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# A Multivariate Cointegration Analysis for Groundwater Pattern Recognition; Based on Rainfall Distribution, in Terengganu Malaysia

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*Abstract:* **Development and effective utilization of groundwater resources is essential especially in semi-arid region and in a region with abundant rainfall such as the study area for activities such as water supply and irrigation. The present study aims to analyse statistically the groundwater level, stream flow and rainfall data of 13years (2000-2012) collected from the Department of Minerals and Geosciences and Department of Irrigation and Drainage Terengganu for the seven stations: Besut, Dungun, Kemaman, Bukit, Paka, Cherul and Menerong of Terengganu Malaysia. The homogeneity test was made to make sure that all the series of data are homogenous. The regression analysis method was adapted to analyses the relationship of groundwater level variability with the rainfall distribution. The analysis indicated that the rainfall distribution has an influence on groundwater level in the study area due to positive relationship shown by regression analysis. Although in some stations the influence is not much significant, that is the groundwater levels depends on runoff and other factors rather than rainfall. Such stations are Site 4930401 SG. Berang at Menerong shows 14.7%, Site 4232401 SG. Kemaman shows 27.2 %, and Site 4732461 SG. Paka shows 35.2%. The station that shows great influence of rainfall in determining the groundwater level is Site 5229436 SG Nerus, which has 58.5%, while the remaining stations are moderate. Therefore Vector Error Correction Model were employed after the introducing of stream flow data to test and confirmed this relationship, and were found to be strong as indicated by the result of the analysis.**

*Keywords:* **Groundwater level, rainfall, stream flow, time series regression analysis, homogeneity test, correlation, vector error correction model.**

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## 1. INTRODUCTION

Water is an essential commodity to mankind, and the largest available source of fresh water lies underground. About 97% of it is found in the Oceans and is too salty for drinking, irrigation, or industry. The remaining 3% is fresh water, 2.997% of which is locked up in ice caps or glaciers rather buried so deep down and will cost too much to extract. Only about 0.003% of Earth’s total volume of water is easily available to use as moisture, exploitable groundwater, water vapour and lakes and streams. (Asadi S.S et.al. 2012)

There are three (3) major sources of water available to man: rain water, surface water and groundwater. Rain water falls only during a well-defined period and in so many places it is so scanty that it cannot be relied upon for domestic, industrial and even agricultural purposes. Surface water is the water found on the ground surface in streams, rivers, lakes, dams, wetland or oceans. It is related to water collected in the ground which is called groundwater and is naturally replenished by precipitation and lost through discharge to evaporation and sub-surface seepage into the ground. Groundwater is located beneath the ground surface in soil pore spaces and in the fractures of rock formation. It is also often withdrawn for agriculture, municipal and industrial use by constructing and operating extraction wells which is exploited using hand-dug wells and boreholes. Probably because of it is reliability, the use of groundwater for industrial, agricultural and domestic purposes both in urban and rural areas, is continuously increasing. (Johnson, R. and McCartney, M. 2010)

Therefore the development of this vital resource is of great interest to meet these requirements. As such the relationship of groundwater and rainfall has to be highlighted.

In humid region, the amount of recharge is high in wet season because the region is receiving excessive amount of rainfall and the relative proportion of these components fluctuate according to the climatic conditions, geology and geomorphology. In spite of the fact that, in humid tropics region such as the study area (Terengganu) the most important mechanism of groundwater recharge are considered to be indirect recharge by infiltration from floods through the beds of ephemeral streams. (Merechal, et al, 2008)

In Malaysia, groundwater resources are underutilized. The use of it for domestic purposes is mainly confined to rural areas. Plentiful rivers and abundant rainfall contribute a lot in leaving the groundwater system relatively “untouched”. The groundwater resources of Malaysia, is mainly used in rural areas, where there is no pipes borne water supply for their domestic purposes. However in the study area (Terengganu) and Kelantan, it is being significantly utilized for public water supply. Other States that supplement the water supply system with groundwater are Perlis, Pahang, Sarawak and Sabah. Therefore Groundwater pattern recognition is very important in assessing the regional aquifer conditions, for a sustainable agricultural development and domestic used.

To develop a sustainable management strategy for groundwater development, it is substantial to know the pattern of groundwater fluctuation levels base on recharge in space and time either natural or artificial recharge. Rainfall is the most vital component of the water cycle and is the major source of groundwater recharge.

