Evaluation of groundwater pollution risk (GPR) from agricultural activities using DRASTIC model and GIS

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Abstract. Groundwater Pollution risk (GPR) map which utilized groundwater quality is important in order to prevent the groundwater contaminant concentration due to the agricultural activities. DRASTIC model and GIS application are two important tools that had been used for accessing and predicting the quality of groundwater. These supplementary tools are calculating, visualizing, and presenting the GPR by using DRASTIC index for each hydrogeologic factor through ArcGIS software. This study was covered approximately Selangor basin area where the GPR has been defined. There are four categories of agricultural activities in the Selangor basin which are animal husbandary areas, horticultural lands, short term crops and tree, palm and other permanent crops. The map showed that the “low” zones of GPR occupied 56% of the east side of the Selangor basin, 34% of the west side of the Selangor basin exposed to “medium” zones of GPR and the “high” zones of GPR covered 10% at the north side and the south to the west side of the Selangor basin. As a particular, for agricultural activities which is 52% of Selangor basin area, the “low”, “medium” and “high” zones of GPR was occupied as 42%, 43% and 15% respectively. Based on four categories of agricultural landuse, GPR map validated by nitrate distribution map, shows that the 99% of the variation in nitrate distribution zones are explained by GPR zones. In conclusion, groundwater pollution risk was affected by agricultural activities.

1. Introduction
Recently groundwater has become a major source of water for many industries and municipalities and also for agriculture activities [2], [5]. Most of the groundwater is clean, but groundwater can become polluted or contaminated if no further protection is being considered [12], [22]. The movement of contaminants that infiltrate into soil and groundwater occurs through wastes disposals, discharge of effluent from industries or release of chemicals through agriculture activities [13, 17]. Agricultural activities have been identified as one of the non-point sources of pollutants to groundwater and soil. They affect groundwater quality in many ways. For example, it can become polluted when people use too much fertilizer or pesticides on their crops area. Agricultural pollutants such as nitrate and heavy metals from fertilizer will dissolve in the surface water such as river or irrigation water and then infiltrate through the soil and groundwater zone [1].

Agricultural activities for example paddy field, palm oil plantation and large scale farming have high risk to contaminate the groundwater such as by nitrate and heavy metals leaching generated from fertilizer used in agricultural lands [14]. The fertilizer which contains nitrogen, phosphorus and potassium will be more soluble in water. Solute transport movement is due to groundwater flow. [5] have reported growing incidences of nitrate pollution and increase of nitrate concentration in groundwater in intensive agricultural areas. Nitrogen rich fertilizers is a major source which makes the level of nitrate concentrations increased [7]. Leaching of various pollutants from agricultural land through the unsaturated zone and groundwater zone gives rise to contamination in these zones. This process varies from one location to another [6]. According to Malaysian Environmental Quality Report 2006 by Department of Environment (DOE), Ministry of Natural Resources and Environment
Malaysia showed that in nitrate sample collected from 12 monitoring wells in agricultural land use area exceeds the National Guidelines for Raw Drinking Water Quality.

Many technical methods have been created and applied by scientist and other researchers from previous study to monitor issue of groundwater vulnerability to contamination. There were several methods and approaches for groundwater vulnerability assessment through model and mapping such as DRASTIC [3], GOD [10], AVI [23] and SINTACS [8]. These models can be classified as conventional methods. According to [24], conventional methods can differentiate the level of vulnerability at wide scales where the existence of various lithologies. The DRASTIC model is a famous method developed by U.S. Environmental Protection Agency (EPA). It is a standardized system which is employs numerical ranking system that assign to relative weights to various hydrogeological parameters affecting the level of groundwater vulnerability.

Nowadays with the advancement and development in technology, most scientist and researchers were using the help of technology for planning, monitoring and decision making. Geographic Information System (GIS) is a technology that is very useful for agricultural scientist and other researchers such as [2], [4], [15] and [20] to locate and explore groundwater. Using this technology, the techniques were widely used in groundwater pollution potential mapping. The main benefit of GIS mapping is the unification of data layers and modification of data parameters that applied in vulnerability classification [25].

