SPATIAL ANALYSIS OF RADON GAS CONCENTRATION DISTRBUTED AT BAGHDAD CITY USING REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM TECHNIQUESD

F. K. M. Al- Ramahi
Assis. Prof.
Remote Sensing Unit, College of Science, University of Baghdad, Baghdad, Iraq
Phdfouad59@gmail.com

ABSTRACT

Spatial analysis (spatial statistics) contain systematic techniques, that study actually geographic data have geographic properties such as topological and geometric, spatial analysis involve difference types of technique. Spatial analysis represented new understanding complex topics in form easy by any method or statistical for study area include mathematics and logic. Using function of point density which represented the Radon gas measurement geographic location, and limitation the density area by finding the radii (bandwidth) Kernel Density Estimation (KDE) techniques variation to reach interest regions and hotspot of point's neighborhood. The aim of the research, applied the spatial statistical method to acknowledge concentrations of radon gas pollution for environmental and human life conservation, and focuses on the region affected by determination and orientation it in this method or tools for control outbreak to be facilitated, this potential possibility aid to avoid research randomly for radon gas pollution regions, this processing consist by extraction the spatial characteristics distribution that depending on distance measurements, by using geographic information system (GIS) technical, and which exploited Global Positioning system to accurate simultaneously the spectral bands of landsate satellite imagery to referencing the study area, and they have been determining the topology objects such as land cover (water, vegetation and soil) and land use, to connected with points measurement of Radon gas in Baghdad city only soils election, thought the soils were caused pollution based for objects type such as water and air, because, the natural formative of layer soils by decay of radioactive isotope Uranium with erosion the rocks and drift process with dissolved water or flood throughout the ages. Doing field the soil samples measurement by RAD7 Mobil detector for 58 point samples election, which represented using soil type such as vegetation land and land use touched with human life.

Keyword: mathematics measurements, Landsat satellite imagery, classification GPS, KDE techniques.

التحليل المكاني لانتشار تركيز غاز الرادون في مدينة بغداد باستخدام تقنيات الاستشعار عن بعد ونظم RS و GIS المعلومات الجغرافية

فؤاد كاظم ماشي الرماحي
استاذ مساعد
كلية العلوم – جامعة بغداد

المستخلص

يحتوي التحليل المكاني (الإحصاء المكاني) على تقنيات منهجية ، والتي تدرس في الحقيقة أن البيانات الجغرافية لها خصائص جغرافية مثل الطوبوغرافية والهندسية ، والتحليل المكاني يشمل على أنواع مختلفة من التقنية. يستعرض التحليل المكاني في فهم جديدة لمواضيع معقدة بأي طريقة أو إحصائية سهلة لمنطقة الدراسة ضمن الرياضيات والمنطق. باستخدام وظيفة كثافة النقطة التي تمثل الموقع الجغرافي لقياس غاز الرادون، يتم تحديد مساحة الكثافة من خلال إيجاد نصف القطر (عرض النطاق الترددي، تقوم تقنية تخمين التغاير في كثافة كيرنل (KDE) للوصول إلى مناطق المفيدة وجوار النقاط الساخنة (أعلى كثافة ضمن منطقة الدراسة). يهدف هذا البحث إلى تطبيق الأسلوب الإحصائي المكاني لتثبيت صحة تراكيز تلوث غاز الرادون من أجل الحفاظ على الحياة البشرية و البيئية ، ويركز على المنطقة المؤثرة بتحديدها واتجاهها في هذه الطريقة أو بقية الأدوات للسيطرة بتفشي التلوث بسهولة، هذه الجهد الممكن يساعد على تجنب البحث عشوائيا عن مناطق تلوث غاز الرادون، تتكون هذه المعالجة من خلال استخراج توزيع الخصائص المكانية التي تعتمد على قياسات المسافة ، باستخدام تقنيات نظم المعلومات الجغرافية (GIS)، والتي تم استثمار نظام تحديد التموضع العالمي (GPS) من أجل الدقة المتزامنة مع الحزم الطيفية لصور الأقمار الصناعية لاندسات لتكون مرجعا لمنطقة الدراسة، وقد تم تحديد العناصر الطوبوغرافيا مثل الغطاء الأرضي (الماء ، الغطاء النباتي والتربة) واستخدام البشري للأرض، ، للربط مع النقاط المقاسة لغاز الرادون في مدينة بغداد والمختارة فقط ، لاعتقادنا أن الترب تسببت في التلوث اكثر من بقية أنواع العناصر الأخرى مثل الماء والهواء ، بسب، التكوين الطبيعي لطبقات هذه الترب وبواسطة تحلل النظائر المشعة لعنصر اليورانيوم بتآكل الصخور وعملية ذوبانها بالمياه و انجرافها بالفيضانات على مر العصور. تم العمل الحقلي بقياس عينات الترب بواسطة جهاز الكاشف RAD7 المتنقل ل 58 عينة من النقاط المختارة، والتي تمثل نوع التربة المستخدمة مثل الغطاء النباتي والاستخدام البشري للأرض التي تمس حياة الإنسان.

