the effects and looked for the relationship of school support and after school activities of TAU student-athletes. It also presents the discussion and interpretation of the results of the analysis.

***Table 1.****Profile of TAU Student-athletes*

| | Monthly Allowance | Clothing Allowance | Athletes Insurance | Training Allowance | Athletes Housing | Sports Development Program |
|---|---|---|---|---|---|---|
| **No. of Students** | **0** | **55** | **0** | **55** | **0** | **6** |
| **%** | **0** | **100** | **0** | **100** | **0** | **10.90** |

It can be gleaned on the table that there were25 females of the TAU student-athletes and 30 were all males. Furthermore, most of the athletes were at the age of 19-21 which indicates that they are still in the midst of their prime as student-athletes. Along their involvement in sports, most of them belong to theball games followed by athletics, martial arts, archery and swimming. With regards to their athletic performance, most of the student-athletes are middle performers; this was based on the number of athletes that 45 of them are middle performer out 55 respondents. This result indicates that the Tarlac Agricultural University (TAU) student-athletes need to perform better in their own respective sports discipline.

**Table 2.** School Support of TAU Student-Athletes

The table 2 presents the School support of Tarlac Agricultural University (TAU) student-athletes. It can be seen on the table that all the student-athletes receives clothing allowances in terms of competition uniforms and training allowances. But there were only 6 or 10.90 percent receives sports development in terms of their respective sports discipline. Furthermore, it was also found out that there is no housing, athlete insurance, and monthly allowance for all student-athletes in the university. This contradicts the study of Hartman & Kwauk (2011), on their study, "Sport and Development: An Overview, Critique, and Reconstruction", which states the generalpurpose is to show that practitioners interested in using sport for development however defined must acknowledge these theoretical issues and create appropriate programming if their intended outcomes are to be achieved.

***Table 3.*** *After School Activities of Student-athletes*

| **Number of student-athletes (n = 55)** | **Courses' requirements** (assignments, projects/outputs) | **Hanging out with friends** | **Hooked in multi-media platforms** (facebook, instagram) | **Still training for improvement** |
|---|---|---|---|---|
| **F** | **20** | **7** | **30** | **17** |
| **%** | **36.37** | **12.72** | **54.54** | **30.90** |
| **Rank** | **2** | **4** | **1** | **3** |

In table 3, the after school activities of the student-athletes were presented. It shows that student-athletes hooked in multi-media platforms with 30 or 54.54 percent which rank first, followed by doing their courses' requirements with a frequency and percentage of 20 and 36.37 respectively, at rank third is still training for improvement which has a frequency and percentage of 17 or 30.90, while the last is hanging out with friends with a frequency of 7 or 12.72 percent. This only means that most of the student-athletes were hooked into multimedia platforms as their after school activities rather than doing their courses' requirements or have their training after class to improve their capabilities. These findings were agreed to the findings of Fraser-Thomas in her study, "Youth Sports Programs: An Avenue to foster positive youth development", that the importance of sport programs built on developmental assets and appropriate setting features in bringing about the five C's of positive development (competence, confidence, character, connections, and compassion/caring.

***Table 4.*** *Relationship between After School Activities to Academic Performance*

| **Variables (n = 55)** | **Courses' requirements** (assignments, projects/outputs) | **Hanging out with friends** | **Hooked in multi-media platforms** (facebook, instagram) | **Still training for improvement** |
|---|---|---|---|---|
| **Correlation Coefficient** | 0.004 | -0.021 | 0.187 | -0.220 |
| **Sig (2-tailed)** | 0.979 | 0.881 | 0.173 | 0.107 |

Legend: test at α = 0.05 level of significance

In the table 4 above, it shows that there is a significant relationship between the after school activities to the academic performance of student-athletes. It further shows that doing courses' requirements and hooked up in social media platforms has positive relationship while the hanging up with friends and training for improvement shows negative relationship to academic performance. This could only mean that doing courses' requirements and hooked up with multimedia platforms has an effect to the academic performance of the student-athletes. Thisis aligned with the study ofJames Bartlett Presbrey, (2017) on his study entitled "The Development and Sustainability of Sports-Based Youth Development Programs as a Viable Options for After-School Programs", whose findings states that after school programs have become a developmental for young people but the current social, political and economic climate continue to pose the following challenges: funding, program sustainability and expansion, quality improvement and maintenance and programming to meet the needs of an increasing diverse group of athletes.

