Development and Assessment of Outdated Computers: A Technology Waste for Alternative using Parallel Clustering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

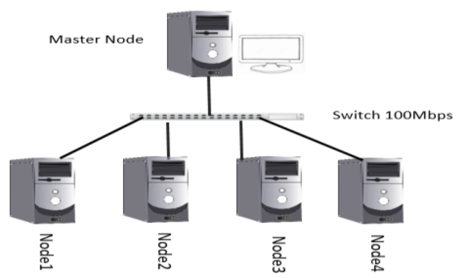

Fig. 1. Indicates the cluster clustering connectivity. The development was based on computer architecture clustered in parallel.

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]

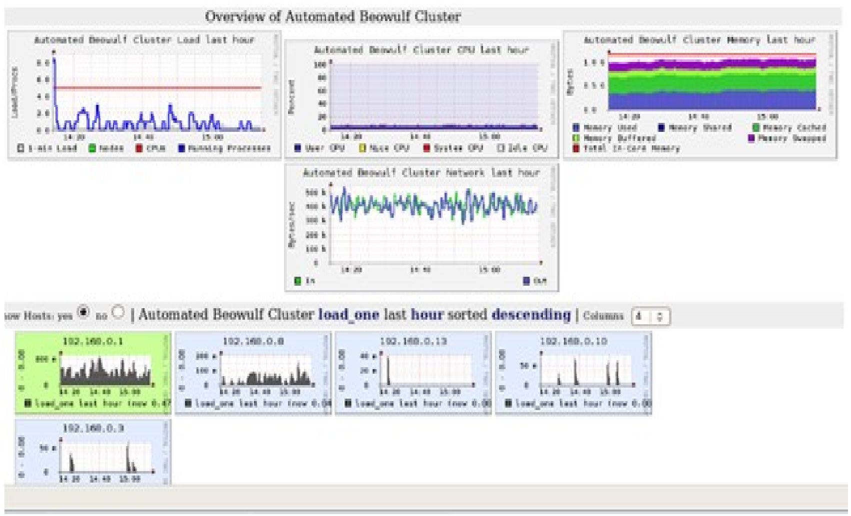

Fig 2. Overview of Automated Beowulf Cluster using Ganglia

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

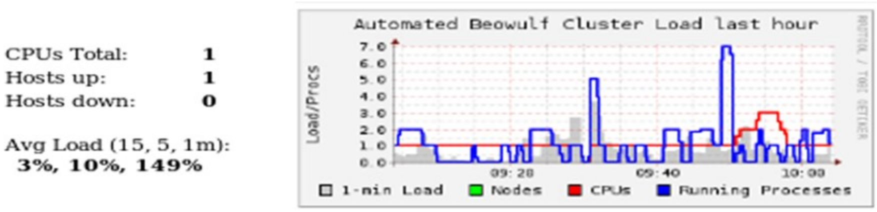

Fig 3. Performnace of Total hosts (1 CPU)

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.

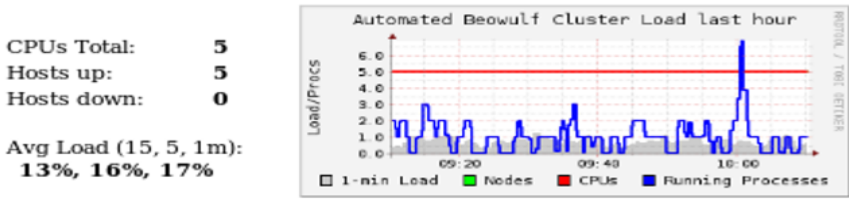

Fig 4. Performnace of Total hosts (5 CPU)

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)

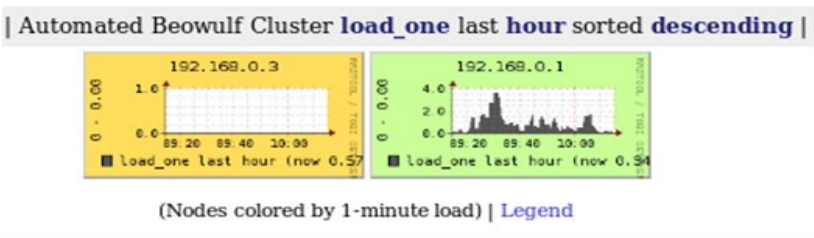

Fig 5. Master Node and Node 1

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)