الكلمات المفتاحية: قياسات غاز الرادون، مصورات التابع الارضي لاندسات، التصنيف، وتقنيات .(GPS, RS, GIS, KDE)

*Received:22/6/2019, Accepted:16/9/2019

INTRODUCTION

Spatial analysis or called spatial statistics involve with many types of difference techniques, which treatment entities using such as topological, geometric and any geographic properties. Location represented to interest in this process by seek place and route algorithms and logical descriptive transformative tabulate structure, Analysis definition is contain many process for breaking a difficult topic or unclear to steps conform of statistical methods in order easy understanding of it, using techniques have been applied the study area of mathematics and logic. Remote sensing techniques when have data raw availability capture huge regions as Baghdad city studies controllable without reached it, and they connected with geographic points measured, Geographic information systems (GIS) have ability to manipulate, analyze and visualize them . And help to expect or predict distribution of points of radon gas measuring high concentrations (Hotspot), it has finding the point's neighborhood distance, (1). Estimation of Radon concentration at sampling locations, and interpolation of the estimates at discrete locations to generate a continuous surface by Kernel Density Estimation (KDE) techniques, the pattern form may be mapped on Radon gas pollution landscape surface occur in three dimensions regions smooth, GIS ArcView is used to executable points of Radon gas pollution hotspot maps and digital surfaces estimations, (2). Achievement the point pattern density accurate may be depicted the satellite imagery with points which taken by Global positioning System (GPS) elections that represented all study area component such as water, vegetation, soil types and landuse, and the points measures coordinate system will be converted from geographic coordinate to Universal Transverse Mercator (UTM) coordinate, (3). The aim of the search, to use modern techniques for spatial analysis to distribute radon pollution concentrations and determine their location and direction and to predict the location of its future spread.

MATERIALS AND METHODS

Figure 1 and 2 illustrate the study area description the Iraqi administrative division map, both showing, that are bounding geographic division, sum areas measuring, and most population actives focus in center of Baghdad land use (Human activity), unlike rural area landcover and sometime a few separate landuse, and illustrating, the points measured of Radon gas pollution election distribution. The most sub- districts significant the landuse are 17 Sub-Districts, which have been describing and presenting as layers, illustrated in Table 1 and Figure 2. According to coordinate system accurate Georeference Baghdad zonal map shown the major regional of Baghdad city lies between the following latitude and longitude lines 33.452°N → 33.184°N and 44.189°E → 44.576°E. The Baghdad population is 8,216,040 according to planning ministry of Iraq estimation, extended over an area of approximately 927.605549 km^2, (4).

