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Spatial analysis of the relationship of ground slopes with water erosion using the Ordinary Least Squares (OLS) and Geographically Weighted Regression (GWR) method in ArcGIS Desktop
-A comparative study between the two methods-

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Abstract

In this study, were performances of two method techniques ordinary least square (OLS) regression and geographically weighted regression (GWR) were compared for the task of predicting the values of water erosion across a study area in Dewana basin as a part of Sulaymaniyah Province, northeast Iraq. The study showed a clear difference between the two methods Because least squares regression methods do not take into account local variations within the study area and it do not give weight to the area or to any other weighted element, it gives a general impression of the type of relationship between the independent variables and the extent of their influence with the dependent variable. The geographically weighted regression model considers the internal local variations of the study area and the ability to give some weights outweigh the elements involved in the process of analysis. These study results have recorded a difference between the two methods approximately (9.3%). The best results were obtained with the GWR model with an area estimated at (199.4 km^2) of total area in the rate of (33.2%). The results showed no significant relationship between water erosion and the degree of slope. It is also found that calculating the values of water erosion by the Bergsma method does not give accurate results for measuring the severity of erosion in general and do not record a strong correlation compared to the degree of slope on the other hand.

Introduction

The beginning of the use of statistics in geographical analysis in the middle of the twentieth century has brought about a qualitative shift in geographic thought and method to rid the

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The Dewana basin is located in southwest of the Sulaimani city, northeast Iraq. The basin area is located between 45°14'00" E and 45° 43' 00" E longitudes, 35°03'00" N and 35°26'00" N latitudes, with a total area of 601.215581 Km^2 (Fig. 1). It is situated in a mountainous terrain with rugged topography of low relief area with a high gradient. The basin is an intermountain valley of elongated shape. The Dewana perennial stream that flows between Sagrma and Baranan mountains and drain into Diyala River. It is surrounded from north by high mountain ridges, and from northwestern part by Baranan Mountain with elevation, reaches 1400 meters, and from southwestern side by Sagrma and Gwllan Mountains with elevation exceeds 1800 meters.

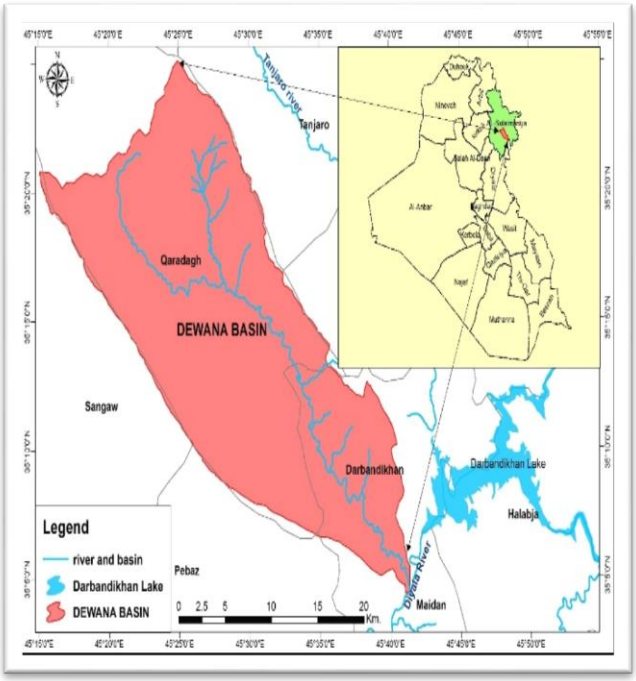


Figure 1. Location map and physiographic features of the study area

2.2 Methods

Multispectral TM imagery from Landsat 7 was acquired for this study to extract spectral information of predicting the values of water erosion across a study area in Dewana basin. However, a series of preprocessing were applied to the image. The DEM for this study was created through interpolating of the Topographic map, Figure 2. The modeling method utilized in this study was based on analyzing data in raster format, and therefore basin and stream vector data were