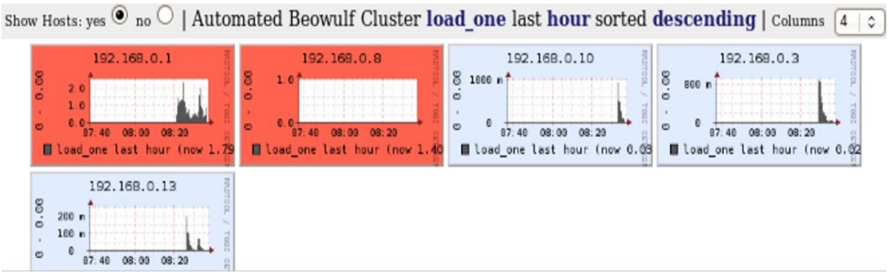

Fig 6. Process Identification of Nodes

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

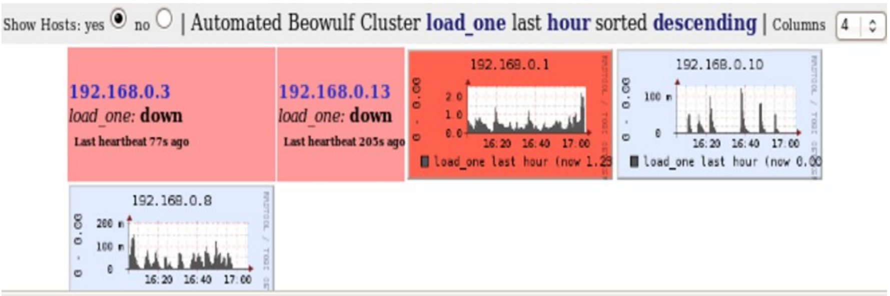

Fig 7. Node Process in Shutting Down

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.

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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 Patwary 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 • Cartons • Plastics • Cans • Styropor containers	• Sharps • Blood • Chemical waste from the laboratory • Cotton swabs • Used facemasks • Used bandages • Used tubing IV • Specimen container of blood and fluids
Public Health Unit	• Glass • Slides • Papers • Cartoons • Used cans • Styropor	• Used syringes • Blood • Urinals • Blood lancets • Phlegm • Cotton swabs • Facemasks
Private hospital 1	• Empty medical bottles • Empty tetra pack containers • IVF container • Plastics, can, soft drinks, straws, wrapper, styropor containers • Waste from the offices	• Disposal materials • Used for collection of body fluid • Dressing bandages • Used folly catheters • Used cotton falls • Used gloves • Used facemasks
Private hospital 2	• Waste from the offices- paper, cans, cartoon styropor containers	• Empty vials • Sharps • Needles • Used gloves • Used cotton, pharmaceutical waste • Facemask • Radioactive waste
Public hospital	• Paper products • bottles • Packaging materials • Waste from offices	• Pharmaceutical waste • pathological waste • radioactive waste • sharps • chemical waste • used foley catheters • used blood product bags or tubing • used gloves • specimen container of blood and fluids • used suction tubes • cotton applicator soaked with blood • body fluids from dressing of infected wound and post operative cases • waste from isolation room • 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 – Only Laboratory and the T and B DOTS sections were observing waste segregation – 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 – Solid wastes were stored for not more than 2 days
Private Hospital 2	– Had Material Recovery Facility for solid waste – Had concrete vault for temporarily storing hazardous and infectious wastes
Public Healthcare Center	– Stored infectious wastes in the drum for 1 year before disposal – 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 – 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 – 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 – The hospital was using Lysol to disinfect hazardous wastes – 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 – 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

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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 – Waste bags were labeled – Residual wastes were hauled using PEO dump truck in landfills at Matubog dumpsite – 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 – 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 – 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 – 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 - Treated material before reusing it
Private Hospital 2	- Did not practice recycling - Treated material before reusing it
Public Healthcare Center	- Did not practice recycling - Treated material before reusing it
Clinic	- Did not practice recycling - 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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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.