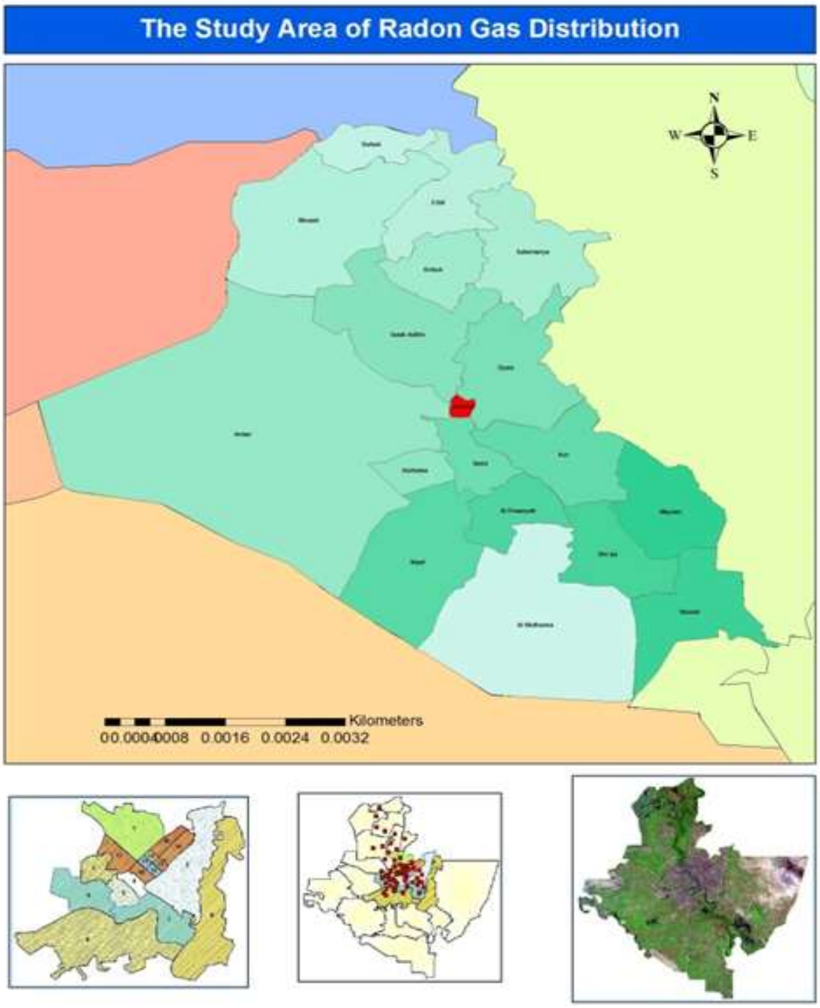


Figure 1. The large picture is Iraq administrative, the low pictures are representing study area of Bagdad.

