

IMPACTS OF INTERPOLATION TECHNIQUES ON GROUNDWATER POTENTIAL MODELING USING GIS IN PHUKET PROVINCE, THAILAND

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Abstract: Groundwater is one of the most valuable natural resources, which supports human health, economic development and ecological diversity. To understand the spatial distribution of groundwater specific capacity (SPC) which referred to groundwater potential in Phuket province is necessary. The objectives of this study were to investigate an appropriate interpolation method to estimate SPC trend and monitor the groundwater potential in Phuket Province, Thailand. SPC data was collected from Department of Groundwater Resources between 1995 and 2011. The data was processed by GIS using three different interpolation techniques (Inverse Distance Weighting (IDW), Kriging, and Splines). Statistical analysis using stepwise regression was applied for each interpolation technique to select the best fitted model. Results showed that IDW method produced the most accurate interpolating model for SPC estimation compared to Kriging and Splines. It was therefore concluded that the IDW method should be used in producing the SPC surface maps in the study area.

INTRODUCTION

Phuket province is one of place that has been changed in development rapidly such as expansion of economic, society, industries, especially tourism business (Phuket Municipality, 2006). Consequently, water resources are insufficient to meet demand in each area, especially, during the tourist season between November and April. Due to limited of surface water, therefore, groundwater is an alternative to replace the water shortage in Phuket area (Regional Environment Office 15 Phuket, 2006). To find out the groundwater potential, the Groundwater specific capacity (SPC) should be collected. SPC is the relationship between drawdown and discharge which describes the productivity of both the aquifer and the well. SPC is determined on a designed production well. It must be time-consuming and extremely costly to explore groundwater potential zone in large area using the traditional methods (Vanaree, 2000).

Geographic Information System (GIS) is an influential tool and has great potential for using in environmental problem solving. Recently, GIS can be explored of groundwater resources which assist in assessing, monitoring and conserving groundwater resources. Currently, there are computer software that can be applied in groundwater research such as ARC Info, ARCVIEW MapInfo and ArcGIS etc. The demarcation potential of groundwater by the application of the GIS model is simple and easy way to update the information in the map of potential groundwater.

Many studies have used GIS techniques to analyze the groundwater potential zone using many multi-criteria such as (Conforti, Aucelli, Robustelli, & Scarciglia, 2011), drainage pattern (Shankar & Mohan, 2005), lineament (Mondal, Pandey, & Garg, 2008), (Dunhill, 2012), and soil (Giordano & Liersch, 2012) etc. Several researches have been done on comparing different interpolation methods in a variety of situations using GIS in particular areas (Chao, Chou, Yang, Chung, & Wu, 2009; Chiang et al., 2010; Iescheck, Sluter, & Ayup-Zouain, 2008) such as groundwater depth, groundwater contamination, groundwater quality etc. Geostatistics provides a set of statistical tools for analyzing spatial variability and spatial interpolation. Interpolation is a method that estimates the values at locations where no measured values are available. These techniques generate not only prediction surfaces but also error or uncertainty surface. There are many geostatistical interpolation methods have (Kumar, 2007) been widely used in the past decades such as Kriging Splines and IDW for interpolation of yields or contaminants in groundwater. However, there have been few publications comparing different interpolation methods for SPC in island areas. The objectives of this study were 1) to select an optimal interpolation method from among interpolation methods including Inverse Distance Weighting (IDW), Splines, and Kriging and 2) to use the best interpolation method to analyze the trend of SPC in the study area.

METHODS

Study area

Phuket is the biggest island in Thailand, located in the Andaman Sea of southern Thailand summarized in Table 1. The area is mostly granite, which is hard and several meters deep, but it provides a good potential groundwater (Witit, 2006). Groundwater is used in both businesses and industrial sections. Figure 1 shows distribution of wells in the study area. Hydrogeological characteristics of the area divided into highland and lowland areas in which groundwater occur in several consolidated rock (46.91%), unconsolidated rock (24.01%), and intercalation between consolidated and unconsolidated rocks (29.08%), respectively. Yields of consolidated and unconsolidated aquifers in the study area range from 1 to 30 m³/hr and 5 to 20 m³/hr, correspondingly.

