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Application of Dempster-Shafer theory of evidence model to geoelectric and hydraulic parameters for groundwater potential zonation

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A B S T R A C T

The application of a GIS – based Dempster – Shafer data driven model named as evidential belief function EBF- methodology to groundwater potential conditioning factors (GPCFs) derived from geophysical and hydrogeological data sets for assessing groundwater potentiality was presented in this study. The proposed method's efficacy in managing degree of uncertainty in spatial predictive models motivated this research. The method procedural approaches entail firstly, the database containing groundwater data records (bore wells location inventory, hydrogeological data record, etc.) and geophysical measurement data construction. From the database, different influencing groundwater occurrence factors, namely aquifer layer thickness, aquifer layer resistivity, overburden material resistivity, overburden material thickness, aquifer hydraulic conductivity and aquifer transmissivity were extracted and prepared. Further, the bore well location inventories were partitioned randomly into a ratio of 70% (19 wells) for model training and 30% (9 wells) for model testing. The synthesized of the GPCFs via applying the DS – EBF model algorithms produced the groundwater productivity potential index (GPPI) map which demarcated the area into low – medium, medium, medium – high and high potential zones. The analyzed percentage degree of uncertainty for the predicted lows potential zones classes and mediums/highs potential zones classes are >10% and <10%, respectively. The DS theory model-based GPPI map's validation through ROC approach established prediction rate accuracy of 88.8%. Successively, the determined transverse resistance (TR) values in the range of 1280 and 30,000 $\Omega\,m^y$ for the area geoelectrically delineated aquifer units of the predicted potential zones through Dar – Zarrouk Parameter analysis quantitatively confirm the DS theory modeling prediction results. This research results have expand the capability of DS – EBF model in predictive modeling by effective uncertainty management. Thus, the produced map could form part of decision support system reliable to be used by local authorities for groundwater exploitation and management in the area.

1. Introduction

The spatial prediction of groundwater potential using the standard method is important for groundwater resources management (Rahmati et al., 2016; Mogaji and Omobude, 2017). Groundwater being a hidden subsurface treasures resource not easily seen with the naked eyes is very difficult to quantify potentially. Subsequently, planners and hydrological engineers have resolved to engage the efficacy of the predictive standard methods in groundwater potentiality mapping. Indeed, this has contributed immensely to managing groundwater resource sustainably (Pourghasemi and Beheshtirad, 2015). This precious natural resource often served as a driven resource in all works of life such as industrial and agricultural purposes (Pradhan, 2009; Ayazi et al., 2010; Manap et al., 2013; Neshat et al., 2014; Nampak et al., 2014). Consequently, the increasing demand for such natural resource in all climatic regions in the world by the way of rapid population growth, urbanization, drought among others, cannot be over emphasized (Magesh et al., 2012; Todd and Mays, 2005; Oikonomidis et al., 2015). Therefore, the optimal maximization of this vital natural resources i.e. potentiality evaluation requires efficient management (Oikonomidis et al., 2015).

Recently, the usage of the multi-criteria predictive standard methods has been reportedly a good alternative in environmental decision making venture (Akinlalu et al., 2017; Oni et al., 2017; Mogaji and Lim, 2017). Thus some renowned GIS – based spatial

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integration models such as weights-of-evidence, probabilistic frequency ratio, Shannon's entropy, logistic regression, artificial neural network, analytical hierarchy process and evidential belief function have been fully engaged in groundwater potential mapping (Al-Abadi, 2015a, Corsini et al., 2009; Lee et al., 2012a,b,c; Pourtaghi and Pourghasemi, 2014; Naghibi et al., 2014; Davoodi Moghaddam et al., 2013; Oh et al., 2011; Ozdemir, 2011a, 2011b; Naghibi et al., 2014; Corsini et al., 2009; Lee et al., 2012b; Kaliraj et al., 2014; Mogaji, 2016; Nampak et al., 2014; Mogaji et al., 2015a). However, it is important to note that the commonest groundwater potential conditioning factors (GPCFs) often used in these priors studies include lineament density, lineament intersection density, drainage density, slope, lithology and rainfall, etc. However, the studies on the use of the geophysical and hydrogeological inclined GPCFs such as (aquifer resistivity, aquifer thickness) and (transmissivity and storativity), respectively in spatial predictive mapping of groundwater potentiality are few. According to Sener et al. (2005) and Madan et al. (2010), these latter GPCFs have direct bearing and an in situ contact with the subsurface fluid flow mechanism. Moreover, among the often used multi-criteria index predictive model, few studies have applied the data-driven evidential belief functions methodology.