In this study, landuse, water quality and hydrogeological factors data from Malaysian government agencies were acquired for Selangor basin area and together assembled in a GIS environment by using ArcGIS software and DRASTIC system to achieve three main objectives as follows:

i. To calibrate hydrogeological parameters of DRASTIC model of Selangor basin.
ii. To determine Groundwater Pollution Risk (GPR) zones based on agricultural activities of Selangor basin.
iii. To correlate the significance of GPR zones and nitrate distribution zones on agricultural area.

2. Methodology

2.1 The study area

The selected study area is Selangor basin where it is located at the northern part of the state of Selangor (Figure 1). The basin is lies within latitudes 3° 9’ 57.6” - 3° 43’ 48” North (350969-412414 RSO meters) and longitude 101° 6’ 14.4” - 101° 49’ 44.4” East (344864-426160 RSO meters). The area of basin is approximately 2900 km² which is covering about a one third of the state of Selangor. The basin is covering four districts in Selangor state which is Kuala Selangor, Hulu Selangor, a west part of Gombak and a north part of Petaling.

Sungai Selangor is the major river in Selangor basin. It starts at elevation approximately 700 m to 7000 m above mean sea level from the west part of Banjaran Titiwangsa between Pahang state and Selangor state boundary. The river flows from the northeast of Hulu Selangor toward the west of Kuala Selangor and finally ends at Straits of Melaka as far as about 110 km. The main tributaries that relate to this river are Sungai Buloh, Sungai Belatak, Sungai Kerling, Sungai Batang Kali, Sungai Rening, Sungai Kul and Sungai Gumut.

Throughout the year, Selangor basin has characterized with tropical climate. The climate of the basin is normally warm but sometimes hot and sunny days, and cool in evenings. Temperatures typically range from 23°C to 34°C. Humidity levels are generally 80% or higher and annual rainfall often exceeds 2,000mm. Selangor basin is also rich with a variety of agricultural activities which is covering about a half of the basin. Most of the agricultural activities are converging at Kuala Selangor and at west side of Hulu Selangor.
2.2 DRASTIC model

In this study, the DRASTIC model will be used to evaluate the potential for groundwater contaminant in the selected agricultural area. DRASTIC is an empirical model developed by U.S. Environmental Protection Agency (EPA) which is widely used for evaluating relative groundwater pollution susceptibility by the use of hydro-geological factors [3]. It can be used to assist planners, managers and administrators in the task of evaluating the relative vulnerability of an area to groundwater contamination from various sources of contamination. It is an acronym for the 7 most important hydro-geological factors affecting groundwater pollution, which are D (depth to water table), R (net recharge), A (aquifer media), S (soil media), T (topography), I (impact of vadose zone media), and C (hydraulic conductivity of aquifer).

[1], [4], [19] and [21] have demonstrated the successful use of this model to develop a groundwater contamination risk map using GIS techniques. The outcome of the project will be mapped as Groundwater Pollution Risk (GPR) zones which could be used to estimate the groundwater pollution risk due to agricultural activities. It is necessary to provide guidelines for groundwater protection. This study is also to employ Information Technology to the field of agriculture. GIS is used for data capture, data management and map presentation design.

Evaluation of DRASTIC index is based on 3 significant parts which are ranges, ratings and weights that have been devised using the DRASTIC factors. The DRASTIC factors are measurable parameters where it is generally available from miscellaneous of sources. The use of DRASTIC involves rating for each of the individual parameters at the certain location and multiplying the rating by a relative importance or weight constant. The formula of DRASTIC or known as DRASTIC index to evaluate the total of score (Rating x Weight) for each range in every parameter on certain area is (Equation 1):

\[
DrDw + RrRw + ArAw + SrSw + TrTw + IrIw + CrCw = GPR
\]