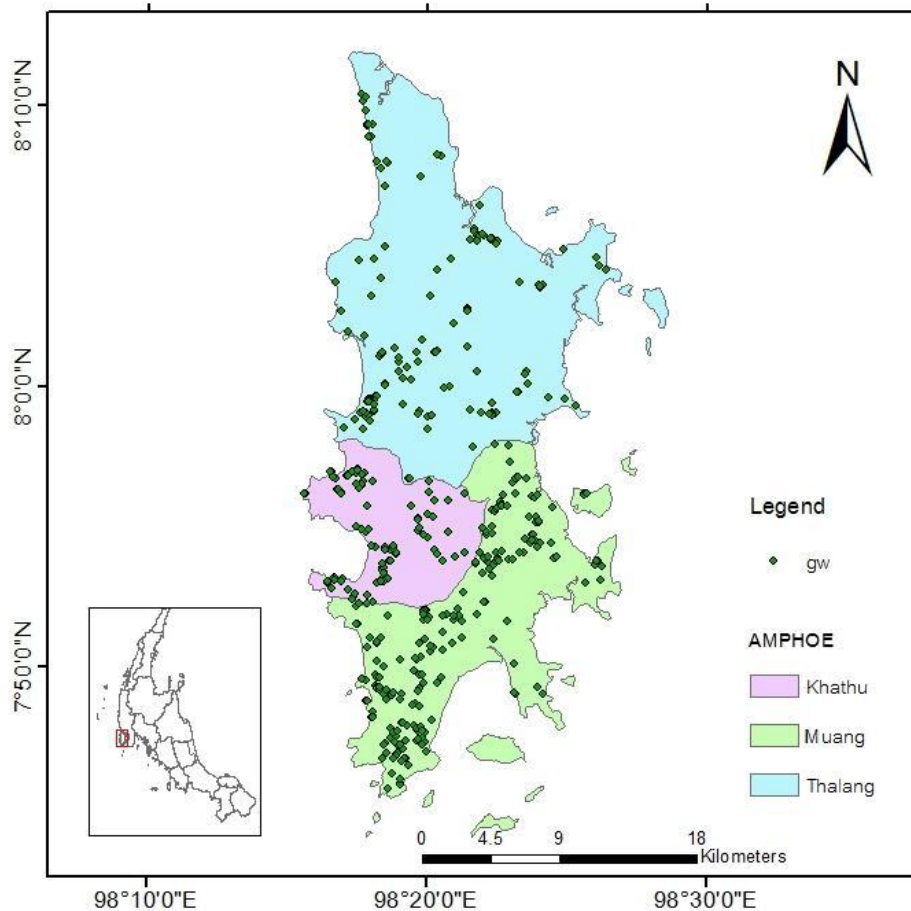


Figure 1: Distribution of wells in Phuket province, Thailand

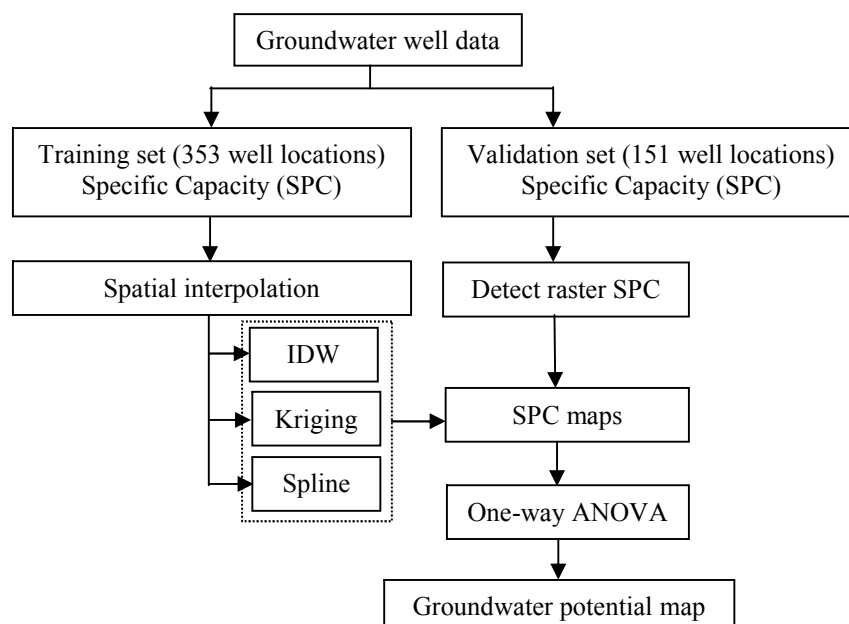
Table 1: Characteristics of study area.