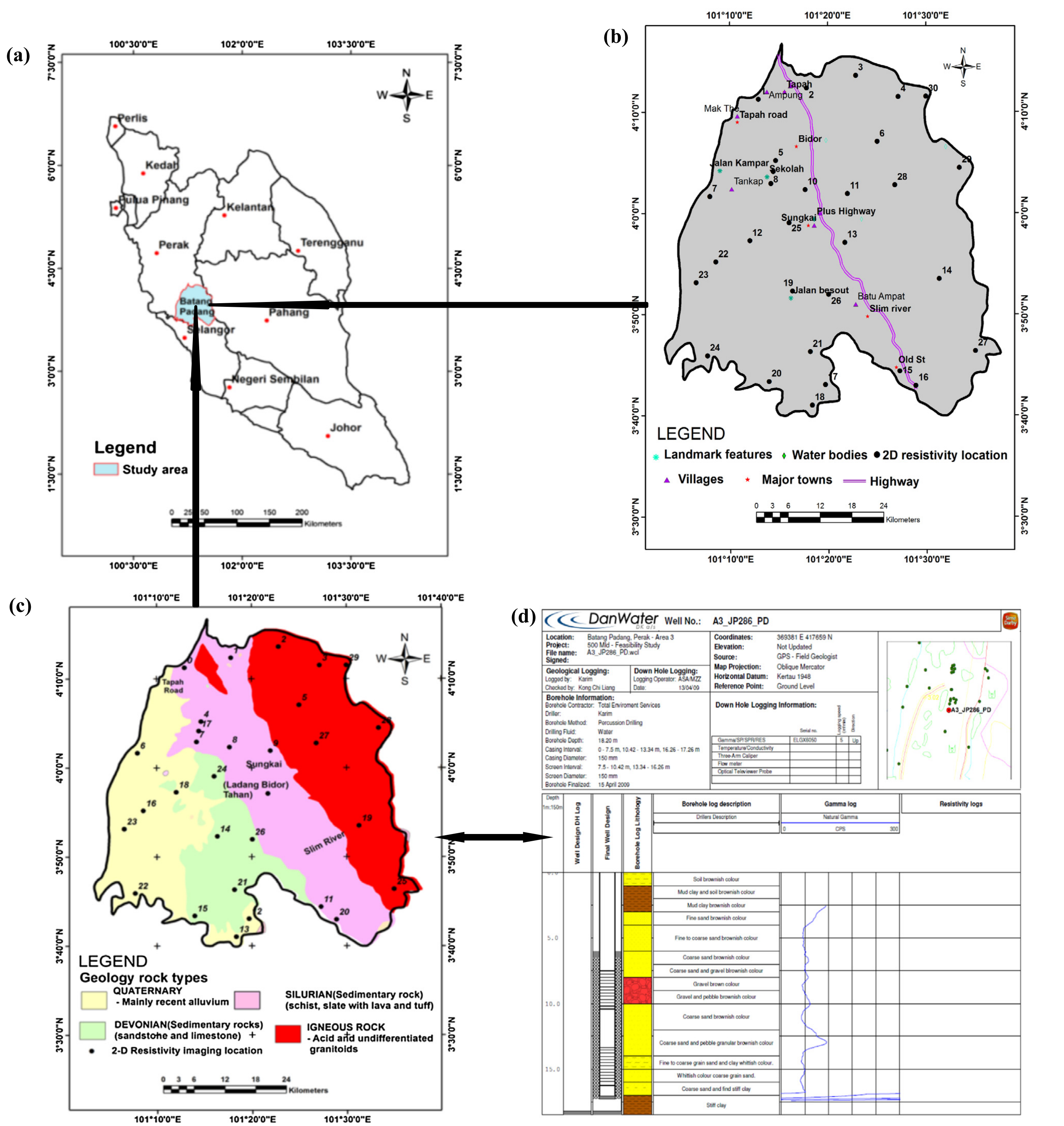

Fig. 1. The study area description materials showing a: map of Peninsular Malaysia; b: site location map depicting the 2D Resistivity imaging location point; c: the area geologic rock types map and d: typical borehole litho – log of the area.