According to Allen et al; (2004) as a part of hydrologic cycle, it can be anticipated that groundwater system will be affected by changes in recharge (encompasses changes in precipitation). It is understandable that, the change of climate such as in recharge rate will cause adjustments in the global hydrological cycle which will affect the distribution and availability of regional water resources.

Baalousha (2005) estimated the groundwater recharge for Gaza coastal aquifer using cumulative rainfall departure (CRD) method, where rainfall is the main source of groundwater recharge.

Melloul and Batchman (1975) have estimated the groundwater recharge for the Gaza strip using recharge coefficients. They sub divided the area into three sub-zones and computed the coefficients for each sub-zone based on the average rainfall and the soil type. The coefficient were estimated based on regression analysis between groundwater recharge and soil type.

Dripps and Bradbury (2007) estimated the spatial and temporal distribution of groundwater recharge in the temperate humid areas, using simple daily soil-water balance (SWB) model. The model uses available soil, land cover, topographic and climatic data in conjunction with GIS to estimate the temporal and spatial distribution of groundwater recharge at the watershed level for temperate humid areas. Like many other hydrological phenomena, recharge varies both spatially and temporally, depending upon the combination of influencing factors such as climate, soils, geology, geomorphology, hydrology, vegetation and land use (R.W. Healy, 2010).

The present study uses integrated modelling techniques, which include the use of statistical analyses, such as linear regression analysis and Vector Error Correction Model (VECM) to analyse the data collected from different hydrological and meteorological stations to predict groundwater pattern based on rainfall distribution in the study area.

## 2. STUDY AREA

Terengganu is a state of Malaysia; it is situated in the coordinate $4^0$ $45^1$N latitude and $103^0 0^1$E longitude which is located in the north-eastern of Peninsula Malaysia. The state has a total area of 13,035km$^2$ (5,033 sq. mi) and the total population of 1,015,776 as for the 2010 census with a density of 78km$^2$ (200/sq. mi) as for the year 2006. In 2000, the state’s population was only 48.7% urban; the majority lived in rural areas. By 2005 census, the proportion had changed significantly with 51% of the population living in urban areas and 49% in the rural areas (Laporan, 2010; Data Asas Negeri, 2006).

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The region has tropical monsoon climate which is generally fairly hot and humid all year around. The temperature is relatively uniform within the range of 21$^0$C to 32$^0$C throughout the year. During the months of January to April, the weather is generally dry and warm. Humidity is consistently high which approximately 80% in day time and slightly cooler after sunset. The study area characterized by two main types of monsoon, the southwest monsoon season which is usually established in the latter half of May or early June and end in September. The prevailing wind flow is generally south-westerly and light, below 15 knots. The northeast monsoon season which is usually starts in early November and ends in March. During this season steady easterly or north-easterly winds of 10 to 20 knots prevail. The winds over the east coast states of Peninsular Malaysia may reach up to 30 knots or more during period of strong surges of cold air from the north (cold surges).

Terengganu being exposed to the coast receives heavy rainfall of approximately between 2034mm to 2504mm per year which can easily break the bank of the rivers and cause overbank discharge. When the northeast monsoon blows between Novembers to January some areas suffer flooding at this time of year and however in some clear sunny days during the monsoon season, surprisingly east coast is always presented with clear blue sky and cooling wind.

However in the whole of Peninsular Malaysia, the north-east monsoon is the major rainy season which develops in conjunction with cold air outbreaks from Siberia produce heavy rains which often cause severe floods along the east coast states of Terengganu, Kelantan, Pahang and east Johor in Peninsular Malaysia (www.terengganutourism.com/ weather.htm).

Terengganu covered a total area of 13,035km$^2$ which is about 4% of Malaysia, and has a land use distribution which categorized as agriculture 22.6%, forest 43%, building 6.5%, industry 0.3% and others 27.6%. The land use contributes a lot as one of the factor influencing recharge. If an area is more of building the recharge will be less because of the hindering of rain water and stream flow to enter into the saturated zone. But for the study area the high percentage comes up from forest, which indicate that there will be a strong relationship between groundwater and rainfall since the recharge will be directly and more of rainfall. (R.W. Healy, 2010).

## 3. MATERIALS AND METHODS

The daily data of rainfall, and stream flow from seven stations of Terengganu Malaysia was collected from Department of Irrigation and Drainage (DID), also data for the groundwater level from the Department of Minerals and Geosciences, for the period of 2000 to 2012 were sorted and arranged in an excel format for different homogeneity test. Below are the list of the stations, codes and their coordinates in the table.