***Table 5.*** *Relationship between After School Activities to Athletic Performance*

| **Variables (n = 55)** / **Athletic performance** | **Courses' requirements** (assignments, projects/outputs) | **Hanging out with friends** | **Hooked in multi-media platforms** (facebook, instagram) | **Still training for improvement** |
|---|---|---|---|---|
| **Correlation Coefficient** | **0.004** | **-0.144** | **0.065** | **0.033** |
| **Sig (2-tailed)** | **0.979** | **0.295** | **0.636** | **0.812** |

Legend: test at α = 0.05 level of significance

The table 5 shows the relationship between the after school activities to athletic performance of the Tarlac Agricultural University (TAU) student-athletes. It shows that there is a significant relationship between after school activities to their athletic performance. Furthermore, doing courses' requirements, hooked in social media platform, and still training for improvement shows positive relationship to athletic performance and only the hanging out with friends shows negative relationship. This could only mean that these factors will greatly affect the athletic performance of the student-athletes.

***Table 6.*** *Relationship between Academic Performance to Athletic Performance*

| Variable / Academic Performance | Athletic Performance |
|---|---|
| **Correlation Coefficient** | **-0.035** |
| **Sig (2-tailed)** | **0.799** |

Legend: test at α = 0.05 level of significance

The table 6 shows the relationship between the academic performance to athletic performance of the student-athletes of the Tarlac Agricultural University (TAU). It can be gleaned on the table that there is a significant relationship between the academic performance to the athletic performance of the student-athletes. The academic performance has slight effect on the athletic performance of the student-athletes

## IV. CONCLUSION

Based on the findings of the study, the following conclusions were formulated:

1. Most of the student-athletes were middle performers and prefer ball games as their sports discipline.
2. School support is not adequate to maintain student-athletes in order for them to perform well.
3. Most of the student athletes were hooked up in social media rather than have their focus in doing their courses' requirements and training.
4. After school activities of student-athletes were significantly related to their academic performance.
5. After school activities and athletic performance of the student-athletes were significantly related.
6. The athletic performance and academic performance of the student athletes indicates relatedness.

## REFERENCES


1. Akiyama, Gregorio et al., (2018),"Youth sports activity and young people's well-being after a disaster: a trial with the Mastery Approach to Coaching (MAC) in the Philippines".BMC Research Notespublished October 22, 2018.
2. AS Kornspan andEFEtzel., (2001)."The Relationship of Demographic and Psychological Variables to Career Maturity of Junior College Student-Athletes".Journal of College Student Development 42 (2), 122-32
3. Burns et.al.(2013). "Academic Support Services and Career Decision-Making Self Efficacy in Student Athletes". The Career Development Quarterly/ Vol. 61, Issue 2.
4. Byrd, C.E. & Ross, S.M. (1991)."The Influence of Participation in Junior High Athletics on Students Attitudes and Grades". Physical Educator; Indianapolis Vol. 48, Issue 4.
5. Carodine, Almond, and Gratto (2001). "College Student Athlete Success Both in and out of the Classroom".New Directions for Student Services, n93 p19-33 Spr 2001
6. Comeaux, E & Harrison, CK (2007), "Faculty and Male Student Athletes: Racial Differences in the Environmental Predictors of Academic Achievement". JournalRace Ethnicity and Education Volume 10, 2007 - Issue 2.
7. DalmanValbuena, MJ (2015), "A study of Athlete Engagement, Athlete Identity and Individualism: Collectivism Cultural Behaviours among Filipino Athletes Compared with US American Athletes".Australian Catholic University ACU Research Bank 10-2015.
8. Deb Agnew & Shane Pill, (2016)."I think it's going to save lives" Sport administrator Perspectives on Youth Development ThroughSport."The Sport Journal, ISSN: 1543-9518. Vol. 20