Geographic information	Study area
Topography	70% of the area is mountains stretching from north to south, while the other 30% are plains, mainly in the central and eastern parts of the island. There is no important river but a total of 9 brooks and creeks. The west coast is stretches of white sandy beaches.
Location	7° 53' 24" N, 98° 23' 54" E 47N 433678 872185
Area	The total area is approximately 570 square kilometers (including the province's other islands).
Elevation	
Range	0-549 m
Mean	68.33 m
Std	90.56 m
Gradient	
Range	0-57 °
Mean	9.61 °
Std	8.41 °

Methodology

SPC was calculated from 504 wells and randomly divided into 2 groups including training set (70%) and validation set (30%), respectively. To select the best method in the study, several interpolation methods – the inverse distance weighting (IDW) method, the Splines method, and the Kriging method- were compared, and then the best interpolation method was used to give the spatial distribution of SPC. The processing outline is shown in Figure 2.

The data used in this study were collected from Department of Groundwater Resources between 1995 to 2011. The SPC was calculated using the pump test from the collected data. The SPC was used as an indication of the productivity of well. High specific capacity indicates a high transmissibility and, conversely, low SPC indicates a low transmissibility of a well discharging. SPC data was randomly selected in 70% (353 well locations) to interpolate the SPC and 30% (151 well locations) to validate the models.

**Figure 2:** Processing outline of the study

RESULTS

SPC in Phuket province was interpolated using IDW, Kriging and Splines methods. The interpolation process was carried out. The results of each interpolation process were represented over the study area. The mapping result of SPC is shown in Figure 3. Afterward, the interpolation values were compared with validation dataset (Table 2) using One-Way ANOVA and stepwise multiple linear regression analysis. From the results, IDW performed significantly different from Kriging and Splines. In all the stepwise linear regression analysis performed in the study, predictors were included in the model when $p \leq 0.05$.