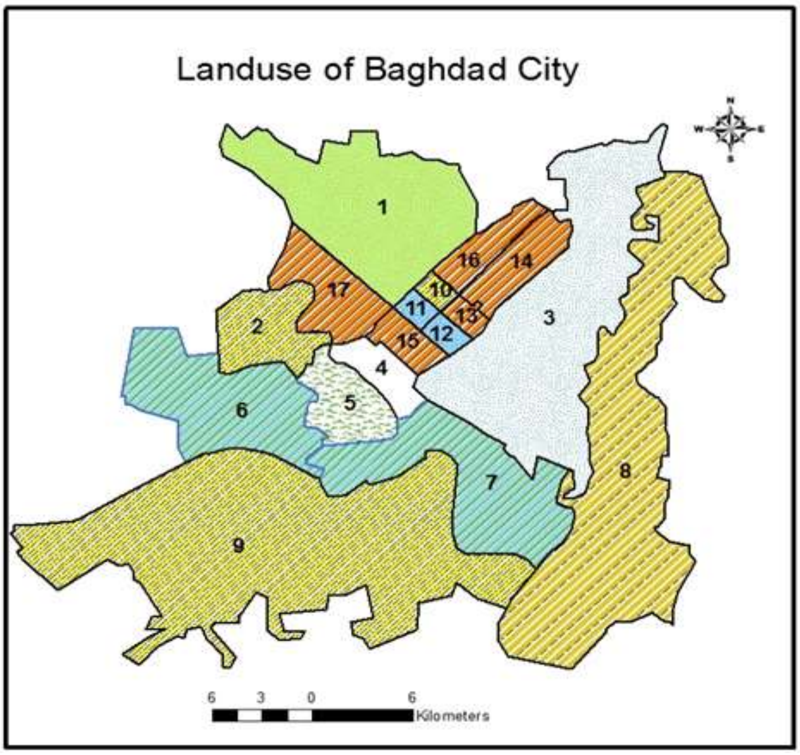


Figure 2. Baghdad capital of IRAQ include all human life actives

Table 1. All sub-district name landuse of Baghdad and calculate the area for each them.

ID	Sub-District	Area Km^2	ID	Sub-District	Area Km^2
1	Al Fahama	93.8134	10	Abnaa Al Rafedein	3.64792
2	Al Kadhimiya	28.7674	11	Sader city1	3.8924
3	Baghdad Jededa	142.344	12	Sader city2	4.44329
4	Risafa centre	14.0648	13	Al Sadeeq Akbar	4.45586
5	Karkh centre	23.6714	14	Al Furat	18.8617
6	Al Mansour	65.7097	15	Palestine street	9.80748
7	Al Karrada	72.4918	16	Al Monawra	13.7726
8	Jisr dyala	169.868	17	Al Adhamiya	27.2428
9	Al Mamoon	230.751		Area Sum = 927.605549	

Descriptive caused radon gas in soil

The all soil types in Baghdad are precipitated of soils sediment, Radon is producing by the radioactive decay of radium U^{-226}, that is finding in uranium element of ores, which it mixture in alloy such as phosphate rock, igneous, phosphate, shales and lead miner. In age ago the rocks are causing dissolution flood and erosion in water stream that is forming sedimentary in all study area region. The rocks are representing such as schist, granite and gneiss, schist and limestone. In table 2 shown Radon varies widely concentration in any region of study area, see figure 3. Although, climatic vary is significant role release the Radon gas by erosion with increase wind, temperature and rainfall, and the place of residual building utilize and raw material are randomly in study area. The pollution coming from wrong agricultural practices are not able to be detected by remote sensing before the addition of pollutants, (5). Uranium is easily leached even at a normal pH of around 5-7 day, and many of the large uranium ore deposits are formed by ground water that has transported uranium which has been precipitated in a reducing environment, (6).