9. Gaston-Gayles Joy L. (2004).“Examining Academic and Athletic Motivation among Student Athletes at a Division I University”..Journal of College Student Development, v45 n1 p75-83
10. Gayle J.G. & Hu, S. (2009). “The Influence of Student Engagement and Sport Participation on College Outcomes Among Division I Student Athletes.”The Journal of Higher Education. Vol. 80, No. 3, pp. 315-333.
11. Grimit (2014).“Effects of Student Athletics on Academic Performance”.The Journal of Undergraduate Research.Vol. 12.
12. Halsall, T., Forneris, T. (2016).“Challenges and strategies for success of a sport-for-development programme for First Nations, Métis and Inuit youth.”Journal of Sport for Development.;4(7):39-57
13. Hartmann, Douglas & Kwauk, Christina (2011).“Sport and Development: An Overview, Critique, and Reconstruction”. Journal of Sports and Social Issues. Published July 29, 2011 Research Article
14. Henson, J.M. (2014). Sporting Chance.https://www.philstar.com
15. Hobneck, Mudge, and Turchi(2003). “Improving Student Athlete Academic Success and Retention”. Master of Arts Action Research Project, Saint Xavier University and SkyLight Professional Development Field-Based Master's Program
16. Presbrey, J.B. (2017).“The Development and Sustainability of Sports-Based Youth Development Programs as a Viable Options for After-School Programs”. Boston University Theses & Dissertations. http: //open.bu.edu.
17. R.A. 6847.“The Philippine Sports Commision Act.” July 4, 2000. Congress of the Philippines.Metro Manila.
18. Schulenkorf et.al. (2016).“Sport for Development: An Integrated Literature Review”Journal of Sport Management, 2016, 30, 22 -39© 2016 Human Kinetics, Inc.
19. Shurts and Shoffner (2004).“Providing Career Counseling for Collegiate Student-Athletes: A Learning Theory Approach”. Journal of Career Development, 31(2), 95–109
20. Simons, Rheenan, and Covington,.(1999).“Academic Motivation and the Student Athlete”.Journal of College Student Development, v40 n2 p151-62 Mar-Apr 1999.
21. Umali-Peneyra and Payad-Jocano Jr.,(2013),“Meaning of Sport among Filipino Athletes”. ASIA LIFE SCIENCES22(1): 191-202, 2013The Asian International Journal of Life Sciences.
22. Umbach, Palmer, Kuh, and Hannah.,(2006). “Intercollegiate Athletes and Effective Educational Practices: Winning Combination or Losing Effort?”. Research in Higher Education, v47 n6 p709-733 Sep 2006.
23. https://www.officialgazette.gov.ph/constitutions/1987-constitution/
24. https://www.google.com.ph/maps/place/Tarlac+Agricultural+University

# Survey of Physical, Chemical and Microbial Water Quality of Irrigation Sources in Tarlac, Philippines

**Edmar N. Franquera, Cielito A. Beltran, Ma. Asuncion G. Beltran and Ruth Thesa B. Franquera**

**Abstract** The main sources of irrigation water for irrigating crops comes from major rivers. Usually these water sources which can be used for irrigating various crops could be very vulnerable to contamination. The aim of the study was to determine the physical, chemical and microbial water quality of the different irrigation sources in Tarlac and to compare it with the existing water quality guidelines stipulated in the DENR AO 08 Series of 2016. The water samples collected from the surface water of different rivers were subjected to laboratory analysis. Higher TSS was found to be during wet season as compared during the dry season. Higher COD was found both in dry and wet seasons in Benig river. All of the major rivers have a less than 0.05 mg/l lead and 0.0002 mg/l mercury based from the result of the laboratory analysis. The highest dissolved oxygen was found to be within the Tarlac River both during the dry and wet season. Comparing with the National standards from the DENR the major rivers of Tarlac surpasses the minimum standards of classification of water bodies with dissolved oxygen ranging from 2 to 6 mg/l. The lowest dissolved oxygen was found in Concepcion River during the dry season (5.0 mg/l) and in Rio Chico River (4.8 mg/l) during the wet season. Higher total dissolved solids were observed in the different rivers during the dry season which ranges from 300 to 560 mg/l as compared during the wet season which ranges from 169 to 540 mg/l respectively. The nitrate concentrations of the different rivers in Tarlac shows to be within the range of the National Standards of the DENR. Higher concentrations of *E. coli* and fecal coliform count were also noted within the different rivers of Tarlac.