**Table 1: Showing the stations with their codes and coordinates**

| Codes | Stations | Latitude | Longitude |
|---|---|---|---|
| 5524001 | Besut | 5$^0$44ˊ20ˊˊN | 102$^0$29ˊ35”E |
| 4832011 | Dungun | 4$^0$47’00”N | 103$^0$26’00”E |
| 4234109 | Kemaman | 4$^0$14’00”N | 103$^0$27’00”E |
| 5229430 | Nerus at Bukit | 5$^0$17’30”N | 102$^0$55’20”E |
| 4733084 | Paka | 4$^0$39’00”N | 103$^0$26’00”E |
| 4131001 | Cherul at Ho, Tereng. | 4$^0$21’56”N | 103$^0$17’50”E |
| 4930038 | Menerong | 4$^0$56’20”N | 103$^0$03’45”E |

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## 4. DATA QUALITY AND ANALYSIS

The homogeneity of data (Rainfall, Stream flow and Groundwater level) in this study was checked using the standard approaches such as Wijngaard et al. 2003, Von Neumann ratio test and the Standard normal homogeneity test. All the data from these seven stations were found to be homogenous. The missing value were found to be less than 5% for the period 2000 to 2012, these missing values in the data series were estimated using various types of weighting methods such as inverse distance, correlation and normal ratio.

**Linear regression analysis** is a method used to apply on a data set for determining the presence (cointegration) or absence of a correlation between data points. Linear regression is applies to statistical data, for which two variables are related systematically such that one is a fairly constant multiple of the other. It is also known as the least-square best- fit line that has a linear appearance $as\ \ y = mx + c$. (Andy D.W. and Stanley W.T., 2003)

**The Vector Error Correction Model (VECM):**

Once the co-integration is confirmed to exist between variables, then the third step requires the construction of error correction mechanism to model dynamic relationship. The purpose of the error correction model is to indicate the speed of adjustment from the short-run equilibrium to the long-run equilibrium state.

A Vector Error Correction Model (VECM) is a restricted VAR designed for use with non-stationary series that are known to be co-integrated. Once the equilibrium conditions are imposed, the VECM describes how the examined model is adjusting in each time period towards its long-run equilibrium state. Since the variables are supposed to be co-integrated, then in the short-run, deviations from this long-run equilibrium will feedback on the changes in the dependent variables in order to force their movements towards the long-run equilibrium state. Hence, the co-integrated vectors from which the error correction terms are derived are each indicating an independent direction where a stable meaningful long-run equilibrium state exists. In other words, it shows the direction of long run causality among the variables. The VECM is represented by the following equation:

$$\varDelta Xt \ = \ \mu + \Sigma \varGamma i \varDelta Xt - i + \varPi Xt - p + \xi t$$

where $\varDelta$ is the first difference lag operator, $Xt$ is a$(kx1)$ random vector of time series variables with order of integration equal to one, $I(1)$, $\mu$ is a $(kx1)$ vector of constants, $\varGamma i$ are $(k\ x\ k)$ matrices of parameters, $\xi t$ is a sequence of zero-mean $p$- dimensional white noise vectors, and $\varPi$ is a $(k\ x\ k)$ matrix of parameters, the rank of which contains information about long-run relationships among the variables. If the $\varPi$ - matrix has reduced rank, implying that$\varPi\ = \alpha\beta'$, the variables are cointegrated, with $\beta$ as the cointegrating vector. If the variables were stationary in levels, $\varPi$ would have full rank. The error correction term represents the long-run relationship. A negative and significant coefficient of the error correction term indicates the presence of long-run causal relationship.

## 5. RESULTS AND DISCUSSION

Regression analysis of rainfall data and groundwater level data from 7 sampling stations in the Terengganu for the period 2000-2012 shows a trend and relationship between the two variables. The percentage relationship between the two variables was lower in some of the stations, which indicate that rainfall is not the only factor responsible for the formation of groundwater of that area, although all the stations showed a positive relationship between the two variables. The groundwater level in any month at any station in the study area is correlated with the rainfall of the month. The partial correlation coefficient ($R^2$) which measure the extent of association of independent variable with dependent one indicate that, some stations have strong relationship more than the others. This may be due to other factors not observed in this analysis which has an influence in the formation of groundwater of the district/station. Some stations showed a significant changes in amount and distribution of rainfall as determine by the line graph (Figure 2), however some showed similarities between them. The Stations that show the similarities in their results were found to be in the same coordinate and differ on the others with different locations. Stations were located near the Sea such as (Dungun) have less percentage of rainfall influence for the groundwater formation. This indicates that other factors such as stream flow, flood have more influence on that area.
Some of the linear regression tables' results and scatter plots of dependent variables against independent one are shown below, similarly, the equations of all the seven stations are shown in table 5 (equations of the model):

