Study of Spatial Distribution of Greenhouse gases (methane gas) Over Iraq using Geostatistical Analysis

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Abstract

Wetlands are one of the most important natural resources on Earth. Marshes are important wintering and resting area for migratory water birds and other migratory birds. Historical data on bird migration in the Marshes suggest that they were one of the largest wintering areas for migratory water birds in the Middle East. The Iraqi marshlands lies in the floodplain which is created by the Tigris-Euphrates river system in the lower part Mesopotamia basin. The existence of water vapor, carbon dioxide, methane and ozone in the troposphere makes surface of our planet habitable. The greenhouse gases absorb thermal radiation and also emit these wavelengths, making the mean surface temperature of the earth higher, and contribute to global warming. Human activities produce large amounts of greenhouse gases, like carbon dioxide, methane, ozone and others. Methane is produced by the decomposition of plants in wetlands. Geostatistical interpolation methods are adopted in this paper. We use the analyst in ArcGIS to apply cross-validation. The cross-validation calculate some criteria to insure the accuracy of predictions made using the ordinary kriging method. Maps were created for methane over Iraq. Cross validation errors were calculated using ArcGIS. The produced maps assure that lower Mesopotamian basin have high concentration of Methane gas which make it as a wintering and resting area for migratory water birds.

Keywords: Wetlands, Bird Migration, Greenhouse Gases, Mapping, Geostatistical Analysis.

دراسة التوزيع المكاني للغازات الدفيئة (غازالميثان) فوق العراق باستخدام التحليل الجيواحصائي

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الملخص:

تعتبر الاراضي الرطبة واحد من اهم المصادر الطبيعية على الارض. ان الاهوار مهمة كمساحة لاستراحة وقضاء فصل الشتاء لطيور الماء المهاجرة وانواع اخرى من الطيور المهاجرة. ان البيانات التاريخية لهجرة الطيور الى الاهوار تثبت بانها من اكبر المساحات لقضاء الشتاء بالنسبة لطيور الماء المهاجرة بالشرق الاوسط .ان الاهوار العراقية تقع في السهل الفيضي و الذي تولد بواسطة نظام نهر دجلة –الفرات في حوض الميزوبيتيميا الاسفل. ان وجود بخار الماء، ثاني اوكسيد الكربون، الميثان، والاوزون في طبقة التروبوسفير يجعل من سطح كوكبنا قابل للعيش فيه. تمتص هذه الغازات الاشعاع الحراري وتبعثه، وبالتالي تجعل معدل درجة حرارة السطح على الارض اعلى وتساهم في الاحتباس الحراري. تنتج النشاطات البشرية كميات كبيرة من الغازات الدفينة مثل ثاني اوكسيد الكربون، الميثان، والاوزون واخرى. يتولد الميثان من تحلل النباتات بالاراضي الرطبة. استخدم المحلل الجيواحصائي في ArcGIS لانجاز التدقيق المتقاطع. ان طريقة التدقيق المتقاطع تزودنا بمعايير دقة للتنبؤات التي نستخدمها بطريقة الكرجنج الاعتيادي. تم انتاج خرائط الميثان فوق العراق، و تم حساب اخطاء التدقيق المتقاطع باستخدام ArcGIS . توكد الخرائط المنتجة ان حوض الميزوبيتيميا الاسفل فيه تراكيز عالية من غاز الميثان والتي تجعله كمساحة للاستراحة وقضاء فصل الشتاء لطيور الماء المهاجرة .

الكلمات المفتاحية:ألاراضي الرطبة، هجرة الطيور، الغازات الدفينة، انتاج الخرائط، التحليل الجيواحصائي.

Introduction:

A greenhouse gas absorbs and emits thermal IR, and keeps the temperature of the atmosphere warmer. The greenhouse gases are mainly: water vapor, carbon dioxide, methane, nitrous oxide and ozone. The absorption is happened because vibration and rotational molecular states are excited by IR radiation. Tropospheric and the temperatures of the earth surface increase until a balance is achieved between the outgoing thermal radiation and the incoming solar radiation. This what we call the greenhouse effect. When we change the gases in the Earth's atmosphere because of everyday living, this energy will not be able to exit from the atmosphere of the earth and is trapped in it as heat. The heat is then causes a warming of the air gradually. This warming is what we call as the greenhouse effect. Many authors deal with this problem in the literature [٧, ٩].

Methane Sources:

Methane is emitted by both natural sources such as wetlands, and human activities like natural gas systems leakages. Methane's lifetime is shorter than $CO^{٢}$ in the atmosphere, but $CH^{٤}$ can be considered more effective in trapping radiation than $CO^{٢}$. Methane is emitted from activities like: industry, agriculture, and waste management. The creation of methane b humans is faster than removing it from the Earth. Wetlands have high moisture content, and can be considered as oxygen depletion, and will creates an environment for producing microbes that will decompose the organic matter. The majority of methane gas gets released into the atmosphere. A pie chart in figure(٢) demonstrating the relative effects of various sources of atmospheric methane.

