An Integrated Open-Source GIS and Object-Oriented Programming Approach for the FC Contamination-free Well Depth and Age Analysis in Butuan City

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ABSTRACT: This paper describes a method of an integrated Open-source Geographical Information System (GIS), Object-Oriented Programming Language and Multiple Linear Regression (MLR) approach in characterizing groundwater fecal coliform contamination and determination of safe depth and safe age for prospect well sites through an interactive user interface.

GIS geospatial analyses and MLR were employed to determine the models that will describe the safe well depth and age of prospect sites considering the percent distributions of built-up and cropland areas within its potential contributing area and of persons using the well was significant factors. Derived models yielded an R^2 of 0.727 for safe depth and 0.801 for safe age. The Graphical User Interface (GUI) of the system was created and programmed in Visual Basic 2008 Express Edition implemented in .Net Framework 3.5. The GIS layers were displayed through the use of Map Control from Active X component of MapWindow. Hence, the developed GUI provided and easy and fast access of the valuable information that can guide users on the depth and longest duration of a prospect well will be safe from fecal coliform contamination.

1. INTRODUCTION

Ground water is an important natural resource. Groundwater makes up about twenty percent of the world's fresh water supply (Sinkevich , et al.2005). Groundwater can be polluted by landfills, septic tanks, leaky underground gas tanks, and from overuse of fertilizers and pesticides. Municipal sewage contains human and animal feces that have a disease causing organism that can harm the groundwater (Japitana, 2010). Fecal coliform bacteria are bacteria that carried by the human or animal feces, they are sensitive and commonly used indicators of bacterial pathogen contamination on natural waters; their presence implies the potential presence of microorganism that may cause harmful effects in human's life.

Coliform bacteria originate as organisms in soil or vegetation and in the intestinal tract of warm-blooded animals (Laws, 1993). This group of bacteria has long been an indicator of water contamination and possible presence of intestinal parasites and pathogens. Coliform bacteria are relatively simple to identify, are present in much larger numbers than more dangerous pathogens, and react to the natural environment and treatment processes similarly to pathogens. By observing coliform bacteria, the increase or decrease of many pathogenic bacteria can be estimated. Sources of bacterial pollution include runoff from woodlands, pastures, and feedlots; septic tanks and sewage plants; and animals and wild fowl. Domestic animals contribute heavily to the bacterial population. Many coliform bacteria may be directly deposited into natural streams from waste in water and runoff from areas with high concentrations of animals or humans (Treyens , 2009). Total coliform and FC numbers in ground water were generally higher in the faster flowing basalt aquifer than in the sand aquifer, indicating that the slower flow and finer grain size may filter more TC and FC bacteria from water (Entry et.al , 2001).

In Butuan City, water supply from some areas was based primarily in groundwater as their source of drinking and other daily activity. Since, some people desire to have their own wells; they usually place it wherever they want to, without thinking the possible contaminants present in the area, Butuan City poses an alarming threat. This study aims to assist and inform the people of Butuan City, Philippines, especially those who are living in Metro Butuan, regarding the potential occurrence of fecal coliform contamination in the waters abstracted from wells. The researchers employed Geographical Information System (GIS) to visualize, analyze and delineate the potential contributing area covered and the possible factors of fecal contamination present within the area. The said factors are the *Land Cover,* and number of *Household* in the area where we going to base the septic system. The *Multiple Linear Regression* is the statistical analysis use to derive a corresponding equation for the computation of the safe depth of the well, including the well age.

2. MATERIALS AND METHODOLOGY

2.1 Delineating the Potential Contributing Area (pca)

Potential contributing area (*pca*) is the area that can potentially contribute fecal contamination to the groundwater base from the well prospect site. In order for the researchers to characterize the area that are safe in FC contamination and characterize the factors that were present within the area of their residence, variable maps that includes Butuan Barangay and Land Use Land Cover map was first gathered, including its ASTER® Digital Elevation Model (DEM) that is useful in determining the elevation of the said area in order to do watershed delineation process.