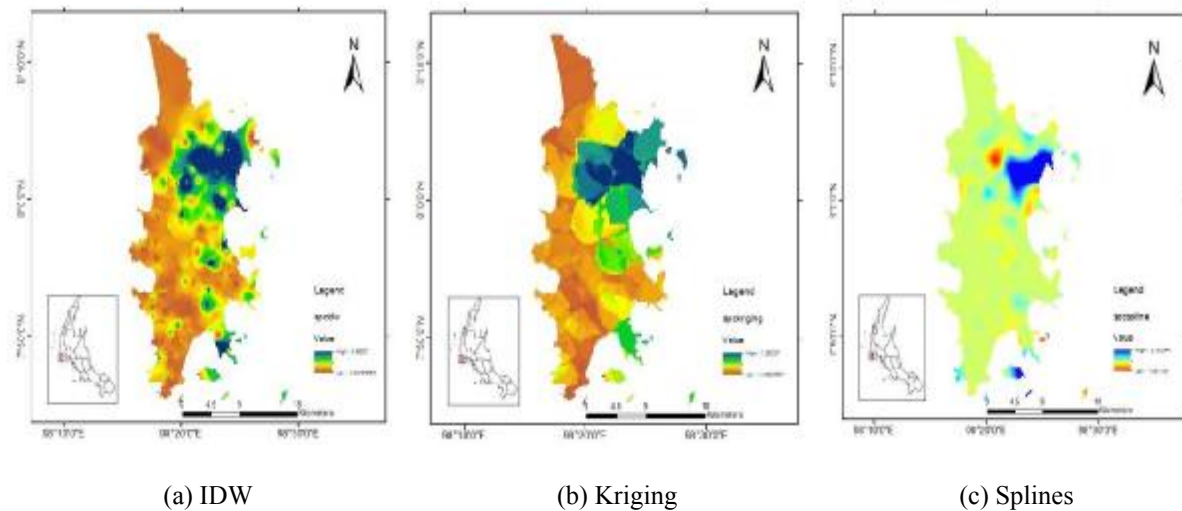


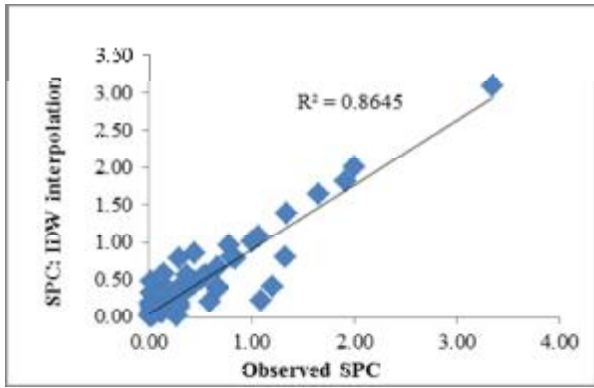
Figure 3: SPC Interpolation using different techniques

Figure 3 shows that IDW was sensitive to extreme SPC values, and had low resistance, which can produce bigger interference to the performance of the whole trend. The maximum or minimum values of SPC can only appear at the sampling points. Kriging could perform smoother than IDW and Splines.

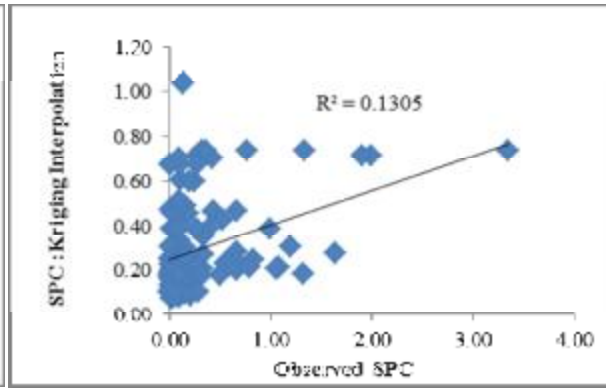
Table 2: F-values and degree of freedom from One-Way ANOVA analysis performed on different interpolation methods

		Sum of Squares	df	Mean Square	F	Sig.
IDW	Between Groups	23.576	108	0.218	26.059	0.000
	Within Groups	0.352	42	0.008		
	Total	23.928	150			
kriging	Between Groups	3.972	108	0.037	1.333	0.147
	Within Groups	1.159	42	0.028		
	Total	5.131	150			
Splines	Between Groups	172.813	108	1.600	0.890	0.688
	Within Groups	75.480	42	1.797		
	Total	248.293	150			

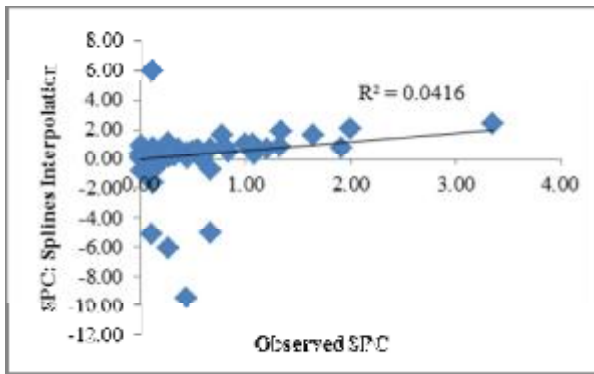
Table 2 shows the significant differences in IDW, Kriging and Splines interpolation method for estimating SPC in the study. Figure 4 shows tend of observed SPC and estimated SPC from each interpolation methods. From table 3, IDW was the highest coefficient of determination ($R^2 = 0.865$) using stepwise multiple linear regression analysis between observed SPC and estimated SPC from IDW, Kriging and Splines interpolation methods ($R^2 = 0.865$, $R^2 = 0.131$ and $R^2 = 0.046$, respectively). The results found that IDW was the best interpolation method to estimate SPC in the study area as the reasons above.