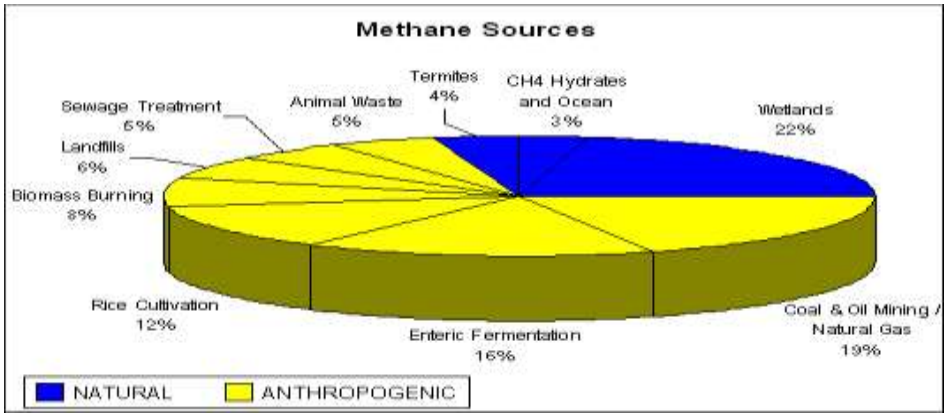

Figure (١): Sources of Methane,
http://icp.giss.nasa.gov/education/methane/intro/cycle.html.

Birds Migration: Migration can be considered as seasonal movement of animals from a place to another. Many types of animals migrate, among them the butterflies, fishes and mammals, but the migration of birds are familiar. The reasons of birds movement is to improve their chances of

survival, and because the climate provides an environment for feeding better than the original place. Migration is an important stage in the lives of these animals: it is most suitable way for adapting to seasonal change. The reasons are complex and not fully understood. Migration is related to food supply, and wind and oceans currents. For this some routes and locations will be easier to reach.

Figure (٢): Migration of birds, http://en.wikipedia.org/wiki/Bird_migration.

Birds migrate to mate, search for food, escape harsh weather, evade predators and to flee from diseases. Birds also migrate to raise their young in a safe environment. Birds migrate when food is scarce. Birds that stay in a single area consume much of the food sources in a particular area, forcing them to flock north to places where there is more food. When food dwindles in the fall, they flock back to warmer conditions where food is more abundant. Birds normally looks for adequate shelter, safety, food and proper breeding grounds when nurturing young. However, adult birds mostly choose such locations for the sake of migrating back to a certain region on their own, and young birds are left to migrate alone when capable.

Methodology:

The variogram is used to measure the average of dissimilarity between our data value and the unsampled values. The value of the

variogram given a separation distance of h is equal to half the average squared difference between the value at z (xi) and the value at z (xi + h):

$$\hat{\gamma}(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [z(x_i) - z(x_i + h)]^2 \qquad (1)$$

Where N (h) is the number of data pairs. After the analysis of the variogram, we can use a suitable model to fit the data and usually this is achieved by weighted least squares[٣, ١١, and ١٢].

Fitting a variogram model: The variogram is expressed as a mathematical function. This is achieved by fitting a suitable function to the experimental variogram. In our study we use two functions, namely spherical and circular. Below the spherical function adopted, which is defined by:

$$\gamma(h) = \begin{cases} c_0 & \text{when } h = \varepsilon \text{ (a very small lag)} \\ c_0 + c\left(\frac{3h}{2a} - \frac{1}{2}\left(\frac{h}{a}\right)^3\right) & \text{when } 0 < h \le a \\ c_0 + c & \text{when } h > a \end{cases} \qquad (2)$$

Where c٠ is the nugget variance, c+c٠ is sill, h is the lag and a is the range. The spherical model is the most commonly used model for experimental data.

A variogram is plotted using the experimental data points, and we call it an experimental or sample variogram. Then the model will be fitted using the experimental data points[٥, ٦]. The variogram is shown in Figure (٣).

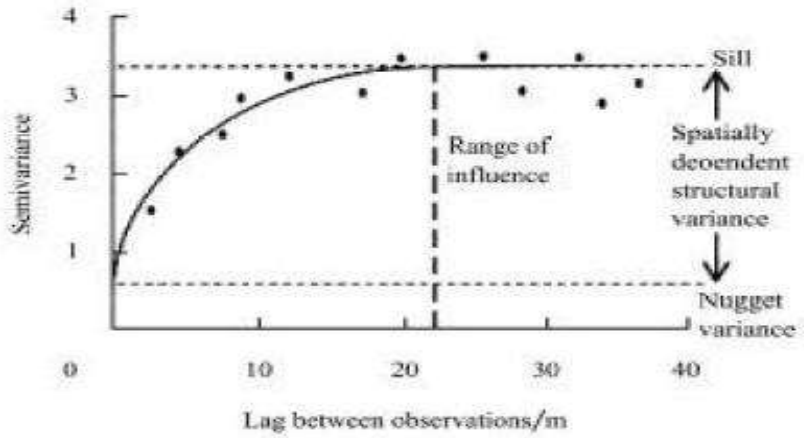

Figure (٣): The variogram.