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**Table 2: Goodness of fit statistic table**

| | |
|---|---|
| Observations | 156.000 |
| Sum of weights | 156.000 |
| DF | 154.000 |
| $R^2$ | 0.585 |
| Adjusted $R^2$ | 0.582 |
| MSE | 0.289 |
| RMSE | 0.537 |
| MAPE | 4.767 |
| DW | 1.607 |
| Cp | 2.000 |
| AIC | -191.771 |
| SBC | -185.671 |
| PC | 0.426 |

Table 2; above explain the coefficient of determination ($R^2$) as the percentage variability of the dependent variable (Groundwater) which explained by explanatory variable (Rainfall). The closer to 1 the $R^2$ is, the better fit. As in the station 4 the $R^2$ = 0.58.5, meaning the % variability of groundwater which is explained by rainfall is 58.5%. The remainder of the variability is due to some effects (other explanatory variables) that have not been included in this analysis

.**Table 3: Analysis of variance**

| Source | DF | Sum of squares | Mean squares | F | Pr > F |
|---|---|---|---|---|---|
| Model | 1 | 62.670 | 62.670 | 217.006 | < 0.0001 |
| Error | 154 | 44.474 | 0.289 | | |
| Corrected Total | 155 | 107.145 | | | |

*Computed against model Y=Mean(Y)*

The Table 3 above explained whether or not the rainfall brings significant information (null hypothesis) to the model. Given the fact that in all the seven sampling stations for this analysis the probability corresponding to the F value (Pr>F) is lower than 0.0001, we will be taking a lower than 0.01% risk in assuming that the null hypothesis (no effect of the rainfall data) is wrong. Therefore we concluded that the rainfall do bring a significant amount of contribution to groundwater level of the study area.

**Table 4: Model Parameter**

| Source | Value | Std.error | t | Pr > \|t\| | Lower bound (95%) | Upper bound (95%) |
|---|---|---|---|---|---|---|
| Intercept | 7.304 | 0.064 | 113.690 | < 0.0001 | 7.177 | 7.431 |
| RAINFALL (mm) | 0.003 | 0.000 | 14.731 | < 0.0001 | 0.003 | 0.003 |

The table 4 above is helpful when we want compare the coefficient of the model for a given station with the result obtained from another station, or when prediction is needed. This also shows that 95% confidence range of rainfall parameter is very narrow compared for the intercept.

**Table 5: Equations of the Models**

| | |
|---|---|
| **Besut** | GROUNDWATER LEVEL (M) = 14.0948336481616+1.24460580239912E-03*RAINFALL DATA (mm) |
| **Dungun** | GROUNDWATER LEVEL (M) = 5.71539620806715+5.37986219758273E-04*RAINFALL DATA (mm) |
| **Kemaman** | GROUNDWATER LEVEL (M) = 8.78872824648013+9.71784894960001E-04*RAINFALL DATA (mm) |
| **Nerus** | GROUNDWATER LEVEL (M) = 7.30372586727423+2.90963416109421E-03*RAINFALL DATA (mm) |
| **Paka** | GROUNDWATER LEVEL (M) = 1.55707866643929+2.30421907511554E-03*RAINFALL DATA (mm) |
| **Cherul** | GROUNDWATER LEVEL (M) = 9.92062404289666+2.12755709963399E-03*RAINFALL DATA (mm) |
| **Menerong** | GROUNDWATER LEVEL (M) = 20.642225067975+5.90849337903912E-04*RAINFALL DATA (mm) |

The above table showed the equations for all the seven sampling stations, which shows how increases of rainfall influence the groundwater level. As indicated by station 4, when the rainfall increases by one millimetre (1mm), the groundwater will also increases by 0.003m. This all applied to all other stations but depending on their increases rates