When DRASTIC index has been evaluated, it is possible to determine zones which are more tend to be affected to groundwater pollution relative to one another. The higher of the DRASTIC index, the greater of the groundwater pollution risk [3]. The DRASTIC index gives just a comparative evaluation tool and it is not designed to provide actual answer.
2.3 GIS data and analysis
The systematic procedure and planning are needed in preparation of 7 DRASTIC parameter thematic maps to produce groundwater pollution risk map. Table 1 shows the sources of data based on each of DRASTIC parameter.

| Government agencies                          | D | R | A | S | T | I | C |
|---------------------------------------------|---|---|---|---|---|---|---|
| Department of Survey and Mapping Malaysia (JUPEM) | √ | √ |     | √ |     |     |     |
| Malaysian Meteorological Department (MET)    |     | √ |     |     |     |     |     |
| Minerals and Geoscience Department Malaysia (JMG) | √ |     | √ |     | √ |     |     |
| Department of Agriculture Malaysia (DOA)     |     |     |     |     |     |     | √ |

All the data has been processed by using GIS software which is ArcGIS 9.3. The main task is to bring all the appropriate data together into a GIS database. Basically, all the available spatial data will be converting into GIS platform. The data was added together and assemble in digital form with right coordinate system to make sure the spatial component will overlay correctly.

2.4 Depth to water analysis
In process to design D parameter layer, the elevation data has been generated from topographic map by DEM. Then, water level data (point layer) based on well location has been interpolated using IDW method. Next, the difference between elevation layer and water level layer has been computed to produce the depth to water layer because both of data are measure from mean sea level. The map was reclassified based on range in DRASTIC system and has been assigned with rating and weight to generate D parameter layer.

2.5 Recharge analysis
Recharge layer was generated from calculation of total percentage of slope layer and difference of rainfall and evapotranspiration distribution layer based on general water balance equations which is (equation 2). Calculation has been constructed through spatial analyst.

\[
\text{Recharge (\%)} = \text{Slope (\%)} + [\text{Rainfall (\%)} - \text{Evapotranspiration (\%)}] \tag{2}
\]

Slope layer in percentage are generated from DEM while Slope layer in percentage are generated from DEM while total of rainfall data and evapotranspiration data distribution layer are generated from difference of interpolation of both data using IDW method and raster calculator. The data was obtained from rainfall station in the whole of peninsular Malaysia due to there are no average evapotranspiration data in Selangor basin area and only two principal stations that near to Selangor basin included Lapangan Terbang Sultan Abdul Aziz Shah (Subang) and Petaling Jaya. The recharge layer has been reclassified based on range in DRASTIC system and has been assigned with rating and weight to generate R parameter layer.

2.6 Aquifer media analysis
Based on lithology in attribute table of geology map, its characteristics have been reclassified based on DRASTIC range for aquifer media factor. Type of aquifer media was added in the same attribute table and then the layer properties of the map have been edited to produce aquifer media layer. Each range has been assigned with rating and weight according to the permeability of each aquifer media based on DRASTIC system to generate A parameter layer.
2.7 Soil media analysis
The soil media has been determined based on the percentage of clay, silt and sand data in soil map attribute table using soil textural classification chart (STC). Then, the class of soil media was added into attribute table of soil map based on DRASTIC ranges. The layer properties of the map have been edited to produce soil media layer and it has been assigned with rating and weight to generate S parameter layer.

2.8 Topographic (slope) analysis
Topographic slope was designed by extracted elevation data from topography layer by using digital elevation model (DEM). Then, slope layer in percentage value has been generated and the range has been reclassified based on DRASTIC ranges. Then the layer has been assigned with rating and weight to generate T parameter layer.

2.9 Impact of vadose zone analysis
The impact of vadose zone media is identified based on well logs report and depth to water layer. Once the media has been set based on DRASTIC range, the data was added into attribute table of depth to water layer. Then, the layer properties of the map have been edited to produce impact of vadose zone layer and it has been assigned with rating and weight to generate I parameter layer.