geography of the description and narration that it killed and almost led to it irreversibly, and just as statistical methods provided geography with life and its mission again. GIS came as a technique and as a science to inspire a soul in geography a philosophy, thought, methodology and applied to make it a competitor to the sciences that claim leadership in the use of modern technologies. That GIS. Whether geographic researcher considered science or technology. Remains the lifeline that will ensure. There is no better for geography and geographers. If it is an independent science. Geography is first over it from others because the field of the geographical problem and its subject is the place, and if we consider it a technique or tool. Then it is a first door for the geographer to be able to use his techniques and tools. Geography is the science of relationships. So, a natural or human phenomenon cannot Form and integrate without having several elements available for its formation and these elements vary between strength and weakness according to the nature of the studied geographical phenomenon. The nature of its constituent components and the surrounding conditions. That the mere scientific knowledge of a logical correlation between the constituent elements of a phenomenon may not mean anything from a practical point of view. Considering the development of scientific research techniques and tools. Especially the so-called statistical spatial analysis provided by the programs of GIS. it has become imperative for the researcher to follow these methods and technologies to arrive at facts related to scientific research to answer research questions, including linking relationships, which will be tested In this paper, between the degree of regression and water erosion using the two methods of Ordinary Least Squares (OLS) and the geographically weighted regression method (GWR) in ArcGIS Desktop for its Dewana basin located in the districts of Qara Dag and Darbandikhan within the Sulaymaniyah governorate of Iraq. The research aims to demonstrate and clarify the difference between the two methods of measuring the correlation relationship in geographical studies.

2. Materials and Methods

2.1 – Study area

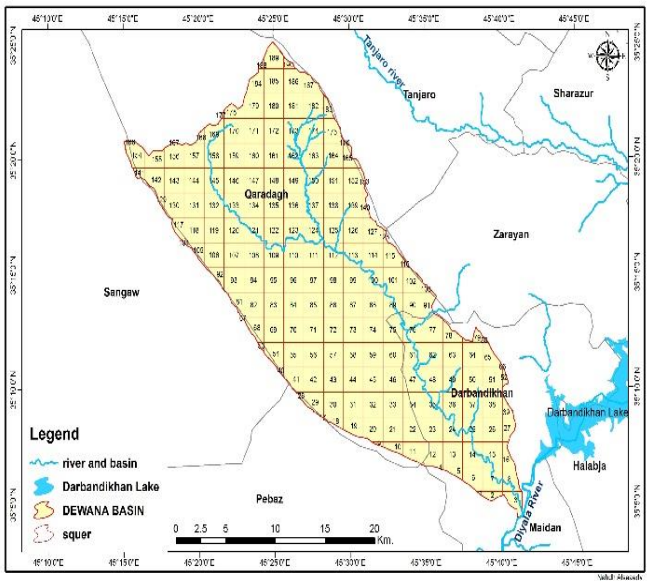


Figure 4: Fishnet over the study area

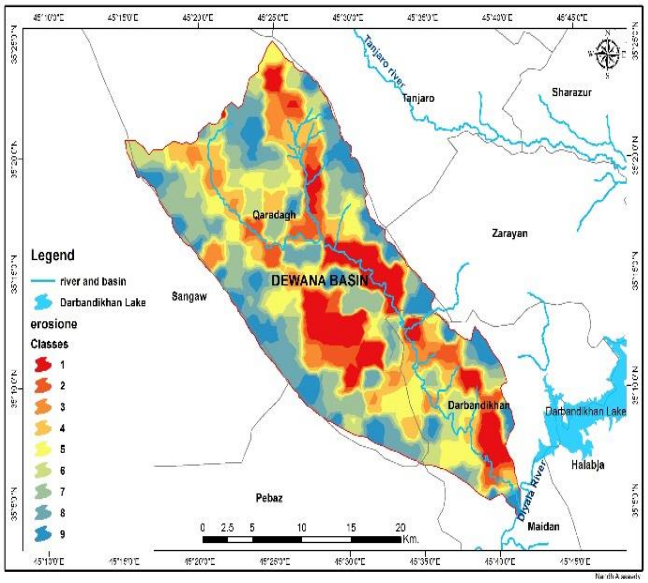
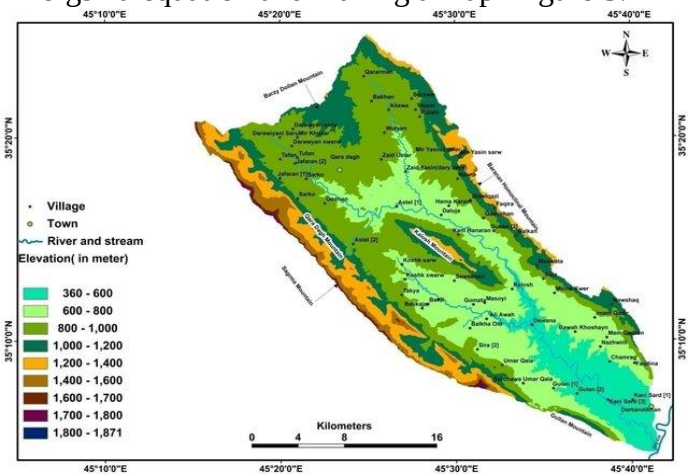