(a) SPC with IDW interpolation



(b) SPC with Kriging interpolation



(c) SPC with Splines interpolation

Remark: SPC unit is qpm/ft

Figure 4: Relationship between observed SPC and estimated SPC from difference interpolation methods: (a) IDW (b) Kriging and (c) Splines

Table 3: Summary of stepwise regression analysis for different interpolation methods as the dependent variables

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
IDW	0.930 ^a	0.865	0.864	0.159

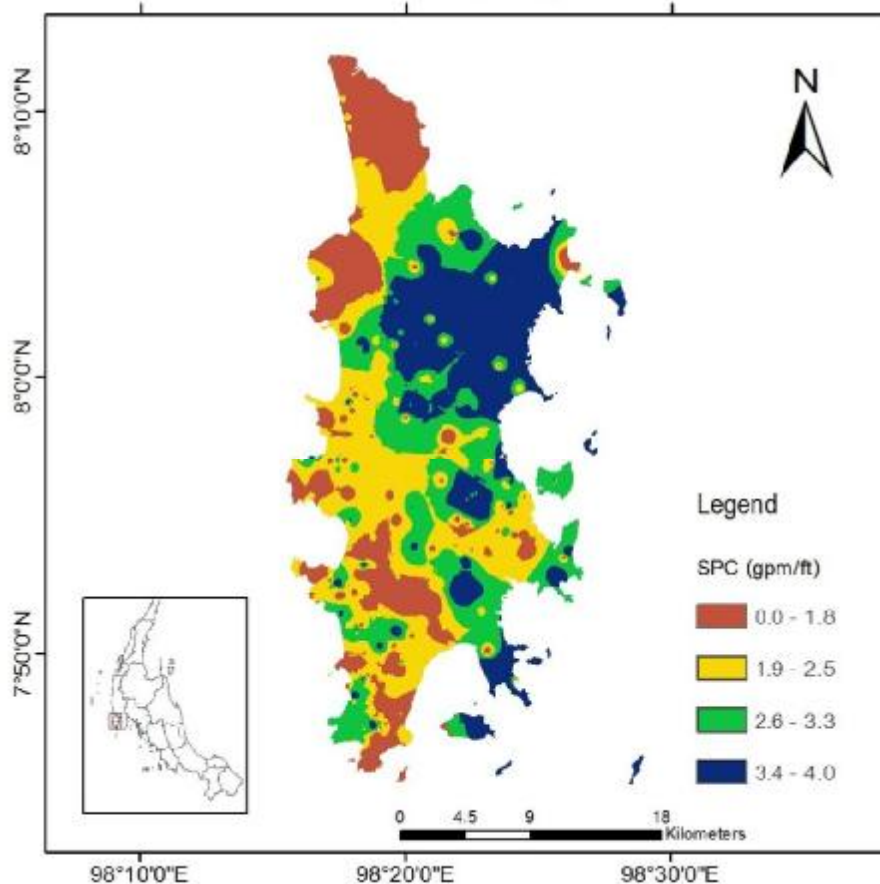


Figure 5: Groundwater potential map

The SPC distribution which referred to the groundwater potential zone in the study area is shown in Figure 5. The highest potential zone is the east area of Phuket Island which SPC range between 3.4-4.0 gpm/ft.

DISCUSSION

The study supports the hypothesis that GIS interpolation method can be used to estimate SPC in the study area. IDW was the best interpolation method to estimate SPC in the study which agreed with Burrough & Macdonnel (1998). Pham and Achara (2011) noted that IDW gave the best prediction for estimating arsenic contamination in groundwater in Thanh Tri, Hanoi, Vietnam. However, SPC is a non-stationary spatially distributed variable as it depends on many factors such as geological characteristics. The further studies should be considered the incorporation of an altimetric model of the radiation sources and measurement points for specific interpolation, as a way to improve the interpolation results (Sun, Kang, Li, & Zhang, 2009).

CONCLUSIONS & RECOMMENDATIONS

In the present study we have presented an interpolation method which included IDW, Kriging and Splines methods to estimate SPC surface trends. This study has shown that IDW interpolation method is most likely to produce the best estimation of a continuous surface of SPC in Phuket area. The IDW method exactness was superior to the one shown by the Splines and Kriging techniques. Nevertheless, it should be noted that IDW interpolation method should be turned adjusting the power parameter and the search radius to improve accuracy, in each specific case. Though the data may have simply lacked spatial structure, it is recommended that the characteristics of the study sites, sampling strategy, and independent variables be explored further to evaluate the causes for the relatively poor model results.

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