Methane Data:

CH_4 is emitted from human-connected (anthropogenic) and natural sources. Human activities such as agriculture, biomass burning, fossil fuel production, waste management. Natural sources are: wetlands, oceans, gas hydrates, termites, and freshwater bodies. The new generation of meteorological sounders was Atmospheric Infrared Sounder (AIRS), onboard the Earth Observing System (EOS) Aqua spacecraft was launched on May ٤, ٢٠٠٢. From height of ٧٠٥ km above the Earth's surface the AIRS measures the numerous atmospheric molecules that are emitted and absorbed the radiation at various temperatures all over the atmospheric path from surface to instrument[١،٤،٨, and ٩].

Cross Validation:

The statistics of absolute and squared differences among the measured and predicted values at measured sampled points are used as an pointer of the performance of the method. Many error criteria have been adopted. They include: mean error (ME), mean absolute error (MAE), mean squared error (MSE) and root mean squared error (RMSE). Cross Validation [٢, ١٠].

Results and Discussion:

With Geostatistical Analyst a continuous surface (a map or a distribution model) can be created from measured sample points. Data collection usually can only be conducted at a limited number of point locations. In order to generate a surface, some type of interpolation method must be used to estimate data values for those locations where no samples were taken. In this work an application of the Geostatistical Analyst for development of CH_4 distribution models will be discussed. Maps were constructed using the Geographic Information System (GIS) software and the Geostatistical analyst extension (ESRI). The produced CH_4 maps are shown in figures (٤) and (١٥) using ordinary kriging and Spherical Model.

Samples of these maps for the years: ٢٠١٢ and ٢٠١٥ and for winter months: January, February, and December.

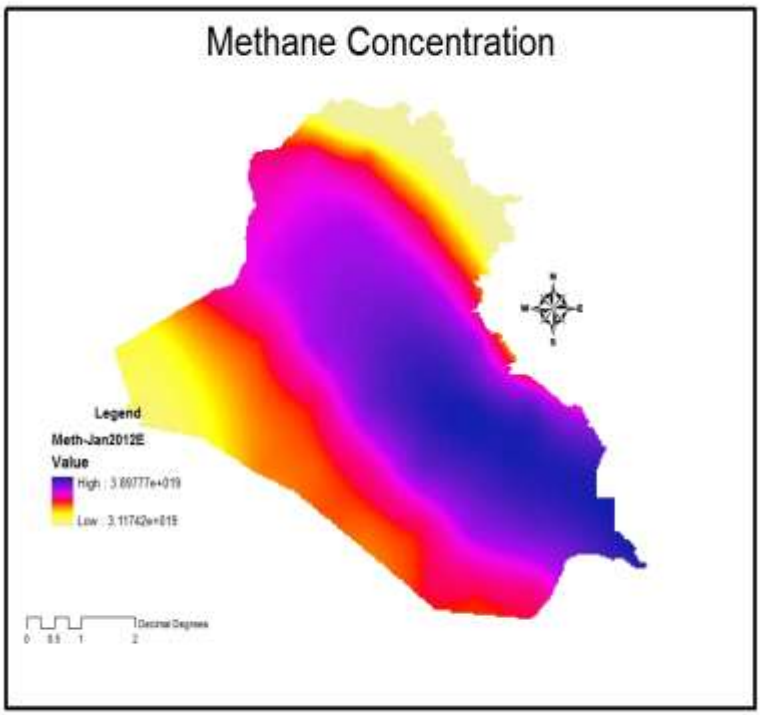

Figure (٤): Methane map January ٢٠١٢.

We Choose winter months because birds migrate to marsh land in south of Iraq during these months. We can notice that the concentration of methane gas in the following maps was high to make this region warmer in winter season. One reason of birds migration is to settle in warmer places. The following maps are produced by the authors using ArcGIS and the data obtained from satellites as mentioned before in methane data section.