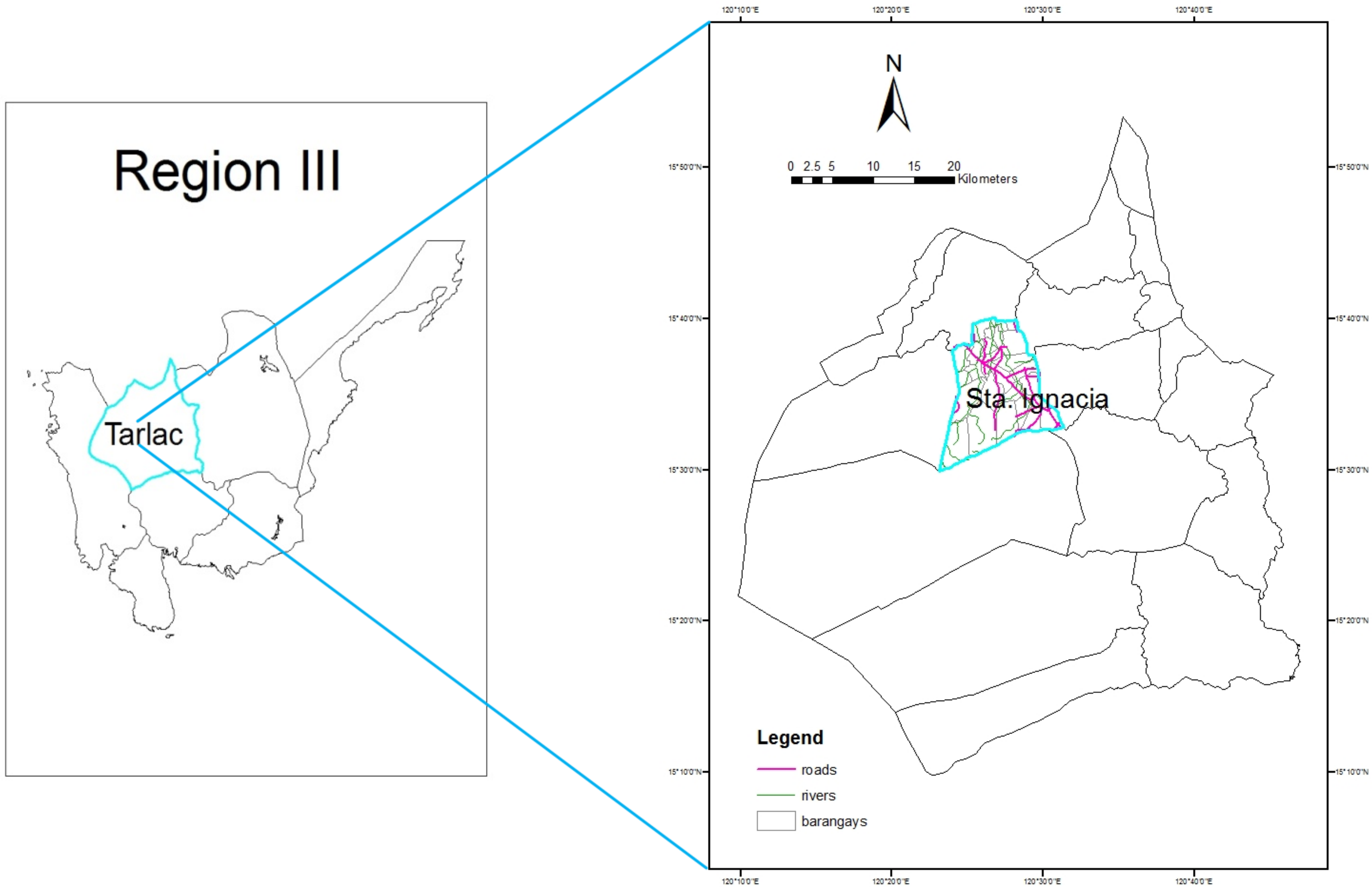


Figure 1. Map of Tarlac Province, Philippines

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

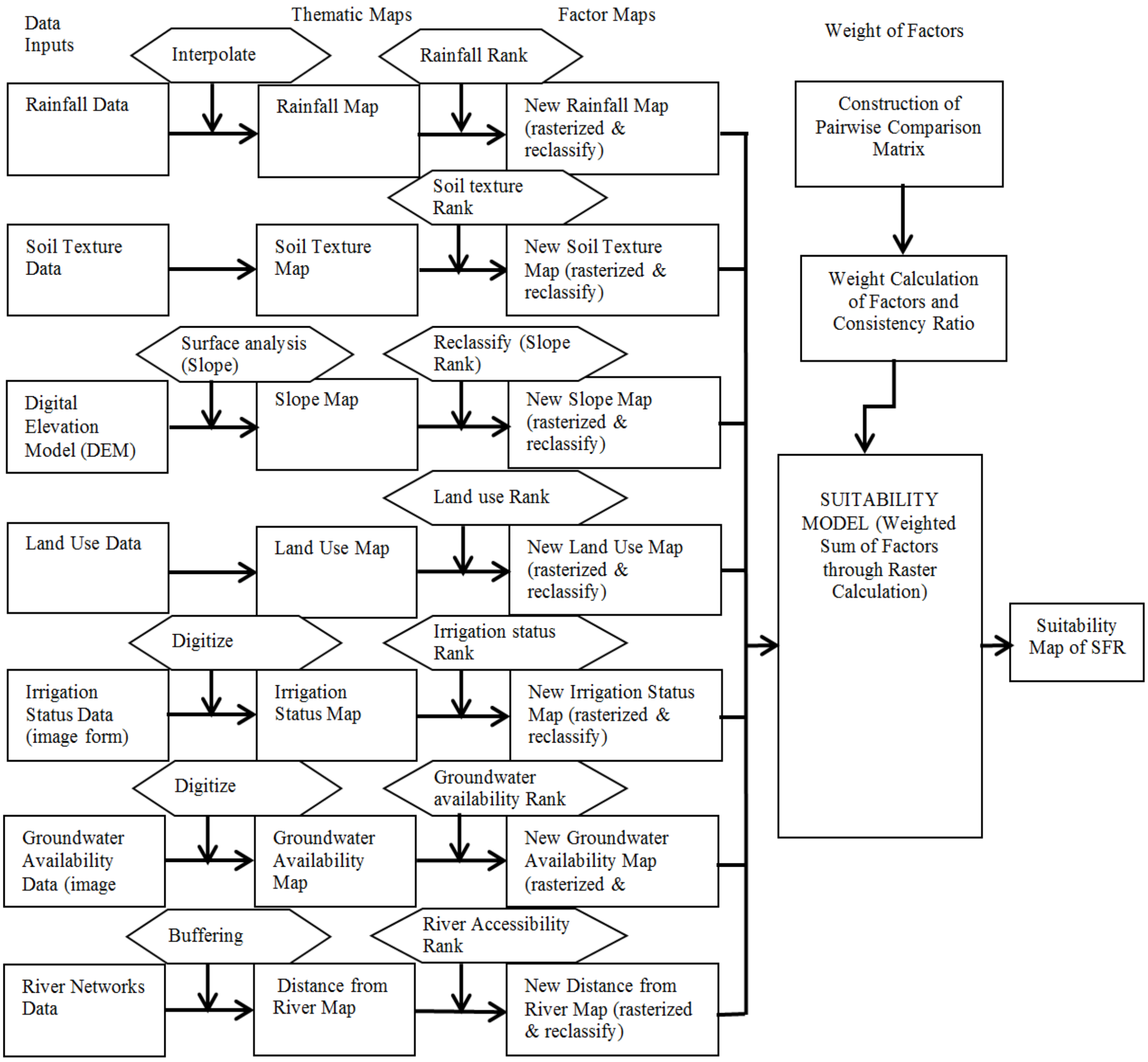


Figure 2. Methodology for identifying potential sites for SFRs

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.

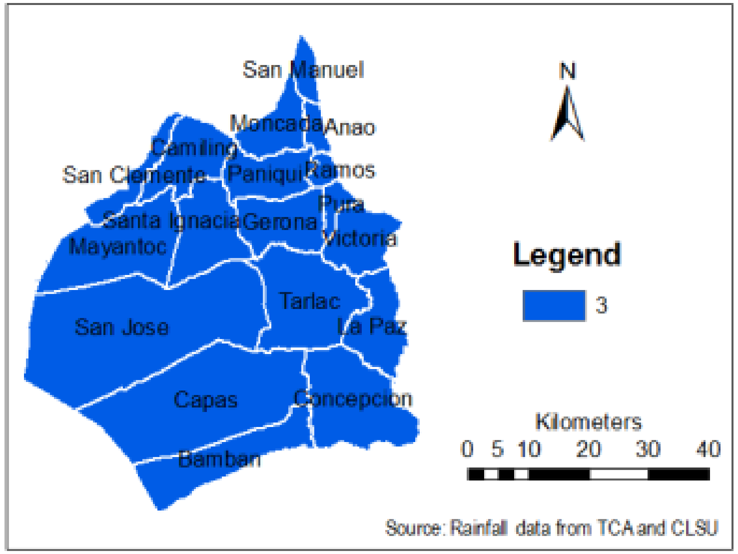
Factor Maps