Figure 5: water erosion values according to Bergsma equation

The Slope length (L) and slope steepness (S) factor reflected the effect of topography on erosion, which is proportional to the length and steepness of the slope. The Slop map was produced in the ArcGIS environment from the DEM. the equation derived from Mitasova et al. (1996) was adopted (Eq. 1)

$$LS = \left(\frac{Flow\ accumulation \times \text{Grid size}}{22.1}\right)^{0.4} \times \left(\frac{\sin(\text{slope}) \times\times\ 0.01745}{0.09}\right)^{1.4} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

converted to raster format using the `Kernel Density Estimation' tool in ArcGIS as shown in Figure 3. the stream lengths was calculate depend on Bergsma1996 equation, Figure 4 shows the a squares network (fishnet) covering the study area with an area of (4 km^2) per square to achieve the requirements of Bergsma equation, then we Extracting water erosion values according to Bergsma equation and making a map Figure 5.



2: Digital elevation model of Dewana Basin.

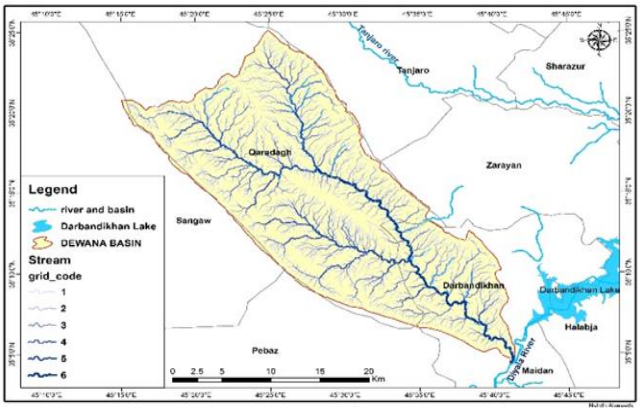


Figure 3: Dewana drainage basin network and sub-basins (Stream from digitizing 1:50000 scale topographic map)

statistically significant or not. If the estimates are not significantly different, the GWR method is essentially the same as the OLS method (Shi et al., 2006).

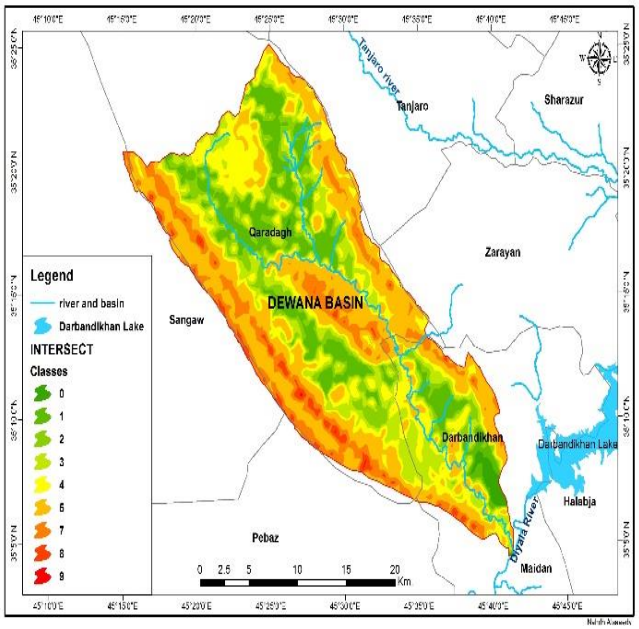


Figure 7. Intersection of the regression and water erosion layers of Dewana Basin