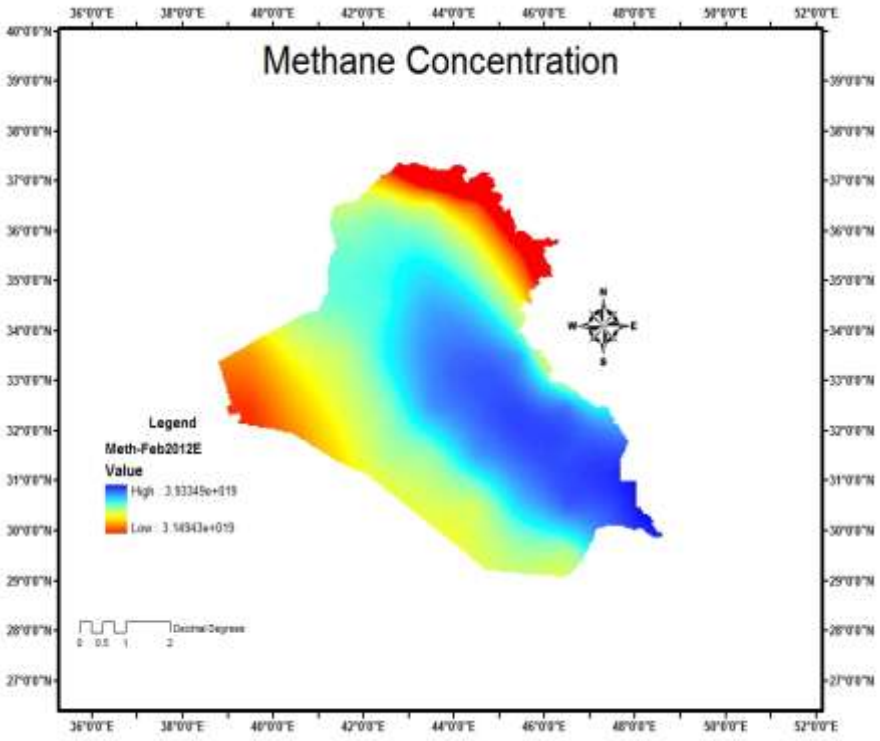

Figure (٥): Methane map February ٢٠١٢.

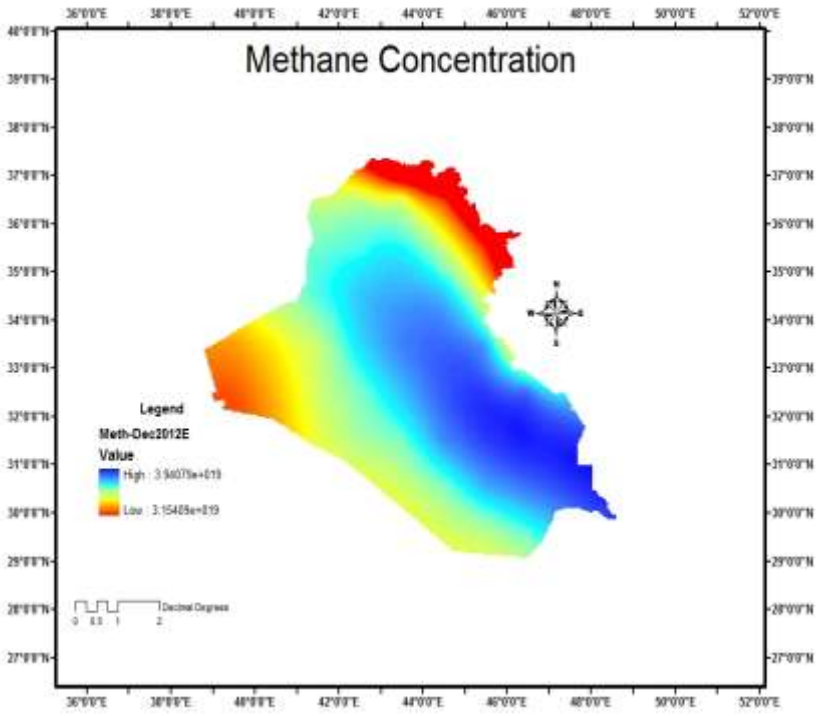

Figure (٦): Methane map December ٢٠١٢.

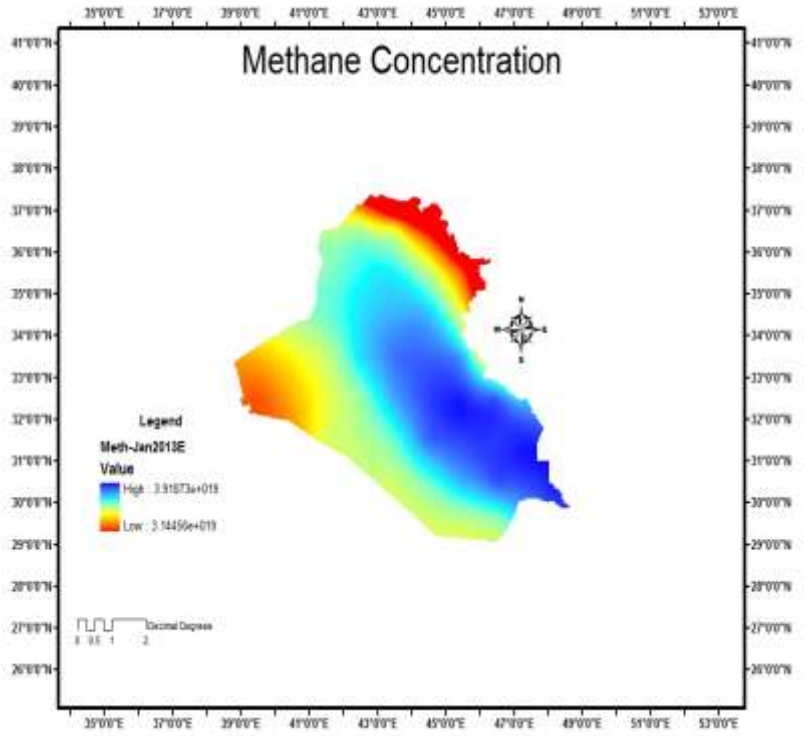

Figure (٧): Methane map January ٢٠١٣.