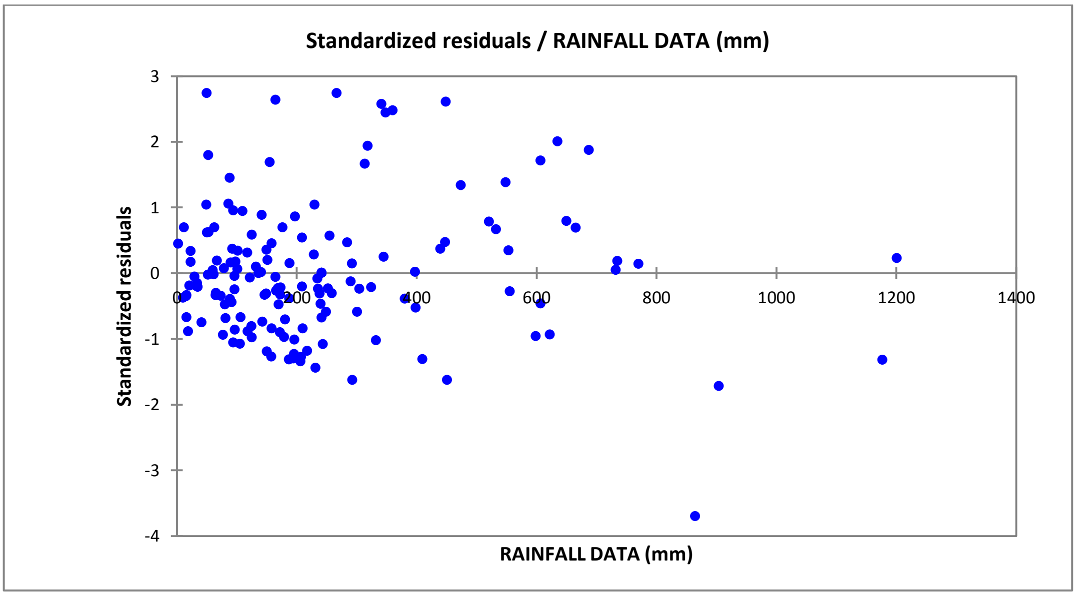


**Figure 1: Residuals explanation**

This residuals gives the assumptions of the linear regression model, should be normally distributed, meaning that 95% of the residuals should be in the interval [-1.96, 1.96] all values outside this interval are potential outlier, or considered that the normality assumption is wrong. This software XLSTAT's data flagger brought those values which are not in the interval out. As in the scatter plots represented in the **figure 2** for Station 4 (Site: 5229436 SG. Nerus at Bukit, Terengganu), out of 156 observations only 7 residuals were outside the [-1.96, 1.96] range, an analysis that does not lead us to reject the normality assumption. The other stations shows almost the same points out of the target as in the result presented above for station four.