2.10 Hydraulic conductivity analysis
Due to the lack of hydraulic conductivity of aquifer data, the value has been taken from previous research based on type of aquifer media (Table 2). The value was added into attribute table of aquifer media map and layer properties of the map was edited to produce hydraulic conductivity layer and it has been assigned with rating and weight to generate C parameter layer.

| Aquifer media | Hydraulic conductivity (m/s) | References |
|---------------|-----------------------------|------------|
| Igneous rock  | $1.6 \times 10^{-6}$ (values range from $8 \times 10^{-9}$ to $3 \times 10^{-4}$) | [9]         |
| Shale         | $2.2 \times 10^{-6}$ (values range from $1.5 \times 10^{-6}$ to $3.3 \times 10^{-6}$) | [21]        |
| Bedded Sandstone, Limestone and Shale | $7.1 \times 10^{-5}$ (values of K range from $2.4 \times 10^{-6}$ to $1.4 \times 10^{-4}$) | [16]        |
| Limestone     | $5.0 \times 10^{-5}$ (values range from $2.5 \times 10^{-2}$ to $9.3 \times 10^{-3}$) | [11]        |
| Alluvium      | $1.9 \times 10^{-4}$ (values of C range from $7.6 \times 10^{-6}$ to $3.7 \times 10^{-4}$) | [19]        |

2.11 Evaluation of GPR through map integration
The groundwater pollution risk (GPR) layer has been prepared using 7 DRASTIC parameters layers in GIS environment. After that, the layers were converted between raster to vector and vector to grid based on DRASTIC index (R x W) in attribute table for each layer with pixel size 250 m x 250 m. The final stage involves combination of all DRASTIC thematic layers based on DRASTIC index by using raster calculator in spatial analyst to evaluate GPR. This system will evaluate product of rating multiplied by weight of these seven parameters. The outcome which is GPR layer in Selangor basin area has been generated with new range. The range of GPR index is within 40 to 176. Based on DRASTIC index, the range was classified into 3 classes which are low (40 – 119), medium (120 – 159) and high (160 – 176). Figure 2 shows the summary of DRASTIC system process where all the 7 DRASTIC parameter layers were overlaid using GIS platform in format raster (grid). Grid represents the layer with pixels which has been set with 250m x 250m size. Every pixels for each the 7 layers have their own value based on (R x W). The pixels values of the 7 layers have been computed to evaluate the new value of pixel in 1 layer which is new layer of GPR.
3. Results and discussion

3.1 Depth to water (D)

Based on Figure 3, the west part of Selangor basin is the shallowest location and mostly occupied on coastal plain area. The east side of the basin, the depth to water are more than 31 m from ground level and mostly covering district of Hulu Selangor and Gombak where the area are dominated by mountainous and hilly area. In general, the higher ground surface elevation, the deeper water level and the highest value of (R X W) index, indicates the highest of groundwater pollution risk where the ground surface is close to groundwater (Figure 4).
3.2 Recharge (R)
Figure 5 shows that more than half of Selangor basin area has a highest recharge value which is more than 250 mm. The low slope contributes to the more amounts of rainfall that will infiltrate into the aquifer. At the northwest part of Selangor basin has the moderate recharge value due to the annual rainfall with low value and influenced by monsoon (seasonal revising wind). In general, the steeper slopes, the lower of recharges value, the lesser groundwater pollution risk. Based on Figure 6, the highest of (R x W) index indicating the highest of groundwater pollution risk. Increases of recharge value are parallel to increases of (R x W) index value.

Figure 4. Map of DrDw parameter.