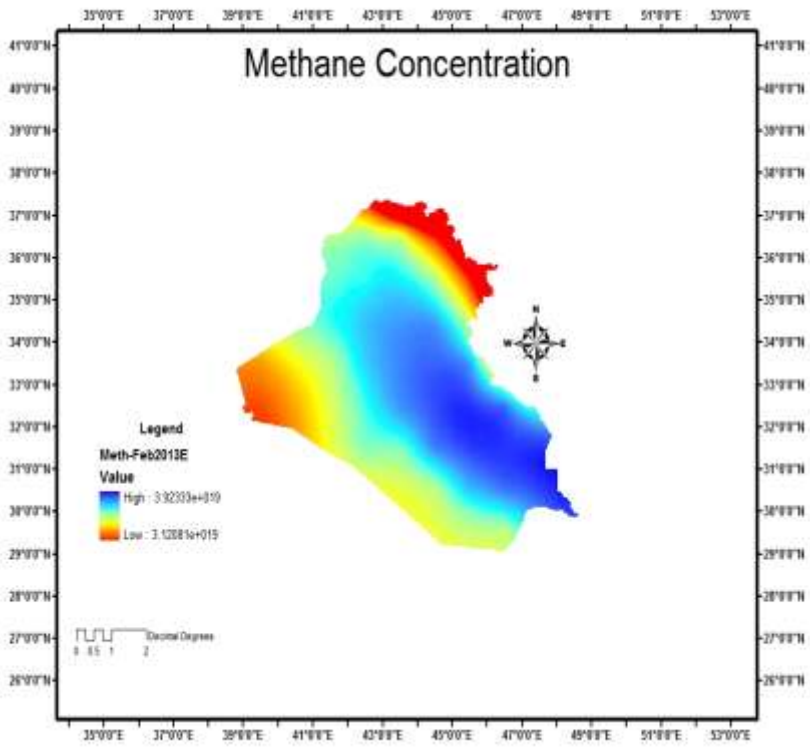

Figure (٨): Methane map February ٢٠١٣.

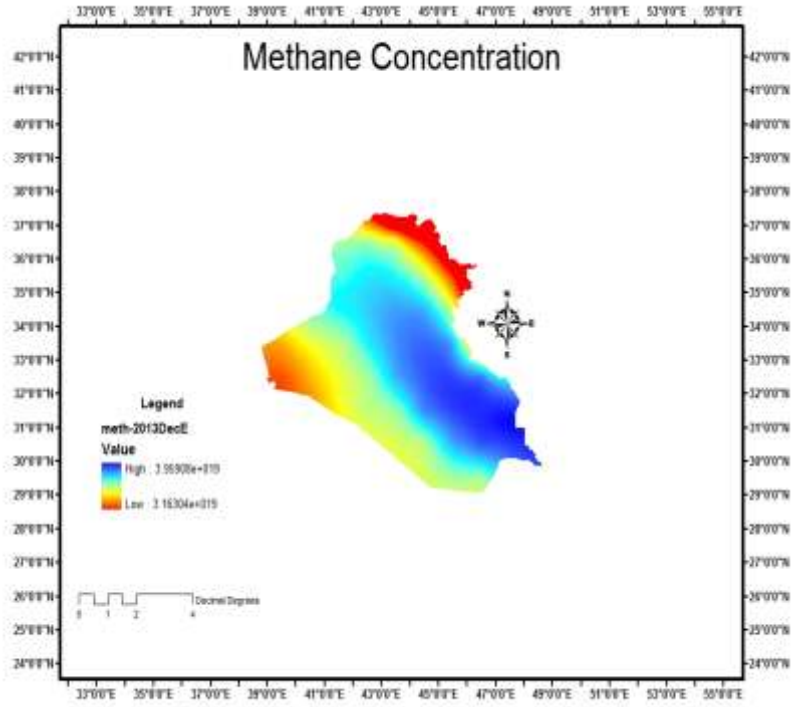

Figure (٩): Methane map December ٢٠١٣.