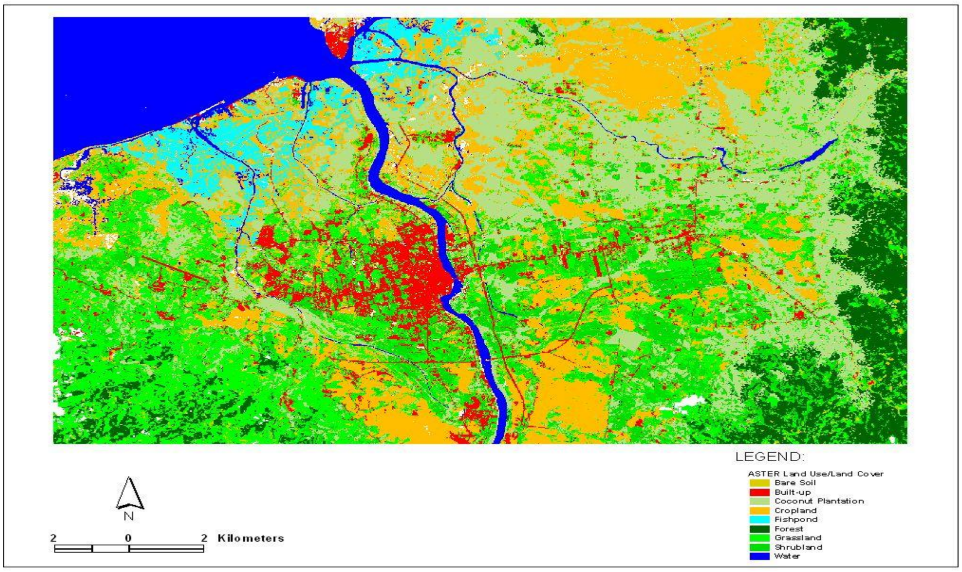

Figure 1: Butuan Land Use/Land Cover Map

2.2 Incorporating number of person using the well as factor for FC contamination

Number of persons using the well was incorporated as one of the factors of contamination. In the works of Japitana (2010), the number of persons using the well was found to be highly associated to groundwater contamination. The relationship between this variable to FC density was explained with the findings of Abdel-lah & Shamrukh (2001) where high discharge rate of wells were found to increase the velocity of pore water and thus makes the travel of fecal coliform to reach pump wells faster.

2.3 Statistical Analysis for Well Depth and Well Age Calculation

In order to derive the model for safe well depth and well age as the number of person using the well was included, the researchers used the MLR or *Multiple Linear Regression* analysis. The computed R^2 of the given data is the basis of the model's strength. There will be two MLR models to be determined that will be used in the system; one is for safe well depth and one for safe well age. The derived models will have coefficients that will be useful in formulating equations for the well depth and well age calculation. Each coefficient indicates the correlation of the independent variables to the well depth and well age variable as dependent variables.

2.4 Designing the System

2.4.1 Visual Basic 2008 (.NET Framework)

The user interface of the system was programmed using Visual Basic 2008 Express Edition version 9.0. It was one of the languages included in the Microsoft Visual Studio Express Edition 2008. It is an Object Oriented

Programming Language that was implemented in .NET Framework version 3.5. VB.Net 2008 has upgraded, advanced functionalities, and has larger class library compared to the older versions. It reads and accept Active X component of the integrated software of any kind. Active X control was a programmable object that enables the integration of the different software. It helps the researcher to import MapWindow functionalities that would make the system development much more efficient, that would provides information to the user in such a way that they can easily understand and visualize it.

2.4.2 MapWindow GIS (version 4.8.4)

MapWindow is GIS software that has an Active X control which is a programming object that can be added to a form in Visual Basic 2008 that enable integration to the other software. Its Active X "MapWinGIS.ocx" and has a specific components and ".dll" files that can be added for additional functionalities like "MapWinInterface.dll" , "MapWinGeoproc.dll", "MapWinUtility.dll" and other possible ".dll" files needed by the program. Some of the basic functionalities that Map Control cursor mode provides were the *zoom in, zoom out, pan, select* and *extent.* This open-source software contains a TauDEM plug-in that enable the user to do the process of watershed delineation to come up a *pca.* According to the developers of MapWindow they are on the process of making the software more efficient in terms of its plug-ins that it would be more useful and easy to use or access by its Active X control component.

2.5 Conceptual Framework

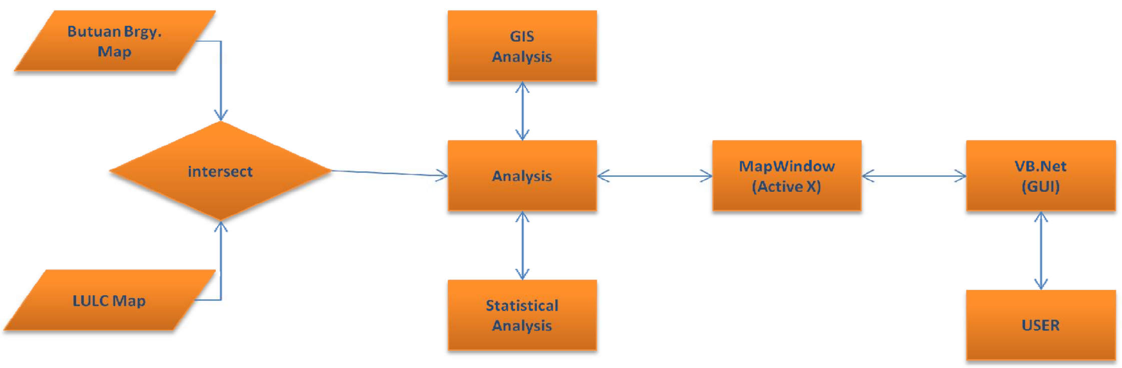

Figure 2: General flow of the study

The above figure shows the flow of the methods, processes and transactions in the study, from gathering Maps, GIS and data analysis, up to its user interface. The determination of the distribution of Land Use that influenced fecal contamination is based on the capture zone (CapZone) concept (Japitana, 2010) in order to characterize the potential contributing area (*pca*) to groundwater fecal contamination. These were delineated in a GIS platform and were processed to be able to employ geospatial analyses. Final maps were then generated to be uploaded to the user interface of the system.