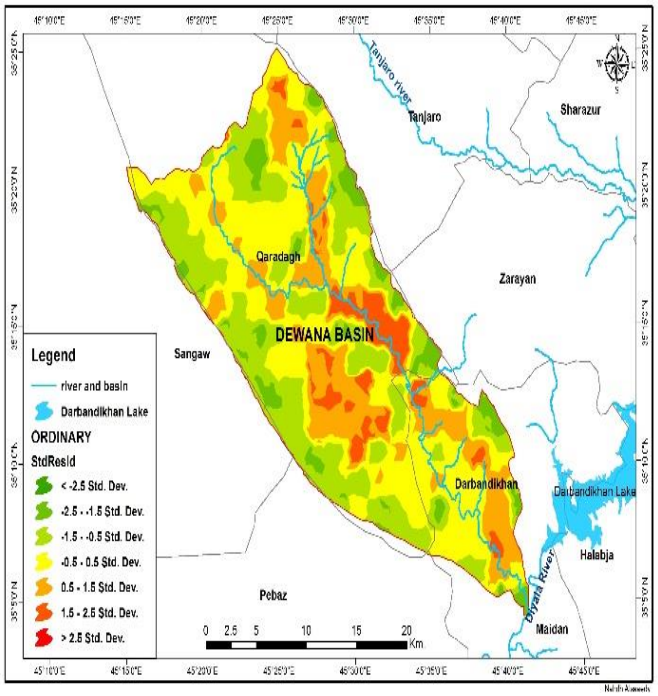


Figure 8. Correlation coefficient by (OLS)

Where accumulation flow is a raster of accumulated flow to each pixel in the image as the slope of the plane formed by the vector connecting the left and right neighbors and the vector connecting the upper and lower neighbors of the pixel, Figure 6

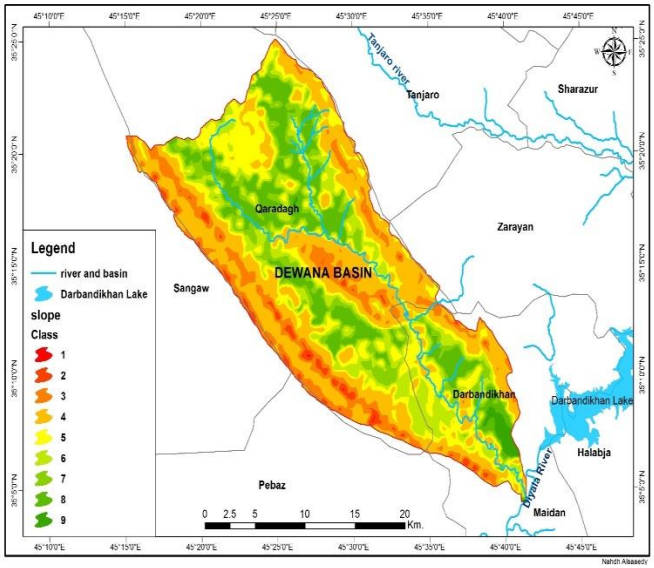


Figure 6. Slope map of Dewana Basin

Reclassification of the values of the results of water erosion and the slope degree in the form of ordinal categories (1,2, 3) to be compatible with the requirements of the method inputs (OSL and GWR). Intersection of the regression and water erosion layers to obtain a new layer containing data of the two layers for the purpose of applying the two methods of measuring the correlation coefficient on the two layers, by entering erosion as a dependent variable and the regression as an independent variable. Because the ground slope always controls the strength of erosion. Make a map of the intersection, as shown in Figure 7. The coefficient of parameter estimates both in magnitude and direction were checked to see how much influence each parameter had on the method. The spatial autocorrelation and spatial correlograms was calculated and tested to see whether it was statistically significant or not, as shown in Figure 8. A non-stationary test was performed to determine if parameter estimates in GWR method were significantly different across the study area by comparing OLS parameter estimates with corresponding GWR estimates, Figure 9. It is important to know whether it is

Summary of OLS Results - Model Variables

Variable	Coefficient (a)	StdError	t-Statistic	Probability (b)	Robust_SE	Robust_t	Robust_Pr (b)
Intercept	4.338788	0.534579	8.116264	0.000000*	0.526644	8.238557	0.000000*
CLASSES	-0.083838	0.105738	-0.792887	0.430409	0.100872	-0.831132	0.408604

Source: Summary of the statistical report resulting from the OLS analysis using ArcGIS.