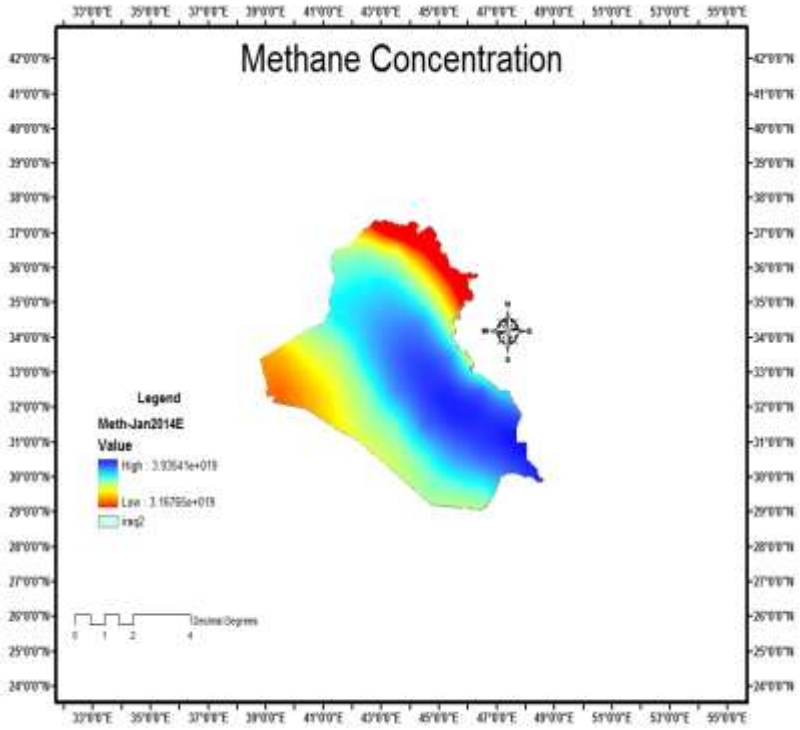

Figure (١٠): Methane map January ٢٠١٤.

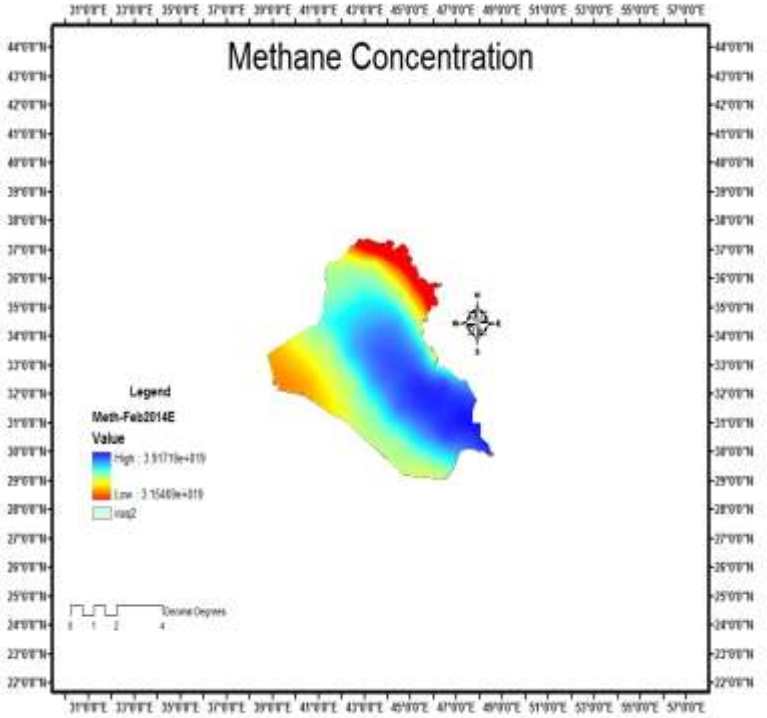

Figure (١١): Methane map February ٢٠١٤.

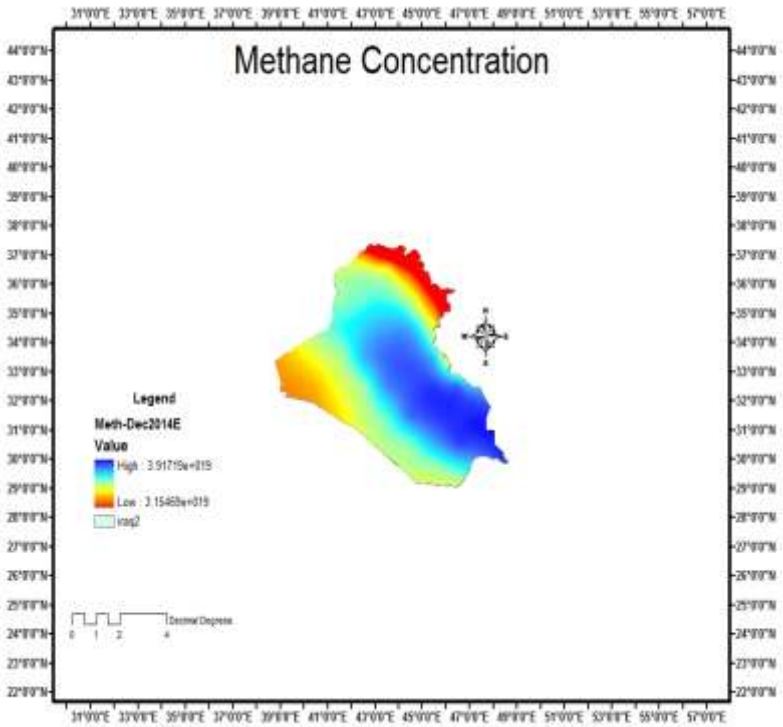

Figure (١٢): Methane map December ٢٠١٤.