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.


San Manuel
Moncada
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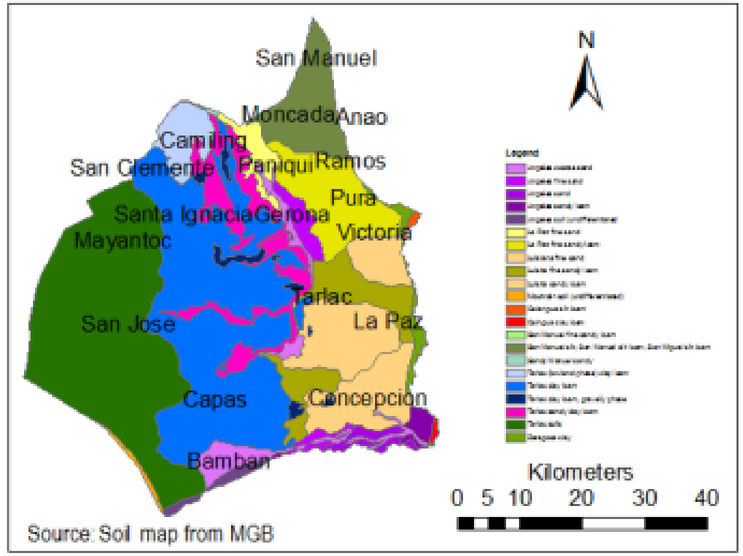
Camiling
San Clemente
Paniqui
Ramos
Pura
Santa Ignacia
Gerona
Mayantoc
Victoria
Tarlac
San Jose
La Paz
Capas
Concepcion
Bamban
N
Legend
3
Kilometers
0 5 10 20 30 40
Source: Rainfall data from TCA and CLSU