Figure 5. Recharge map.
3.3 Aquifer media (A)
Figure 7 shows about two-thirds of Kuala Selangor district is covered with alluvium media and the centre part of the basin are occupied by bedded sandstone, limestone and shale. At the east side of the basin which is mountainous area are dominated by igneous rock and a little part of the basin are covered with a massive limestone and shale. Alluvium medium is unconsolidated mixtures of sand to gravel sized particle which contain varying amounts of fine materials. The geology age of alluvium in the basin is quaternary alluvium and it includes stream alluvium and coastal alluvium (gravel, sand and silt) and floodplain alluvium (sand, silt, clay and peat) [3].
Generally, the larger grain size, the higher permeability and the higher of groundwater pollution risk. Therefore, based on Figure 8, the alluvium media indicates the highest value of \((R \times W)\) index. Massive shale has a lower \((R \times W)\) index value because it is thick bedded shales, clay or claystone which normally yield low amounts of water from fractures and have a low pollution risk. The other aquifer medium in the Selangor basin is consolidated rock and the level of groundwater pollution risk is controlled by degree of fracturing. Hence, bedded sandstone, limestone and shale media and massive limestone media have a same value of \((R \times W)\) index.

3.4 Soil media \((S)\)

Generally, the type of soil media is influenced by topography. Figure 9 shows the east part of Selangor basin which is mountainous area where the soil layer is almost thin or absent because of rock formation within the mountain is more significant. The west part of the basin which is lowland area mainly was underlain by peat and clay. Peat media are covered by swamps while clay is covered by plantation such as paddy and palm oil. The centre part of the basin is dominated by sandy clay but mostly at rivers area is underlain by sand and loam media and there is a little part is underlain by gravel.

Highest \((R \times W)\) index value represents the higher of groundwater pollution risk (Figure 10). There are 2 pairs of soil media type that share the same value of \((R \times W)\) index. The first pair is gravel and thin or absent media which is have the highest value of \((R \times W)\) index. If soil layer is not present or very thin, the pollution risk is higher because attenuation of pollutants is not productive. The size of particles normally is larger than 2 mm. Gravel soils is include a mixture of sand, silt, clay and gravel particles. The second pairs is sandy clay loam and sandy clay which is have the second lower value of \((R \times W)\) index but pollution risk still high due to the higher percentage of sand. Peat and clay have \((R \times W)\) index value in the middle within the other media. Peat contains organic matter which may be significant for pollutants attenuation but they are relatively permeable, thus pollution risk is high \([3]\). Clay has low permeability but it can have high pollution risk based on secondary vertical permeability created by the cracking of the media when it is drying \([3]\). The rest part of the basin that covered by sand which have second higher of \((R \times W)\) index value due its size of particles is smaller than gravel and loam have the lowest value of \((R \times W)\) index because of the lower percentage of clay and silt so that the groundwater pollution risk is low.

![Figure 8. Map of ArAw parameter.](image-url)
3.5 Topographic slope (T)
Figure 11 shows the west side of the basin which is Kuala Selangor district and near to coastal plain is underlain by range of slope area which is 0 – 2% is the lowest slope and its known as lowland area. The highest slope which is more than 18% and its known as mountainous and hilly area was underlain at the east part of the basin. Only a little part mostly at rivers area is underlain by the lower slope to the middle slope between 0 - 12% which is at rivers area. In general, the slope of land is decreasing from east to west of the basin until it reaches the sea.
The lowest slope which is covering the west side of the basin was assigned with the highest value of (R x W) index due to its ability for pollutants to infiltrate into groundwater because it is remain on the surface for long enough to infiltrate (Figure 12). It will contribute to the higher pollution risk. The highest slope which is occupied at the east part of the basin have the lowest value of (R x W) index because it affords a high runoff capacity and therefore a lesser probability of pollutants infiltration and a subsequent a lower groundwater pollution risk. However steep slopes are more conducive to rapid erosion and pollution of surface water [3].
3.6 Impact of vadose zone (I)

Figure 13 shows the area division of 5 classes of media is almost equal within the Selangor basin started from the east which are metamorphic/igneous, bedded sandstone, limestone and shale, shale, sand and gravel with significant silt and clay and silt/clay. Figure 14 shows that the value of (R x W) index become 3 classes only. Silt/clay and shale has a lower value of (R x W) index. Deposits of silt and clay particles act as a barrier to restrict the movement of pollutants.