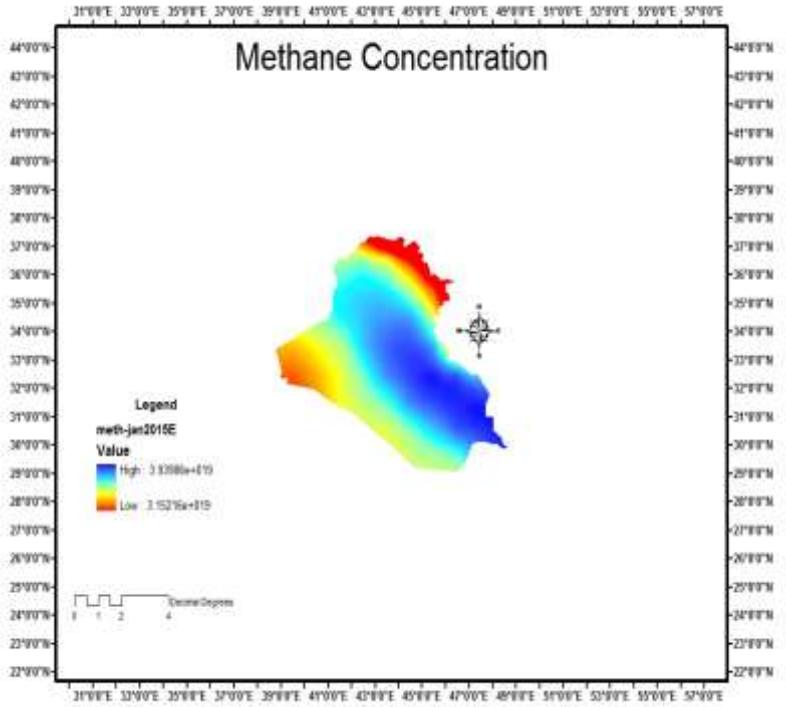

Figure (١٣): Methane map January ٢٠١٥.

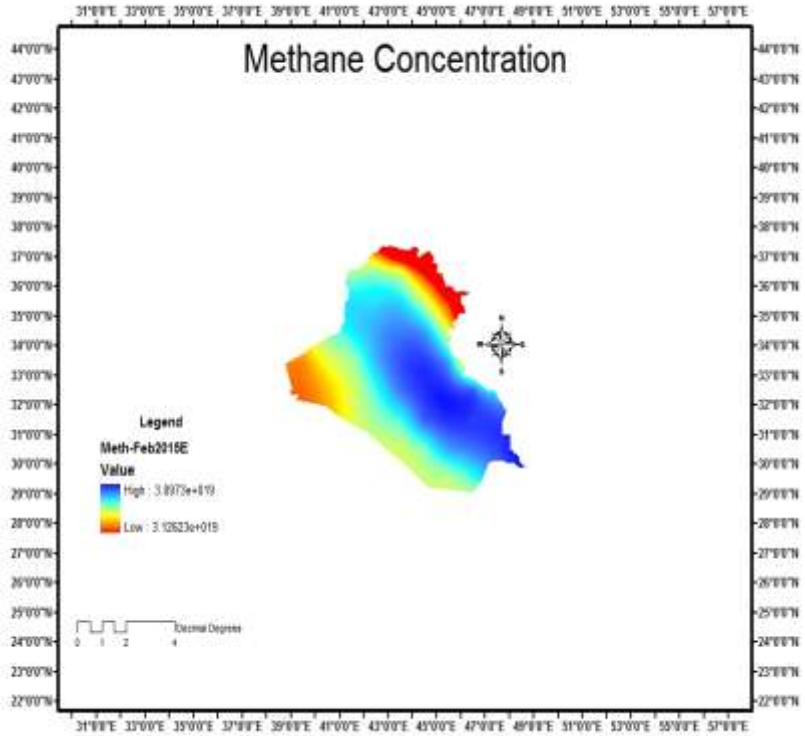

Figure (١٤): Methane map February ٢٠١٥.