**Keywords** Water quality · River · Irrigation · Tarlac

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## 1 Introduction

Water is life. All living organisms on earth need fresh water. The major user of freshwater in most countries is agriculture. The largest single user of freshwater in the world today which consumes an average of 70% globally is accounted in agriculture.[1] However, the availability of freshwater is already decreasing due to water pollution. Agriculture is considered to be a casualty of water pollution but it also causes and contributes to water pollution due to excess nutrients by too much application of fertilizers, excessive use of pesticides and other pollutants. Globally, agriculture is also considered to be the major cause of degradation of surface including groundwater resources as a result of erosion, excessive farming contaminating freshwater like wastewater coming from large poultries and piggeries, chemical run off and other indiscriminate human activities and improper agricultural management practices. Waste coming from swine is significant source of fecal pollution leading to water pollution by contaminating of ground and surface water from lagoon overflow and the use of lagoon surface water for irrigation. Thus, it is important to test a system or test a technology such as potential aquatic plants to decontaminate the wastewaters so that this will resolve the problem.

In the Philippines, agriculture wastewater is one of the major sources of water pollution which accounted 37%.[2] In addition, only 10% of wastewater is treated while 58% of groundwater is contaminated. Regions which had unsatisfactory ratings for their water quality criteria include National Capital Region (NCR), Southern Tagalog Region, Central Luzon (Region 3) and Central Visayas. Hence, there is a need to address the global implications of water quality and there is a need for wastewater treatments. In central Luzon, the agricultural land area is 653,607 $km^2$ and 9.1% contributed to the agricultural BOD generation, 9.0% industrial BOD generation and 9.9% domestic BOD generation leading to water quality degradation and contamination.[3]

Generally, the availability of clean freshwater is becoming a primary limitation to human activities expansion and also the scope or capacity of our agricultural lands to feed the tremendous population growth not only in the Philippines but globally. There are an estimated 2.2 million metric tons of organic water pollution that occur in the Philippines each year and the annual economic losses caused by water pollution are estimated at Php67 Billion which is equivalent to more or less US$1.3 billion.[4] Hence, this study aims to quantify the physical, chemical and microbiological water qualities of the different river waters in Tarlac, Philippines.

[1] www.fao.org. Last accessed 30 Nov 2017.

[2] www.greenpeace.org. Last accessed 30 Nov 2017.

[3] www.wipo.int/wipo_ip_mnl_15_t4. Last accessed 27 Nov 2017.

[4] www.wepa-db.net.philippines.overview. Last accessed 30 Nov 2017.

# 2 Methodology

## *2.1 Gathering/Collection of Data of Existing Irrigation Water Sources in Tarlac*

The existing data on the type of irrigation systems and the irrigation sources were gathered. This was done in collaboration with National Irrigation Administration (NIA). The water qualities that were gathered were compared to the existing standards of the Department of Environment and Natural Resources (DENR).

## *2.2 Water Sample Collection*

Representative water samples were collected in seven major rivers of Tarlac based from the data of the National Irrigation Administration (NIA) and the Department of Environment and Natural Resources and the collection was done from 9:00 AM in the morning until 4:00 PM in the afternoon. A total of six liters of water samples were collected in each sampling sites based from the recommendation of the Department of Science and Technology. The water sampling collection was done on the onset of 2018 dry and wet season productions of rice.

## *2.3 Water Quality Analysis*

Collected water samples were analyzed for its physical, chemical and microbiological qualities (Total suspended solids, chemical oxygen demand, total coliform bacteria, *E. coli*, lead and mercury content). These parameters were analyzed using the standard methods in analysis of water samples. Portable instruments were used for the analysis of the following parameters such as dissolved oxygen (portable oxygen meter), pH (HM pH-200) total dissolved solids and electrical conductivity (HM COM-100). For the nitrate quantification a Horiba portable nitrate meter was used.

## *2.4 Analysis of Data*

Laboratory results from the collected water samples were analyzed and compared with the Water Quality Guidelines and General Effluent Standards of 2016 based on the Department of Environment and Natural resources (DENR) Administrative Order No. 08 Series of 2016.

# 3 Results and Discussions

See Table 1.