(a)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Capas
Concepcion
Bamban
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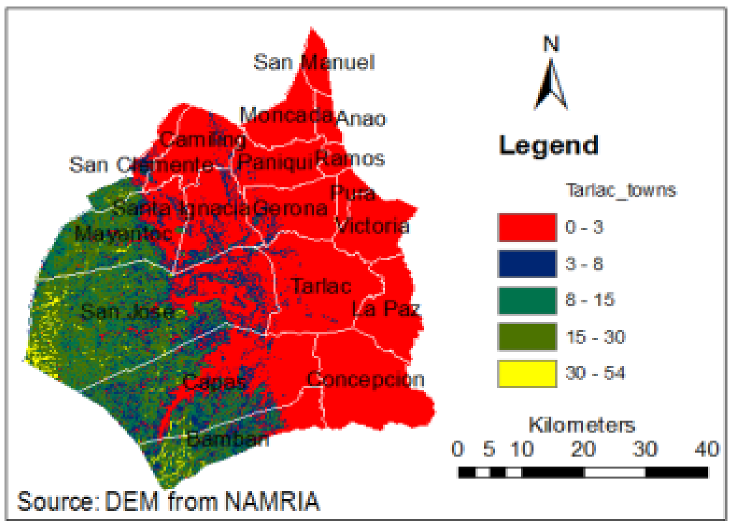
Legend
Kilometers
0 5 10 20 30 40
Source: Soil map from MGB

(b)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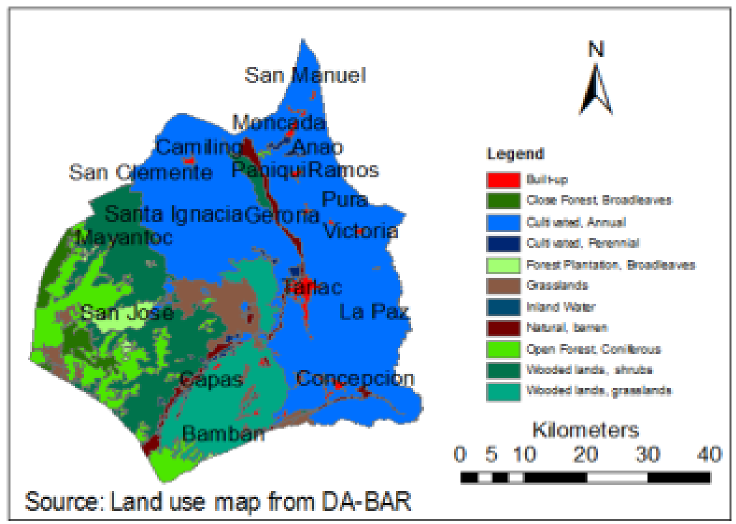
San Jose
La Paz
Capas
Concepcion
Bamban
N
Legend
Tarlac_towns
0 - 3
3 - 8
8 - 15
15 - 30
30 - 54
Kilometers
0 5 10 20 30 40
Source: DEM from NAMRIA

(c)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Cultivated, Annual
Cultivated, Perennial
Forest Plantation, Broadleaves
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Source: Land use map from DA-BAR

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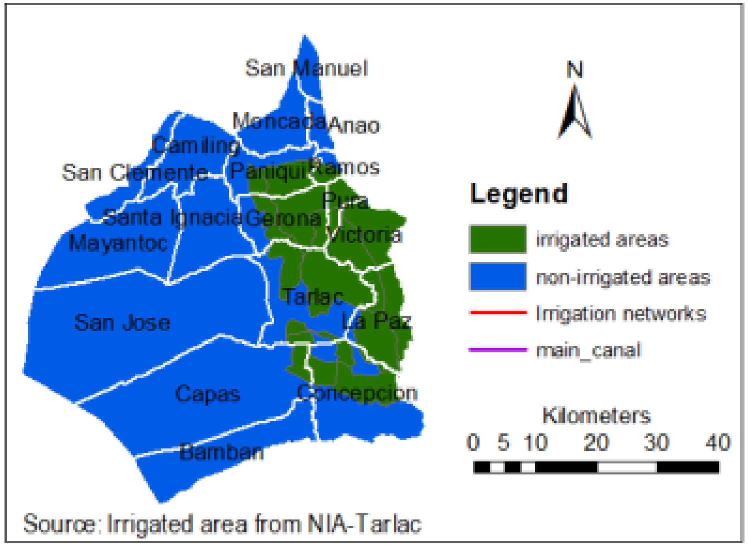