The shrinking clay and higher silt concentrations increase the pollution risk while the high clay contents provide a low pollution risk. Shale is thick bedded clay rock which may be fractured. Pollution risk is low but can be high with the degree of fracturing. Bedded limestone, sandstone, shale is typically thin bedded sequences of sedimentary rocks which contain primary porosity but the level of pollution risk is controlled by degree of fracturing within the media [3]. Sand and gravel with significant silt and clay is unconsolidated mixtures of fine materials includes sand and gravel. These deposits have lower permeability due to the high concentration of clay, thus the pollution risk is lower. Both of the media have the higher value of (R x W) index compare to the other media in the Selangor basin. Metamorphic/igneous rock is consolidated rock which is contain primary porosity but not significant. The movement of pollutants is through the fractures.

Figure 13. Impact of vadose zone map.
3.7 Hydraulic conductivity (C)

In this study, hydraulic conductivity has been determined based on the type of aquifer media. According to Figure 15, the limestone has the highest of hydraulic conductivity and alluvium media at a second place. Hydraulic conductivity for igneous rock is the lowest and shale is the second lower. Bedded limestone, sandstone and shale have moderate hydraulic conductivity. Higher or lower of hydraulic conductivity is depends on a consequences of intergranular porosity, fracturing or bedding planes. Based on Figure 16, the highest value of (R x W) index indicates the highest of groundwater pollution risk.

Consolidated limestone which typically contains fewer bedding planes than bedded limestone, sandstone and shale sequences [3]. Pollution risk is highly affected by the degree of fracturing and the amount of solution cavities in the limestone. Therefore, limestone get the highest value of (R x W) index for highest hydraulic conductivity. The sequences of bedded limestone, sandstone and shale contain primary porosity and pollution risk is influenced by degree of fracturing [3]. For that reason, hydraulic conductivity for these sedimentary rocks is quite low and have the second lower of (R x W) index value. Igneous rock and shale have same value of (R x W) index due to the value of hydraulic conductivity below than 4.72 x 105 m/s. Thick bedded shales and clays yield only a small amount of water from fractures while igneous rock is consolidated bedrock which is contains a little or no primary porosity and it yield water only from fractures within the bedrock [3]. Therefore, pollution risk is controlled by the degree of fracturing. Alluvium with 1.9 x 10^{-4} m/s of hydraulic conductivity has the moderate value of (R x W) index within the others. It is unconsolidated mixtures of sand to gravel sized particles which is containing varying amounts of fine materials [3]. Thus, lower amounts of fine materials in aluvium will increases the level of groundwater pollution risk.
Based on Figure 17, predominantly area in Kuala Selangor district was covered with medium range of GPR. Only at the northeast side and the south to the west side of the district was covered with high range of GPR. The low range of GPR was covering a little part of the southwest side of the district. Furthermore, the whole of Hulu Selangor and a part of Gombak district was dominated by low range.
GPR zones. Generally, the index range value of GPR zone is become higher starting from the mountainous area and followed by hilly area and lowland area until it reaches at coastal plain. Overall, the Selangor basin area was occupied by low, medium and high of GPR ranges is about 56%, 34% and 10% respectively (Figure 18).

![Groundwater Pollution Risk Map of Selangor Basin](image)

**Figure 17.** Groundwater pollution risk.

![Chart of GPR in Selangor Basin Area](image)

**Figure 18.** Percentage chart of GPR in Selangor basin area.

Based on landuse map of Selangor basin, the agricultural landuse layer was extracted from the map through database query. There are 4 categories of agricultural landuse which are animal husbandry areas, horticultural lands, short term crops and tree, palm and other permanent crops. Then, GPR layer of Selangor basin was through the clipping process using analysis tools in ArcGIS based on agricultural landuse layer. Figure 19 shows the agricultural activities on GPR zones. On the whole, low, medium and high GPR ranges that covering agricultural area is about 42%, 43% and 15% respectively (Figure 20).
3.8 Significance of GPR and nitrate distribution zones based on agricultural landuse