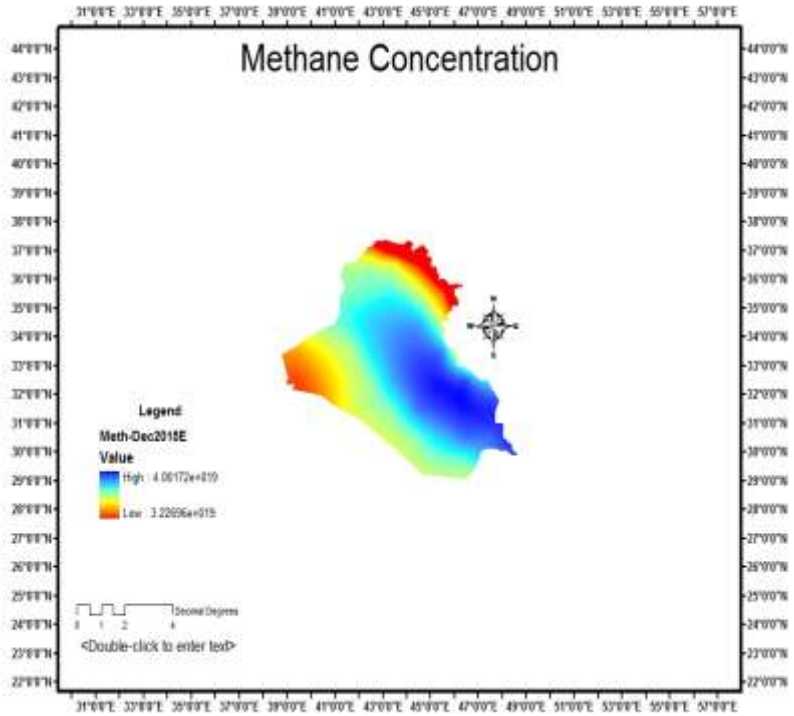

Figure (١٥): Methane map December ٢٠١٥.

The goal of interpolation is to display the spatial patterns of CH_4 data by calculating the values at unsampled locations using measurements at sample points. GIS can analysis and manage a huge spatial data. Cross validation is used as a comparison method between the measured values and the interpolated values. In this study the parameters of the methods are optimized for minimum error. Figures (١٦) and (١٧) below show the cross validation errors for January ٢٠١٢ and ٢٠١٥.

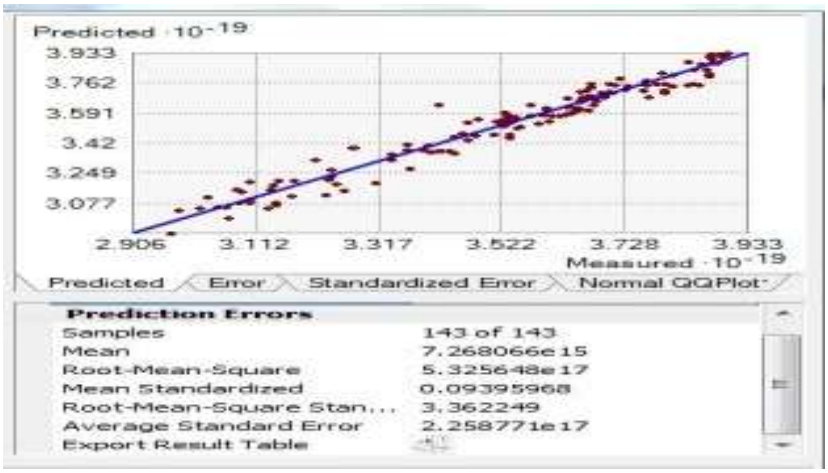

Figure (١٦): Cross Validation Errors January ٢٠١٢.

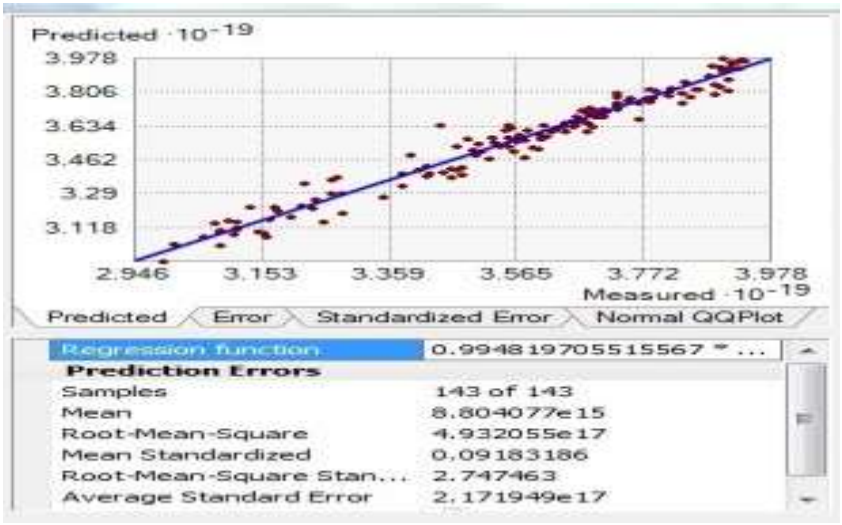

Figure (١٧): Cross Validation Errors January ٢٠١٥.

The measures adopted in this paper are MPE, SMPE, RMSPE, ASE and SRMSPE.

CONCLUSION:

Monitoring of CH_4 is essential because it plays an important role in the processes occurring in the atmosphere and has a large impact on the climate. CH_4 is variable in space and time. In this paper we used geostatistical techniques to model the CH_4 distribution over the study area. CH_4 maps can affects the decisions about the policy of air-quality and also affect the attitudes public and their behaviors.

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