Interpretation of the values of the standard deviation of the residue indicates that the lower values of the categories represented by negative values express the areas of the negative relationship between the slope and the water erosion (the decrease in the intensity of the water erosion due to the decrease in the degree of slope. while the higher values of the categories are represented by positive values. which express the positive relationship between the degree of Regression and water erosion. that is the high intensity of erosion came as a result of the high degree of regression. and the category (-0.5 - 0.5) indicates that there is no relationship between water erosion and the degree of regression. Through the table of characteristics of the results of (OLS) and specifically from the field of standard deviation of the remaining. We find that the negative groups represented (32.1%) of the values with an area estimated at (212.7 km^2) of the area of the study area. at a rate (35.4%) of the area of the study area. while the category (-0.5 - 0.5) which indicates that there is no relationship between water erosion and the degree of slope. It represented (33.3%) of the values occupying a ratio of (38.7%) of the study area with an area estimated at (232.7 km^2) while the categories have positive values It represented (34.6%) of the total values with an area estimated at (155.8 km^2) of the area of the study area. At a rate of (25.9%) of the area of the study area. This is a clear indication that the relationship between the degree of slope and the erosion of water extracted by the Bergsma method is not very strong. As (38.7%) of the area of the study area did not record a significant relationship. and this could be because the Bergsma method did not depend on the introduction of the ranks. Stream as an entry in the equation, and its dependence only on the lengths of

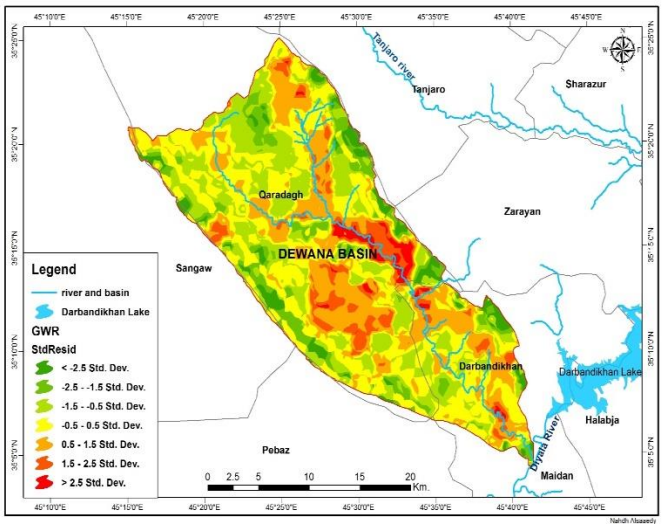


Figure 9. Correlation coefficient by (GWR)

3- Results

3.1 Results of a linear regression analysis using the OLS method:

Ordinary least squares (OLS) are the most well-known regression techniques. It is also an appropriate starting point for all spatial regression analyzes. It provides a global model for the variable or process you are trying to understand or predict. To creates one regression equation to represent that process and uses regression to evaluate the relationships between two or more elements depending on their Attribute table. It allows the researcher to identify and measure relationships and provides a better understanding of what is happening somewhere. It predicting where something will happen or starting to study the reasons for things to happen where they happen. (ESRI, 2020)What distinguishes this method is that it gives an indication of the relationship between the elements entered at the level of the entire study area and does not consider internal (local) variations of the nature of the relationship between the variables included in the model. (Al-Qassab, 2020)

After implementing the work steps represented in entering and processing data, the result appeared to us, as shown in Figure 6, which represents the standard deviation of the Residuals (Std Residuals) as well as a statistical report describing the level of statistical confidence in the relationship between the two variables Table (1).