Same to water level and rainfall data, the nitrate distribution layer was generated by using nitrate values that obtain from water quality data in JMG report for each well in Selangor basin through IDW interpolation method. According to national guidelines for raw drinking water quality, benchmark for nitrate is 10 mg/l. Therefore, the range of nitrate distribution was classified into 3 classes which are low (0-5 mg/l), medium (5-10 mg/l) and high (>10 mg/l). After that, the nitrate distribution layer of Selangor basin was through the clipping process using analysis tools in ArcGIS based on agricultural landuse layer. Based on Figure 21, Selangor basin area was dominated with low range of nitrate level. Generally, the Selangor basin area was occupied by low, medium and high nitrate level ranges is about 90%, 7% and 3% respectively (Figure 22).
Figure 21. Nitrate distribution.

Figure 22. Percentage chart of nitrate distribution in Selangor basin area.

Figure 23 shows the nitrate distribution based on agricultural landuse. The high nitrate level range was underlain by categories of tree, palm and other permanent crops while the medium and low nitrate level range mostly was underlain by all the categories of agricultural activities which are tree, palm and other permanent crops, short term crops, animal husbandary areas and horticultural lands. By and large, the agricultural landuse area in Selangor basin was occupied by low, medium and high nitrate level ranges is about 78%, 16% and 6% respectively (Figure 24).
GPR zones were validated by correlate with nitrate distribution layer. Validation process was analysed by apply Pearson correlation coefficient tests through Microsoft Excel software with add in XL stat software. The pie charts below show the high, medium and low area percentages for GPR zones and nitrate distribution on agricultural landuse (Figure 25). Category of tree, palm and other permanent crops has the highest percentage for all pie charts which is range from 80% to 95%. The rest categories only have percentage 0% to 11%. Furthermore, the percentages division of 3 level areas on 4 categories of agricultural landuse for both layers zones is almost precisely with each other.

Figure 23. Nitrate distribution on agricultural landuse.

Figure 24. Percentage chart of nitrate distribution on agricultural landuse in Selangor basin area.
Based on Figure 26 to Figure 28, the scatter plots for high, medium and low area shows the positive slope relationship. Therefore, GPR zones and nitrate distribution have high positive correlation that indicates both layers increase together. Besides that, the correlation tests results indicate that the strength of relationships between the 2 maps layer for these 3 level regions is very high which are for high area ($r = 1.0$), medium area ($r = 0.998$) and low area ($r = 0.998$) and that the correlation coefficient is highly significantly different from zero ($P < 0.05$). Also, we can say that 99% of the variation in nitrate distribution zones is explained by GPR zones.

**Figure 25.** Pie Charts of percentages for each level area of GPR zones and nitrate distribution on agricultural landuse.

**Figure 26.** Pearson correlation coefficient tests for high area.
4. Conclusion

As demonstrated in this study, seven hydrogeological parameters of DRASTIC were successfully shown through the maps produced by using ArcGIS software. GIS tasks which are spatial database building, spatial data analysis, geographic data modeling and visualization and representation of data has been applied and demonstrated for evaluation of groundwater pollution risk in the Selangor basin area.

Groundwater pollution risk are depends to the environment and hydrogeologic factors. Each DRASTIC factor have own characteristics and play an important role in determining the level of pollution risk. Integration of seven grid layers of hydrogeological parameters through DRASTIC index overlay has been successfully evaluated to construct GPR map. With the aid of agricultural landuse map, GPR based on agricultural activities map was successfully generated.
Application of fertilizers is a main contributor in present of nitrate in groundwater. Accuracy and significance of GPR classification based on agricultural activities has been validated with nitrate distribution layer through Pearson correlation coefficients tests. Significant of GPR zones and nitrate distribution are highly correlated.

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