## 3.1 *Total Soluble Solids and Chemical Oxygen Demand*

Table 2 presents the data of the different major rivers of Tarlac in terms of the total soluble solids and chemical oxygen demand. Results showed that the different river water has a varied total suspended solids and chemical oxygen demand. Higher TSS was found to be during wet season as compared during the dry season. This was also evident in terms of the chemical oxygen demand except for the two rivers, the Rio Chico and the Camiling river which exhibited a lower COD during the wet season with less than. For the TSS, based from the standard water qualifications, Tarlac and Concepcion rivers exceeded the numerical value which a body of water could be classified ranging only from 25 to 110 but for the two rivers it has both 169 mg/l total suspended solids during the wet season. Higher COD was found both in dry and wet seasons in Benig river with 27 and 22 mg/l respectively. Result of the COD laboratory test from the Benig river was also in consonance with the result of research conducted by Fernandez and David (2008) [5] which also shows high COD in Benig River. This implies that the higher COD in the sampling area, the higher level of water pollution. The wastewater discharge coming from the different industries within the area such as the presence of piggery farms could contribute to the higher COD of the water samples which maybe contributed to the deterioration of water quality within the sampling area (Al-Badaii et al. 2013).

## 3.2 *Heavy Metals (Lead and Mercury)*

The heavy metal concentrations (lead and mercury) in the different major rivers of Tarlac are presented in Table 3. All of the major rivers have a less than 0.05 mg/l lead and 0.0002 mg/l mercury based from the result of the laboratory analysis. Compared to the standards for the water quality the result both of the lead and mercury content of all the major rivers showed lesser than that of the standards. This implies that the rivers were not contaminated with heavy metals. This could be due to the non-presence of mining sites within the areas where the different rivers were located. Heavy metals were considered to be toxic and dangerous. The presence of higher concentrations of heavy metals in rivers as source of irrigation for the crops could lead also to the decline in production and these heavy metals could bio accumulate affecting also the humans whom will consume the crops irrigated with higher concentrations of heavy

[5] www.bgr.bund.de.Veranstaltungen. Last accessed 15 Dec 2017.

**Table 1** Water quality guidelines (DENR AO 08 Series 2016)

| Parameter | Water body qualifications | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | AA | A | B | C | D | SA | SB | SC | SD |
| Dissolved oxygen (mg/l) | 5 | 5 | 5 | 5 | 2 | 6 | 6 | 5 | 2 |
| Fecal coliform (MPN/100 ml) | <1.1 | <1.1 | 100 | 200 | 400 | <1.1 | 100 | 200 | 400 |
| Nitrate (mg/l) | 7 | 7 | 7 | 7 | 15 | 10 | 10 | 10 | 15 |
| pH | 6.5–8.5 | 6.5–8.5 | 6.5–8.5 | 6.5–9.0 | 6.5–9.0 | 7.0–8.5 | 7.0–8.5 | 6.5–8.5 | 6.5–9.0 |
| TSS | 25 | 50 | 65 | 80 | 110 | 25 | 50 | 80 | 110 |
| Lead (mg/l) | 0.01 | 0.01 | 0.01 | 0.05 | 0.1 | 0.01 | 0.01 | 0.05 | 0.01 |
| Mercury (mg/l) | 0.001 | 0.001 | 0.001 | 0.002 | 0.004 | 0.001 | 0.001 | 0.002 | 0.004 |

**Table 2** Total soluble solids and chemical oxygen demand data of different major rivers of Tarlac province, Philippines during wet and dry season of 2018

| River | Total suspended solids (mg/l) | | Chemical oxygen demand (mg/l) | |
|---|---|---|---|---|
| | Dry season | Wet season | Dry season | Wet season |
| Benig | 32 | 40 | 27 | 22 |
| Tarlac | 40 | 169 | 10 | 14 |
| Bamban | 58 | 32 | 11 | 15 |
| Concepcion | 52 | 169 | 21 | 19 |
| Lapaz | 223 | 91 | 11 | 28 |
| Rio Chico | 103 | 66 | 10 | <10 |
| Camiling | 17 | 45 | 6.9 | <10 |