Table (1). Summary of the statistical report of the results (OLS)

the categories (that is the program gives weight Greater for the larger area and vice versa) while the higher values for the categories are represented by positive values. Which express the positive relationship between the degree of slope and water erosion weighted (the weight) of the area of each of the categories (that is the program gives more weight to the larger area and vice versa) that the high intensity of erosion Came Result high gradient. Either category (-0.5 - 0.5) refers to the absence of a relationship between water erosion and the degree of regression in terms of the weight of the area covered by this category.

Table (2). Summary of the statistical report of the results (GWR)

OID	VARNAME	VARIABLE	DEFINITION
0	Bandwidth	7570.791222	
1	ResidualSquares	363.062131	
2	EffectiveNumber	4.950619	
3	Sigma	2.276608	
4	AICc	342.2614	
5	R2	0.399363	
6	R2Adjusted	0.365489	
7	Dependent Field	0	Classes_1
8	Explanatory Field	1	Classes

Source: Attribute table resulting from GWR analysis using ArcGIS.

Through the characteristics table for the results of (GWR). Specifically, from the field of standard deviation of the remainder. We find that negative groups represented (26.6%) of the values with an area estimated at (214.4 km^2) of the area of the study area, at a rate of (35.6%) of the area of the study area. As for the category (-0.5 - 0.5). Which indicates that there is no relationship between water erosion and the degree of slope. It represented (42.6%) of the values with an area estimated at (199.4 km^2) of the area of the study area. At a rate of (33.2%) of the area of the study area. As for the categories with positive values. It represented (30.7%) of the total values with an area estimated at (187.5 km2) of the area of the study area. At a rate (31.2%) of the area of the study area. This is a clear indication that the relationship between the degree of slope and the erosion of water extracted by the Bergsma method the water system's streams without considering its levels. As for the statistical report that gives us the results of testing the quality of the model implemented on the study area from a statistical point of view. given Table (1) we note that the value of the standard error (Std Error) is equal to (0.534) and it is very high and this is evidence of the inaccuracy of the model applied in the case of The study As for the robust error value (Robust_SE) which reached (0.526) which is close to the value of the standard error. Which confirms the strength of the adopted model (i.e. the lack of strength of the relationship between the inputs) while the probability value (Probability b) is equal to (0.00) and this an indication of the high level of statistical (significance) confidence to reach (99%) meaning that the results are very reliable.

3-2 Results of Linear Regression Analysis by Geographic Weighted Regression (GWR)

It is a localized form of linear regression that is used to model spatially variable relationships and is one of many spatial regression techniques increasingly used in geography and other disciplines. GWR provides a local model of the variable or process to be understood or predicted by the suitability of the regression equation for each element in the data set. GWR builds these separate equations by combining dependent and explanatory (independent) variables for elements that fall into the bandwidth of each target element. The shape and size of the bandwidth depends on the user input of the type of variables. The bandwidth method the distance and the number of neighborhood parameters. (ESRI, 2015) After implementing the work steps represented in entering and processing data. The result is shown to us by the Figure 9. Which represents the standard deviation of the Residuals (Std Residuals) as well as a statistical report describing the level of statistical confidence in the relationship between the two variables Table (2). Interpretation of the values of the standard deviation of the residue indicates that the minimum values of the groups represented by negative values express the areas of the negative relationship between the slope and the water erosion (the decrease in the severity of the water erosion as a result of the decrease in the degree of slope) weighted by the area of each of

the study area and does not give weight to the area or to any other weighted component that has an effect on the results The analysis that is it gives a general impression of the type of relationship between the independent variables and the extent of their influence with the dependent variable. In contrast to the second method (GWR) which considers the internal local variations of the study area. As well as its ability to give weights that favor some of the elements involved in the analysis process. This is evident from the results shown in Table (3) as the ratios of the recorded values vary for the three categories. This is clear in the category (-0.5 - 0.5) which shows that there is no relationship between the degree of slope on the one hand and water erosion on the other hand. As it recorded a difference of (9.3) % between the two methods in favor of the GWR method. The significant differences were recorded among the other variables shown in Table (3).