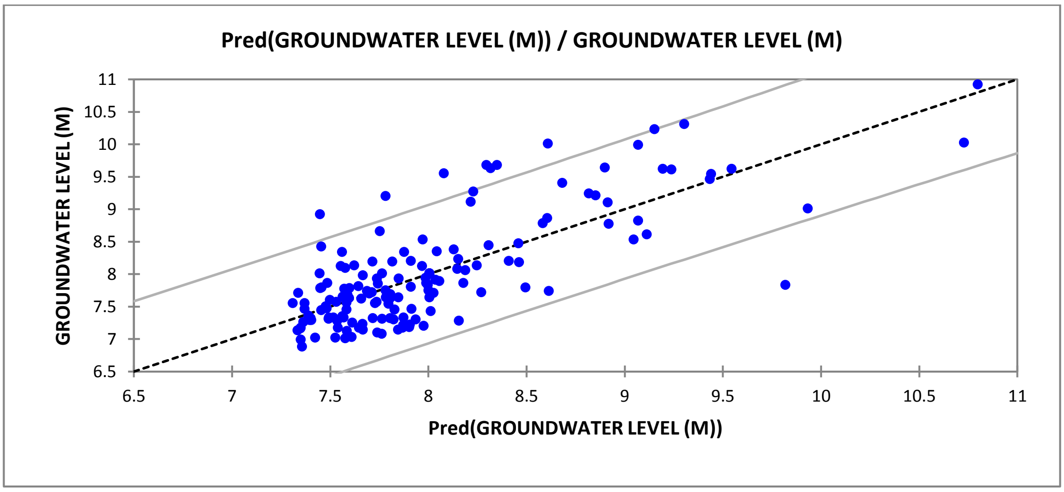


**Figure 2**

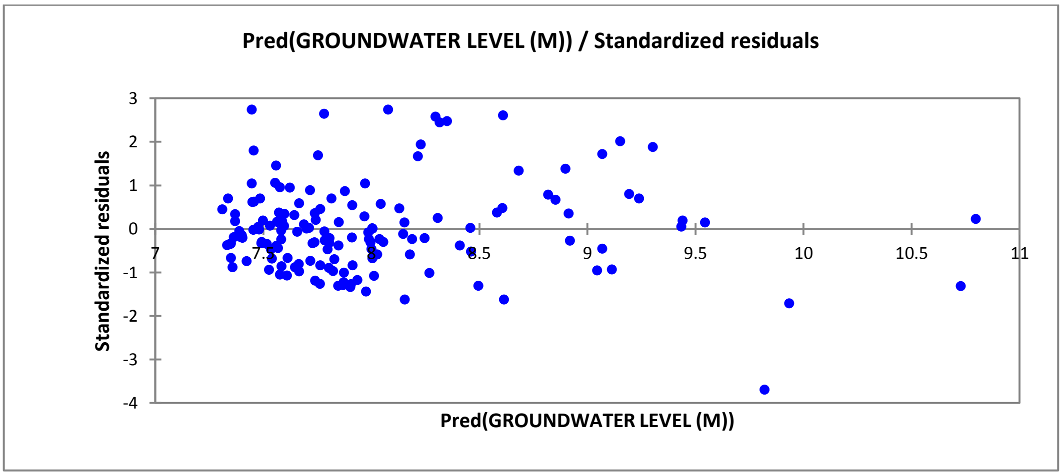


**Figure 3**

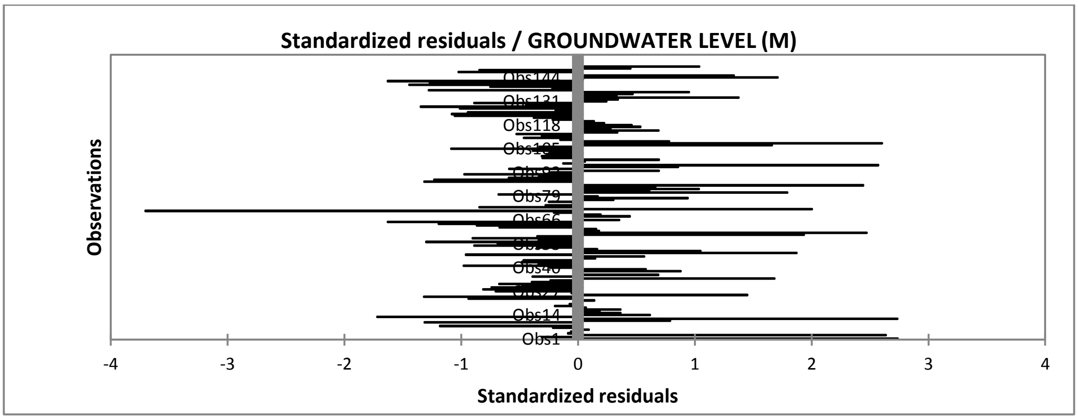


**Figure 4**

The figure 2 shows the confidence intervals on a single prediction for a given value of the rainfall, which shows a linear trend, but that there is high variability around the line. It also shows those observation that are outside the [-1.96, 1.96] interval are outside the second confidence interval as well. It explained the two confidence intervals and allow to visualized data, the regression line (the fitted model). Figure 3 explained the standardized residuals versus the rainfall. It is not the case here but when plotting the residuals against the rainfall data, if a trend is defined, this indicates that the model is not correct of there is an autocorrelation in the residuals, which is contrary to one of the assumptions of parametric linear regression. Figure 4 compared the predictions to the observed values. The confidence limits allow, as with the regression plot displayed in the fig. 3 to identify the outliers. The histogram enables to quickly visualize the residuals that are out of the range [-2, 2].

The results of this linear regression analysis also indicated that there are other factors apart from rainfall that have a significant influence on groundwater level formation in the study area. These other factors will contribute to fill up the remainders of the percentage of the variability of the groundwater showed by the individual station. Therefore another factor is included (stream flow) and Vector Error Correction Model is suggested to run. The groundwater level data (dependent variable), rainfall data and the stream flow data (independent variables) was used to run this model. The results of vector error correction model were presented in three stages that are the unit root test, Johansen co-integration test and vector error correction model.

The result of the unit root test shows that, groundwater level, rainfall and stream flow were not stationary at level and first difference, because they are not following the time. The result of all the sampling stations explained that the t-statistics is greater than the critical value and the probability value (p-value) is less than 0.05 which is the condition that we cannot reject the null hypothesis meaning the data are not stationary at level and at first difference. And whether the data is stationary or not we can use to run the co-integration test.