**Table 3** Heavy metals concentration of different major rivers of Tarlac province, Philippines during wet and dry season of 2018

| River | Lead (mg/l) | | Mercury (mg/l) | |
|---|---|---|---|---|
| | Dry season | Wet season | Dry season | Wet season |
| Benig | <0.05 | <0.05 | <0.0002 | <0.0002 |
| Tarlac | <0.05 | <0.05 | <0.0002 | <0.0002 |
| Bamban | <0.05 | <0.05 | <0.0002 | <0.0002 |
| Concepcion | <0.05 | <0.05 | <0.0002 | <0.0002 |
| Lapaz | <0.05 | <0.05 | <0.0002 | <0.0002 |
| Rio Chico | <0.05 | <0.05 | <0.0002 | <0.0002 |
| Camiling | <0.05 | <0.05 | <0.0002 | <0.0002 |

metals. When crops were irrigated with water contaminated with heavy metals, the soils will also be polluted (Verma and Dwivedi 2013).

## 3.3 *Dissolved Oxygen and pH*

Table 4 presents the data on the dissolved oxygen and pH of the different major rivers of Tarlac province Philippines. Based from the result the highest dissolved oxygen was found to be within the Tarlac River both during the dry and wet season with 16.0 and 14.8 mg/l respectively.

The lowest dissolved oxygen was found in Concepcion River during the dry season (5.0 mg/l) and in Rio Chico River (4.8 mg/l) during the wet season. Comparing with the National standards from the DENR the major rivers of Tarlac surpasses the minimum standards of classification of water bodies with dissolved oxygen ranging from 2 to 6 mg/l. Low DO is also caused by fertilizer and manure runoff from streets, lawns and farms. The growth of too much algae which could be due to the overuse of fertilizers and the presence of fecal matters causes the speeding up of using the

**Table 4** Dissolve oxygen and pH of different major rivers of Tarlac province, Philippines during wet and dry season of 2018

| River | Dissolved oxygen (mg/l) | | pH | |
|---|---|---|---|---|
| | Dry season | Wet season | Dry season | Wet season |
| Benig | 5.3 | 5.4 | 8.0 | 8.26 |
| Tarlac | 16.0 | 14.8 | 8.1 | 8.29 |
| Bamban | 9.2 | 6.0 | 8.0 | 7.96 |
| Concepcion | 5.0 | 5.0 | 7.0 | 6.78 |
| Lapaz | 8.0 | 5.0 | 7.2 | 7.98 |
| Rio Chico | 7.9 | 4.8 | 7.3 | 7.96 |
| Camiling | 15.0 | 14.0 | 8.0 | 8.26 |

oxygen quickly resulting to a lower DO.[6] The dissolved oxygen which drops below 5.0 mg/l causes stress to many aquatic lives. However based from the results, all of the rivers surpass or equal to 5.0 mg/l except for the Rio Chico River during the wet season with 4.8 mg/l.[7] In terms of pH, the major rivers of Tarlac are within the minimum and maximum standard of pH range within the DENR standards. The pH ranges from 6.78 to 8.29 during the wet season and 7.0–8.1 during the dry season.

## 3.4 *Total Dissolved Solids and Electrical Conductivity*

Higher total dissolved solids were observed in the different rivers during the dry season which ranges from 300 to 560 mg/l as compared during the wet season which ranges from 169 to 540 mg/l respectively. Too high or too low concentrations of TDS may limit the growth and may lead to the death of many aquatic organisms.[8] The reduction of water clarity, which contributes to a decrease in photosynthesis and lead to an increase in water temperature, could be due to the high concentrations of TDS. The EC during the dry season ranges from 389 to 423 while during the wet season it ranges from 280 to 420 respectively (Table 5).

## 3.5 *Nitrate*

The nitrate concentrations of the different rivers in Tarlac shows to be within the range indicated in Table 1. During the dry season, the nitrate concentrations from

[6]http://www.ririvers.org/wsp/CLASS_3/DissolvedOxygen.htm. Last accessed 30 Nov 2017.
[7]http://www.mymobilebay.com/stationdata/whatisDO.htm. Last accessed 30 Nov 2017.
[8]http://www.ei.lehigh.edu/envirosci/watershed/wq/wqbackground/tdsbg.html. Last accessed 15 Dec 2017.