3. RESULTS AND DISCUSSION

3.1 Delineated Potential Contributing Area (pca)

In order to efficiently characterize the area, Butuan City barangay map and land use land cover map was intersected, and *pca* were delineated that shows the area that possibly contribute to contamination.

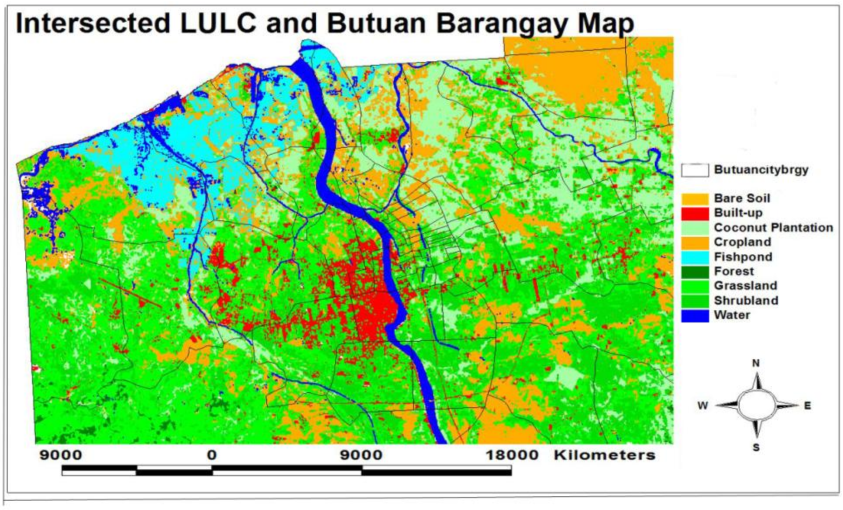

Figure 3: Intersected Barangay and LULC Map

3.2 Derived statistical analysis for well depth and well age calculation

In analyzing the data the researcher used Multiple Linear Regression (MLR). The analysis gives an R^2 as the strength of the derived coefficient of the analysis for calculating the Well Depth and Well Age. For the safe well depth MLR model, it yielded an R^2 of 0.727 with the LULC area coverage (in percent) within a *pca* (built-up and cropland) and the number of persons using the well as the significant variables. While the model derived for the safe well age yielded a higher R^2 value of 0.801. For the safe well age model, the input value for the well depth is the same value returned by the safe well depth equation (Equation 1). Equation 1 and Equation 2 below is the model derived for safe well depth and safe well age, respectively.

$$\textbf{\textit{Safe Well Depth}} = 0.029(\%\text{built-up}) + 0.241(\%\text{cropland}) + 0.782(\#\text{ of person will use the well}) \qquad (1)$$

$$\textbf{\textit{Well Age}} = \frac{4.029 - 0.024(\%\text{cropland}) - 0.017(\%\text{built-up}) - 0.005\,(\text{well depth})}{0.047} \qquad (2)$$

3.4 Graphical User Interface Design

Graphical User Interface of the system was created and programmed in Visual Basic 2008 Express Edition implemented in .Net Framework 3.5. The two models (Equation 1 and Equation 2) were entered in the source code, which are the basis of the interactive system to compute the safe well depth and safe well age.The GIS layers were displayed through the use of Map Control from Active X component of MapWindow. Sample points were created that enabled the user to choose areas where they can possibly construct or establish wells.

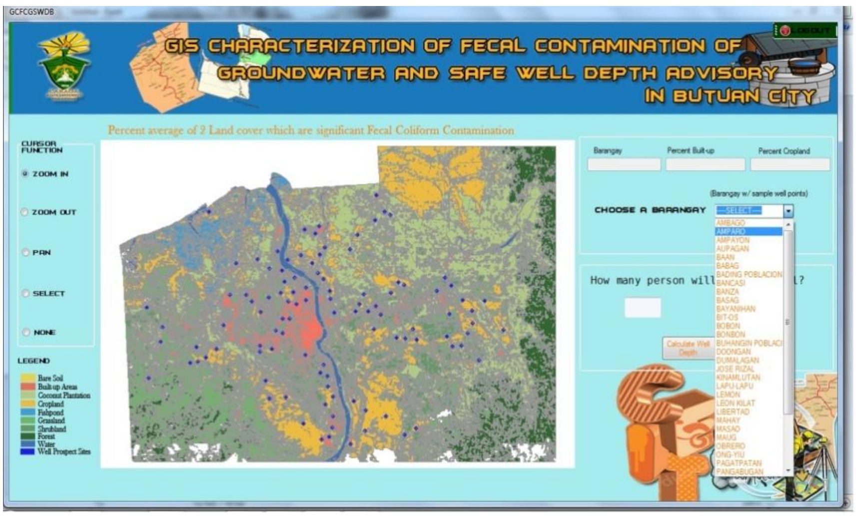

Figure 4: Graphical User Interface

4. CONCLUSION

This paper demonstrated the applicability of integrating GIS and object-oriented programming to develop a system that provided an easy and fast access of the valuable information that can guide users on the depth and the longest duration a prospect well will be safe from fecal coliform contamination.

5. REFERENCES

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