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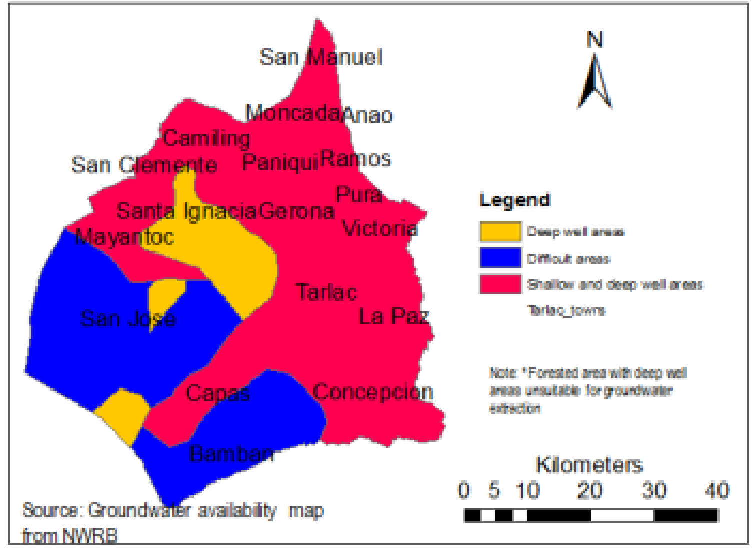

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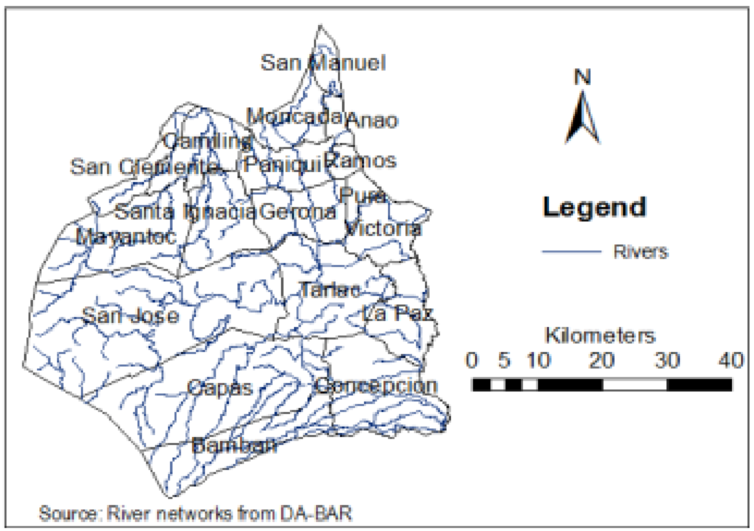