In order to prove the main hypothesis. We find that there is a difference between the Ordinary least squares method (OLS) and the geographically weighted regression method (GWR) to calculate the correlation relationship and linear regression analysis in geographical studies through the tools of analytical GIS programs. It is evident that the results of the OLS method are more general than the GWR method.

In proof of the secondary hypothesis. It was found that calculating the values of water erosion (Bergsma) method does not give accurate results to measure the severity of erosion in general and does not record a strong relationship compared to the degree of slope on the other hand. This is due to the non-dependence of the (Bergsma) method in calculating water erosion on riverine levels and its dependence only on the lengths of waterways.

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is not very strong. As (42.6%) of the values occupying (33.2%) of the area of the study area did not record the existence of a significant relationship. and it could be that Because Bergsma method is not dependent on the introduction of riverine levels as an entry in the equation. and its dependence only on the lengths of the water system's streams without considering their levels.

As for the statistical report that gives us some statistical facts. looking at Table (2) we note that the value of the determination coefficient (R2) - which indicates the degree of influence of the degree of slope on water erosion - has reached (0.39) and is close to the value of the modified determination coefficient (R2 Adjusted) which amounted to (0.36) which means that the degree of the impact of the slopes on water erosion in the study area represents only (39%) of the area of the study area. and that the remaining percentage (61%) is explained by factors other than the degree of slope is responsible About water erosion in the study area.

4- Conclusions:

Through the results of the analysis according to the two methods (OLS & GWR) we can summarize the most prominent results in the following table (3):

Table (3). Summary of the results of the analysis according to the two methods (OLS & GWR)

Categories	Ratio of values (OSL)	Ratio of values (GWR)	Area sq. km (GWR)	Area sq. km (OSL)	Area ratio (OSL)	Area ratio (GWR)
Negative	32.1	26.6	214.4	212.7	35.4	35.6
-0.5 – 0.5	33.3	42.6	199.3	232.7	38.7	33.2
positive	34.6	30.7	187.5	155.8	25.9	31.2
Total	100	100	601.2	601.2	100	100

Source: OLS & GWR analysis of Attribute table using ArcGIS.

We notice from the results of the analysis a clear difference between the method of analyzing linear regression by the method of Ordinary least squares and the method of analyzing geographically weighted regression. As the first method (OLS) does not take into account local variations within

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الملخص :

قامت هذه الدراسة باجراء مقارنة بين أداء طريقتين من تقنيات نظم المعلومات الجغرافية وهي طريقة انحدار المربعات الصغرى العادي وطريقة الانحدار الموزون جغرافيًا للتنبؤ بقيم الانجراف المائي عبر حوض الديوانة الذي يقع في شمال شرق محافظة السليمانية . وقد اظهرت الدراسة على وجود اختلاف واضح بين الطريقتين، حيث بينت الدراسة ان نموذج انحدار المربعات الصغرى لا تأخذ في الاعتبار الاختلافات والمتغيرات المحلية داخل منطقة الدراسة ولا تعطي وزناً للمنطقة أو لأي عنصر مرجح آخر ، وانما تعطي انطباعًا عامًا عن نوع العلاقة بين المتغيرات المستقلة ومدى تأثيرها مع المتغير التابع. اما نموذج الانحدار الموزون جغرافيًا فانه يأخذ في الاعتبار المتغيرات المحلية الداخلية لمنطقة الدراسة والقدرة على إعطاء بعض الأوزان التي تفوق العناصر الداخلة في عملية التحليل. وقد سجلت نتائج هذه الدراسة فرقًا بين الطريقتين تقريبًا (9.3٪). تم الحصول على أفضل النتائج بنموذج GWR بمساحة تقدر بـ (199.4 كم 2) من المساحة الكلية بنسبة (33.2٪). قد أظهرت النتائج عدم وجود علاقة معنوية بين الانجراف المائي ودرجة الانحدار. كما اوضحت عدم وجود علاقة معنوية بين الانجراف المائي ودرجة الانحدار. أن حساب قيم الانجراف المائي بطريقة برجسما لا يعطي نتائج دقيقة لقياس شدة الانجراف بشكل عام ولا يسجل ارتباطًا قويًا مقارنة بدرجة الانحدار من ناحية أخرى.