Johansen co-integration test shows that the likelihood ratio is greater than the critical values meaning there is co-integration. These results (Table 6) had shown three co-integration equations among the variables.

**Table 6: the results of Johansen co-integration test**

| Eigen value | Likelihood Ratio | 5 Percent Critical Value | 1 Percent Critical Value | Hypothesized No. of CE(s) |
|---|---|---|---|---|
| 0.280759 | 81.58044 | 29.68 | 35.65 | None ** |
| 0.1529 | 31.81701 | 15.41 | 20.04 | At most 1 ** |
| 0.043785 | 6.760571 | 3.76 | 6.65 | At most 2 ** |

*(**) denotes rejection of the hypothesis at 5%(1%) significance level

L.R. test indicates 3 co-integrating equation(s) at 5% significance level

Unnormalized Co-integrating Coefficients:

| GWL | RF | STF |
|---|---|---|
| -0.229783 | -0.000216 | -0.000496 |
| 0.475145 | -0.000611 | -0.001427 |
| 0.002361 | 0.000699 | -0.002429 |

Normalized Co-integrating Coefficients: 1 Co-integrating Equation(s)

| GWL | RF | STF | C |
|---|---|---|---|
| 1 | 0.000938 | 0.002157 | -14.7672 |
| | -0.00072 | -0.00196 | |
| Log likelihood | -1909.136 | | |

Normalized Co-integrating Coefficients: 2 Co-integrating Equation(s)

| GWL | RF | STF | C | |
|---|---|---|---|---|
| 1 | 0 | -1.88E-05 | -14.4273 | |
| | | -0.0015 | | |
| 0 | 1 | 2.320006 | -362.345 | |
| | | -1.26698 | | |
| | | | | |
| Log likelihood | -1896.607 | | | |

Therefore the result of this table 6 above indicated that we cannot reject the null hypothesis meaning that there is up to three co-integration equations. Since the result indicated the existence of co-integration, then vector error correction model will be run to know the speed of adjustment between our data of groundwater level, rainfall and stream flow.

Once the co-integration is confirmed to exist between variables, then the third step requires the construction of error correction mechanism to model dynamic relationship. Error correction model is to indicate the speed of adjustment from the short-run equilibrium to the long-run equilibrium state, and the results of this analysis indicated that there is long run relationship between the 3 variables. The table 6 below explained these relationships.

**Table 7: Estimates for VECM regression**

| Co-integrating Eq: | CointEq1 |
|---|---|
| | |
| GWL(-1) | 1 |
| | |
| RF(-1) | 0.000938 |
| | -0.00072 |
| | -1.30717 |
| STF(-1) | 0.002157 |
| | -0.00196 |
| | -1.10154 |
| | |
| C | -14.7672 |

| Error Correction: | D(GWL) | D(RF) | D(STF) |
|---|---|---|---|
| | | | |
| CointEq1 | -0.4686 | -344.822 | -81.0456 |
| | -0.08466 | -51.034 | -20.2055 |
| | (-5.53488) | (-6.75671) | (-4.01107) |
| | | | |
| D(GWL(-1)) | -0.04126 | 337.099 | 65.25739 |
| | -0.13869 | -83.6008 | -33.0994 |
| | (-0.29747) | -4.03225 | -1.97156 |
| | | | |
| D(GWL(-2)) | 0.133185 | 230.452 | 27.97313 |
| | -0.143 | -86.1975 | -34.1274 |
| | -0.93138 | -2.67354 | -0.81967 |
| | | | |
| D(GWL(-3)) | 0.082094 | 232.343 | 26.1699 |
| | -0.13848 | -83.4757 | -33.0498 |
| | -0.59281 | -2.78336 | -0.79183 |
| | | | |
| D(GWL(-4)) | 0.098662 | 121.6059 | 29.93589 |
| | -0.12086 | -72.8549 | -28.8448 |
| | -0.81631 | -1.66915 | -1.03783 |