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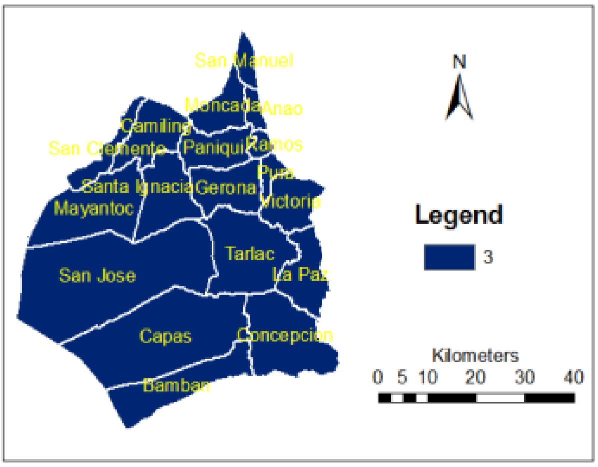
Figure 4. The thematic maps used in suitability mapping (a) Rainfall map (b) Soil texture map (c) Slope map (d) Land use map (e) Irrigation status map (f) Groundwater availability map and (g) River network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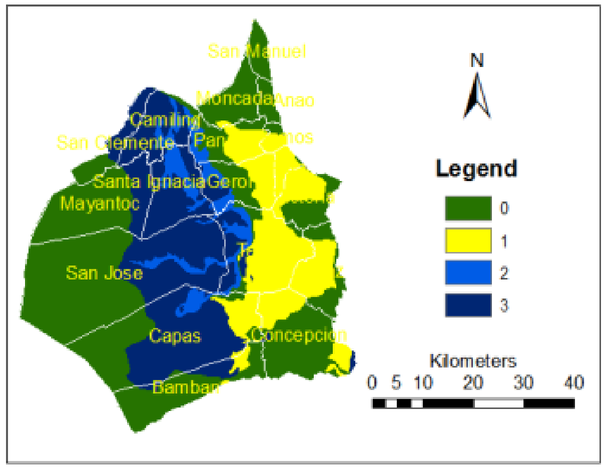
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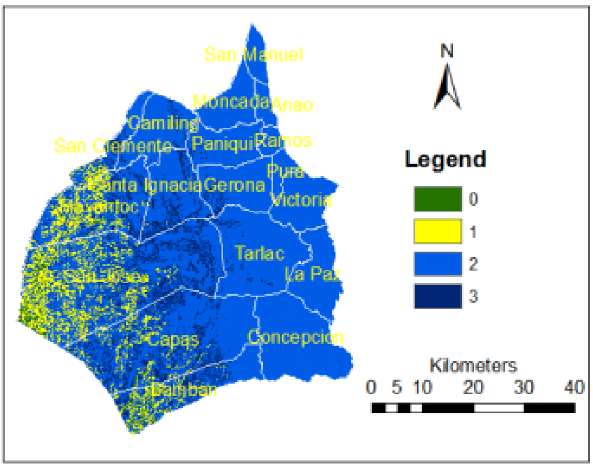
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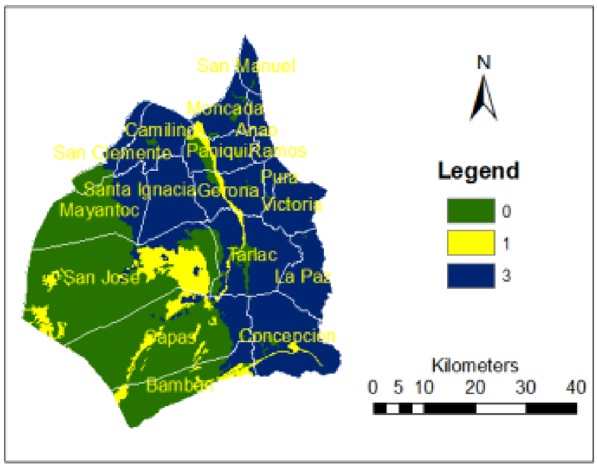
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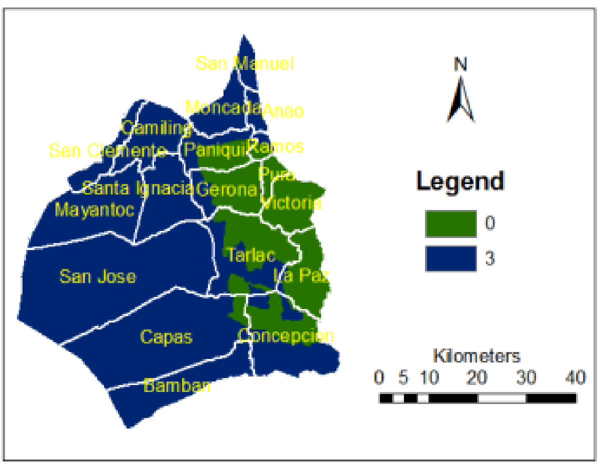
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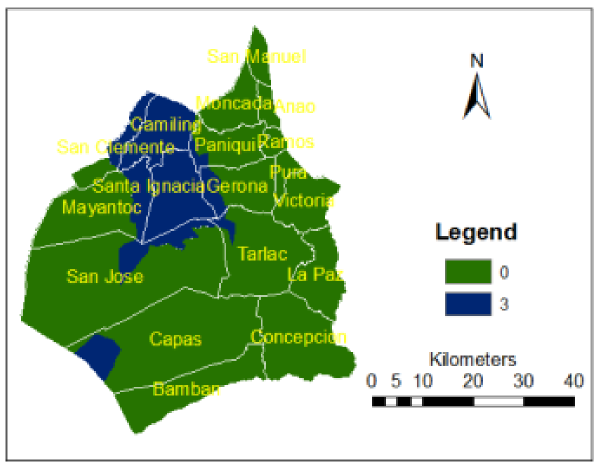
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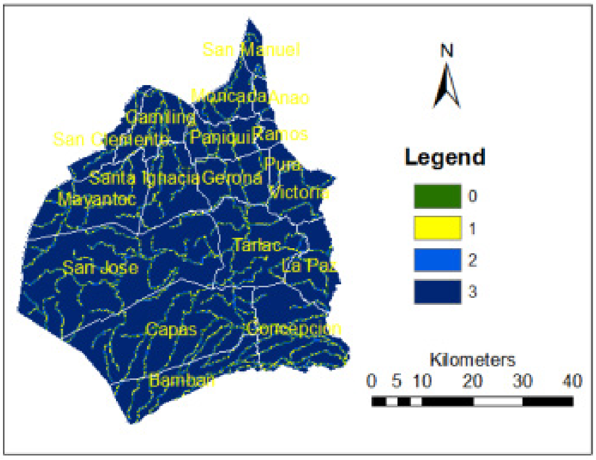