**Table 5** Total dissolved solids and electrical conductivity of different major rivers of Tarlac province, Philippines during wet and dry season of 2018

| River | Total dissolved solids (mg/l) | | Electrical conductivity (μS) | |
|---|---|---|---|---|
| | Dry season | Wet season | Dry season | Wet season |
| Benig | 323 | 218 | 400 | 323 |
| Tarlac | 308 | 169 | 420 | 416 |
| Bamban | 300 | 254 | 418 | 375 |
| Concepcion | 560 | 540 | 423 | 420 |
| Lapaz | 300 | 220 | 400 | 291 |
| Rio Chico | 305 | 250 | 412 | 281 |
| Camiling | 320 | 200 | 389 | 280 |

**Table 6** Nitrate content of different major rivers of Tarlac province, Philippines during wet and dry season of 2018

| River | Nitrate (mg/l) | |
|---|---|---|
| | Dry season | Wet season |
| Benig | 14 | 59 |
| Tarlac | 10 | 48 |
| Bamban | 10 | 17 |
| Concepcion | 10 | 48 |
| Lapaz | 14 | 38 |
| Rio Chico | 10 | 45 |
| Camiling | 10 | 38 |

the different major rivers had a range of 10–14 mg/l. While during the dry season, it ranges from 17 to 59 mg/l with Benig River as the highest. The higher nutrient concentrations within the area could be due to the wastewater from the swine farm lagoons which may be discharged from the nearby farms within the area. Less than 5 mg/l N has little effect, even on nitrogen sensitive crops, but may stimulate nuisance growth of algae and aquatic plants in streams, lakes, canals and drainage ditches (Table 6).[9]

### 3.6 *Fecal Coliform and* E. coli

In terms of the microbiological parameters such as fecal coliforms and *E. coli*, the different river waters of Tarlac was higher than the standards particularly in Benig River with 11,000 MPN/100 ml and within the Concepcion river which exceeds the National standards for safe water with fecal coliform count of 140,000. Higher concentrations of *E. coli* were also noted in Benig and Concepcion River both with

[9]http://www.fao.org/docrep/003/T0234E/T0234E06.htm. Last accessed 15 Dec 2017.

**Table 7** Fecal coliform and *E. coli* concentration of different major rivers of Tarlac province, Philippines during wet and dry season of 2018

| River | Fecal coliform (MPN/100 ml) | *E. coli* (MPN/100 ml) |
|---|---|---|
| | Wet season | Wet season |
| Benig | 11,000 | 1700 |
| Tarlac | 390 | 21 |
| Bamban | 270 | 17 |
| Concepcion | 140,000 | 1700 |
| Lapaz | 2600 | 170 |
| Rio Chico | 2800 | 330 |
| Camiling | 330 | <1.8 |

1700 MPN/100 ml. The high concentrations within the said rivers could be due to the wastewater discharged from the nearby areas contributing to the higher Fecal coliform and *E. coli* in the said areas of concern. The higher concentrations as observed in the two rivers could have a potential to reduce the water quality thus reducing also the recreational value (Table 7).[10]

## 4 Conclusions

The water samples collected from major rivers of Tarlac revealed that there were variations in the results in terms of the different parameters used to quantify the concentrations of the physical, chemical and microbiological quality of the river waters for irrigation purposes. Based from the result, the different river waters were also in accordance with the National Standards set by the Department of Environment and Natural Resources (DENR).

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## References

Al-Badaii F, Shuhaimi-Othman M, Gasim MB (2013) Water quality assessment of the Semenyih River, Selangor, Malaysia. J Chem Article ID 871056, 10 p. https://doi.org/10.1155/2013/871056

Fernandez XD, David ME (2008) Water quality assessment of the benig river: implication to environmental management accessed through https://www.bgr.bund.de/EN/Themen/Wasser/Veranstaltungen/symp_sanitat-gwprotect/poster_fernandez_pdf.pdf?__blob=publicationFile&v=2 December 2017

[10] https://pubs.usgs.gov/wri/wri004139/pdf/wrir00-4139.pdf. Last accessed 15 Dec 2017.

Verma R, Dwivedi P (2013) Heavy metal water pollution—a case study. Recent Res Sci Technol 5(5):98–99. ISSN: 2076-5061. Available Online http://recent-science.com/