| | | | |
|---|---|---|---|
| | | | |
| D(RF(-1)) | 0.000329 | -0.51916 | 0.144104 |
| | -0.00019 | -0.11524 | -0.04563 |
| | -1.72127 | (-4.50493) | -3.15831 |
| | | | |
| D(RF(-2)) | 6.76E-05 | -0.3304 | 0.110734 |
| | -0.00023 | -0.13819 | -0.05471 |
| | -0.2948 | (-2.39092) | -2.02392 |
| | | | |
| D(RF(-3)) | -5.03E-05 | -0.35401 | 0.067323 |
| | -0.00023 | -0.13571 | -0.05373 |
| | (-0.22327) | (-2.60849) | -1.25294 |
| | | | |
| D(RF(-4)) | -0.00013 | -0.1952 | 0.036344 |
| | -0.00018 | -0.11119 | -0.04402 |
| | (-0.67662) | (-1.75550) | -0.82554 |
| | | | |
| D(STF(-1)) | 0.00175 | 1.203027 | -0.41859 |
| | -0.00044 | -0.26504 | -0.10494 |
| | -3.98007 | -4.53904 | (-3.98899) |
| | | | |
| D(STF(-2)) | 0.001495 | 0.743546 | -0.27245 |
| | -0.00053 | -0.31937 | -0.12644 |
| | -2.82188 | -2.32819 | (-2.15473) |
| | | | |
| D(STF(-3)) | 0.001423 | 0.525576 | -0.12652 |
| | -0.00053 | -0.31671 | -0.12539 |
| | -2.70772 | -1.65951 | (-1.00901) |
| | | | |
| D(STF(-4)) | 0.000674 | 0.390041 | -0.0393 |
| | -0.00043 | -0.26113 | -0.10339 |
| | -1.5552 | -1.49367 | (-0.38015) |
| | | | |
| C | -0.00145 | -1.07715 | 5.494726 |
| | -0.03 | -18.0855 | -7.16046 |
| | (-0.04843) | (-0.05956) | -0.76737 |
| | | | |
| R-squared | 0.31551 | 0.460802 | 0.281928 |
| Adj. R-squared | 0.250558 | 0.409637 | 0.21379 |
| Sum sq. resids | 18.5984 | 6757798 | 1059311 |
| S.E. equation | 0.368449 | 222.0968 | 87.93293 |
| F-statistic | 4.857612 | 9.00622 | 4.137587 |
| Log likelihood | -56.1473 | -1022.78 | -882.876 |
| Akaike AIC | 0.929103 | 13.73224 | 11.87916 |
| Schwarz SC | 1.208851 | 14.01198 | 12.15891 |
| Mean dependent | 0.000662 | 0.507285 | 4.429205 |
| S.D. dependent | 0.425607 | 289.0565 | 99.17042 |
| | | | |
| Determinant Residual Covariance | | 19248311 | |
| Log Likelihood | | -1909.14 | |
| Akaike Information Criteria | | 25.88259 | |
| Schwarz Criteria | | 26.78178 | |

*Source: Research's computation output using E-views 3.1*

The Vector error correction mechanism is a means to reconcile the short-run and long-run behaviour. The error correction model with the computed t-values of the regression coefficients is estimated and the results are reported in Table 7 in all the three equations, the estimated coefficients of the error correction terms are statistically significant at 1% level. It means the error terms contribute in explaining the changes in groundwater level, rainfall and stream flow respectively. The relative values (-0.4686, -344.822 and -81.0456) for this analysis, shows the rate of convergence to the equilibrium state per year. Precisely, the speed of adjustment of any disequilibrium towards a long-run equilibrium is the significant percentage corrected each year.

## 7. CONCLUSION

The results of linear regression and VECM Model analysis help us to explain the influence of the rainfall distribution on the groundwater level of the study area. These influences differ from one district/ station to another. Although some station showed almost the same response especially those in the same or nearest coordinate. Such that station 1 and 4 (Besut and Nerus), which showed high values of coefficient of determination of 54.2% and 58.5% respectively where in the nearest coordinate. Likewise station 5 and 6 (Paka and Cherul) where showed nearest values of the determinant of 35.7% and 47.7%. Others were station 2, 3 and 7 (Dungun, Kemaman and Menerong) which are in neighborhood to each other with determinant values of 4.6%, 27.2% and 14.7% respectively.

The results also indicated that there are other factors apart from rainfall and stream flow that have a significant influence on groundwater level formation in the study area. These other factors will contribute to fill up the remainders of the percentage of the variability of the groundwater showed by the individual station.

Conclusively, as the results of these two analyses shows, rainfall has a major contribution in the formation of groundwater of Terengganu, Malaysia. The findings of this research can provide some information to the government on water management and for predicting future climatic events. Nevertheless, further studies should be conducted to consider more characteristics of rainfall occurrences as well as other climate variables. Further analyses such as bootstrap and permutation test can also be suggested for further verification of the existence of trends whether it occurred by chance in these stations.

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