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Figure 5. The different factor maps produced from the thematic maps (a) Rainfall factor map (b) Soil texture factor map (c) Slope factor map (d) Land use factor map (e) Irrigation status factor map (f) Groundwater availability factor map and (g) Distance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

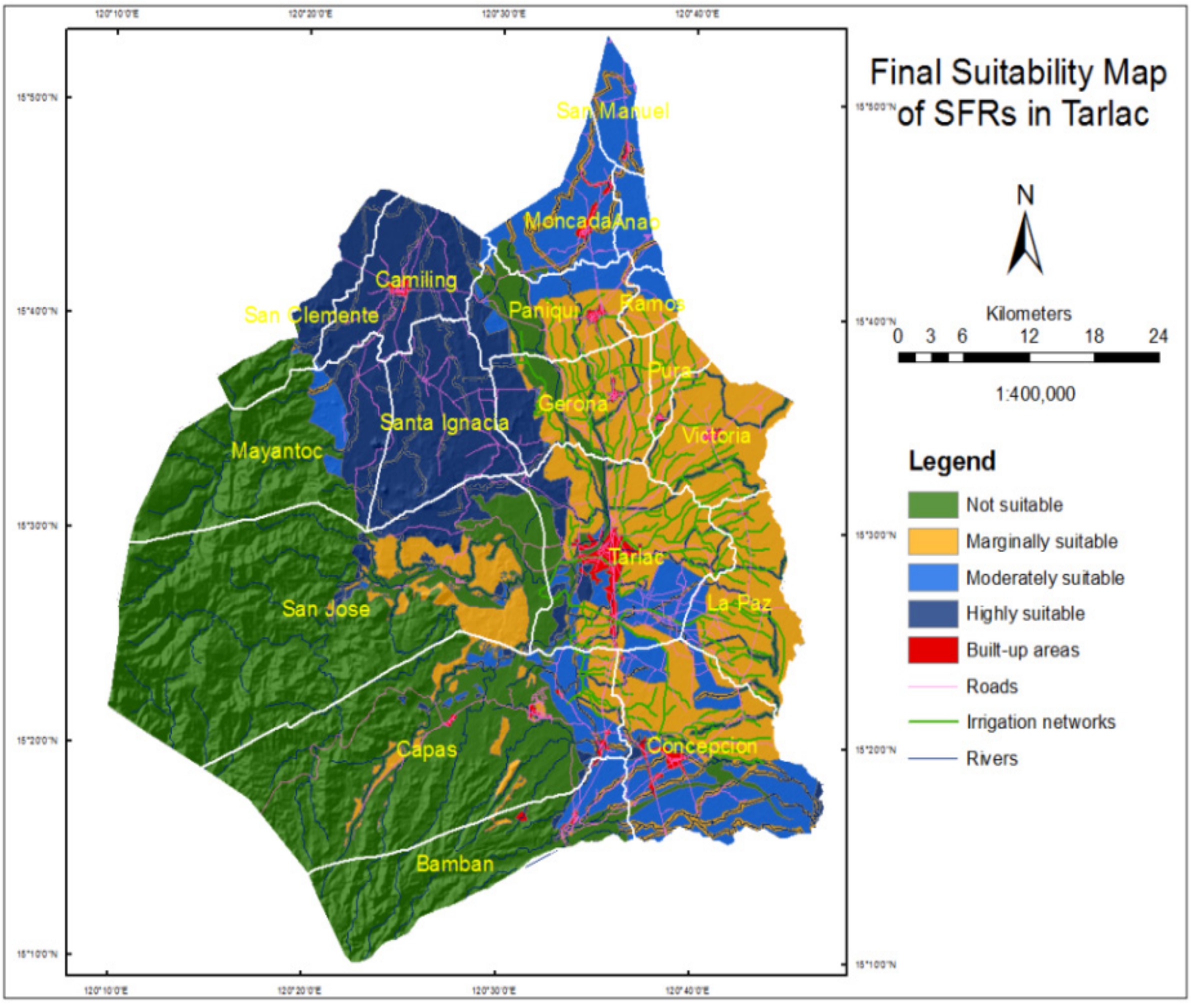

Figure 6. Final Suitability Map of SFRs in Tarlac

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.

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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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