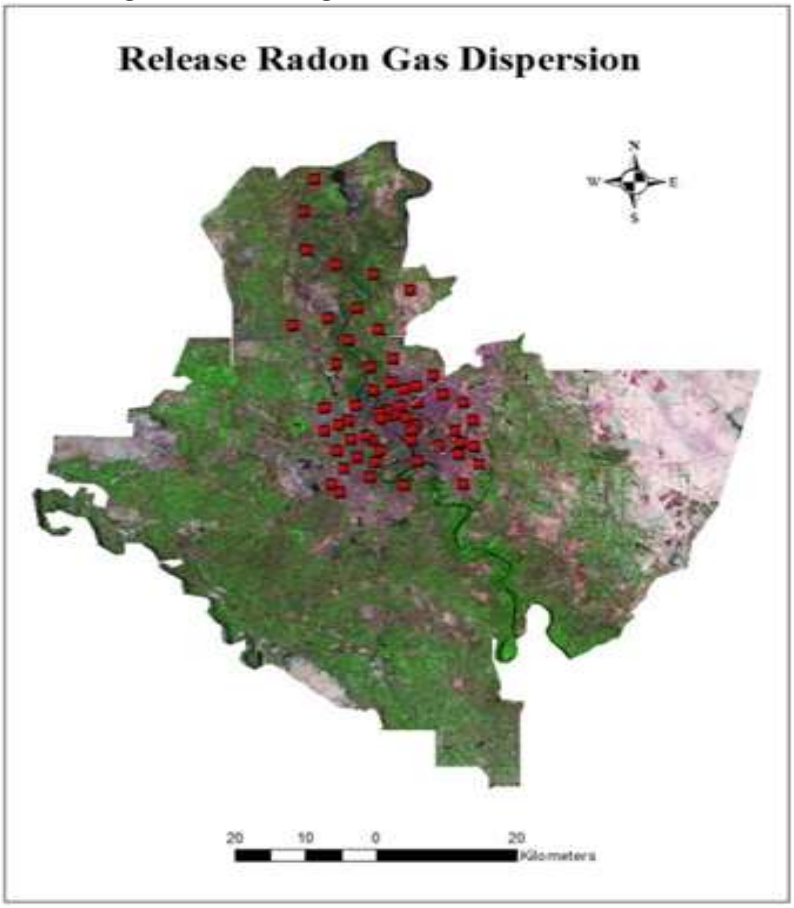


Figure 3. Illustration, the points of release Radon gas concentration distribution in study area.

Table 2. The points of release Radon gas concentrations are measuring in RAD 7 mobile for soil type various in study area, and convert geographic coordinate system to UTM projection coordinate measure GPS, (3).

ID	Geographic Long. (λ)	Geographic Lat. (φ)	UTM Zone	UTM X-Axis	UTM Y-Axis	Radon Concentrate
1	33.494933	44.231020	38 N	428568.317	3706422.078	185
2	33.433089	44.351274	38 N	439696.789	3699489.172	79
3	33.433089	44.351274	38 N	439696.789	3699489.172	79
4	33.411665	44.384321	38 N	442754.257	3697095.717	180
5	33.400687	44.402647	38 N	444451.454	3695868.566	93
6	33.381916	44.423396	38 N	446369.713	3693776.027	108
7	33.348832	44.421540	38 N	446176.112	3690109.674	114
...	……	……	……	……	……	……
52	33.4383729	44.299595	38 N	434896.259	3700106.821	101
53	33.446044	44.385595	38 N	442895.407	3700906.736	80
54	33.399000	44.355817	38 N	440095.705	3695707.290	184
55	33.607632	44.250802	38 N	430496.728	3718904.819	179
56	33.381599	44.493549	38 N	452894.342	3693707.503	139
57	33.474545	44.316525	38 N	436496.089	3704106.395	166
58	33.521505	44.329067	38 N	437695.961	3709305.841	185

Point pattern analysis (PPA)

The points location are interesting role in the study area that representing of point can be analysis by techniques for group or clusters concentrated quantitative method which can be describing the point pattern. The relationship between the points distribution represented series of spatially point pattern. The experimental results demonstrate that the proposed algorithm is superior emulous superior to other conventional methods such as kernel density estimation (KDE) in terms of continuous area can be quantitative analysis and visualization, (7). Many scientific field emerged in years ago to need statistical theory or method developing such as plantation ecology, health care, cancer registration record and any study area which is representing the spatially distribution type (randomly, performance and cluster) having location actualization on the earth for measurement potential to find correlation or autocorrelation neighbored for each points to be affirmed. Point patterns consist a series of spatially distributed points, (8).A point pattern comprise of a many of points location for set criteria highlighted below;

1- The patterns should be mapped on a Radon gas depicted, the topographic of the Radon gas density occur over a three-dimensional continuous surface

2- The study area of Radon gas pollution should be determine objectively as Radon; the boundaries of the study area were portrayed to base on the accessible of data set form as neighbor of points

3- The Radon pollution map must be based on a public health car indicator or any epidemiology outbreaks of the study area.

4- Radon pollution locations must be warning to inspect lung cancer.

The simplest formula, the point's spatial arrangement is behavior in space 2-dimensional;

$X = \{x \in D\}$

Where;

D is represent the study area a subset of R^n , n is dimensional in Euclidean space.

An empirical definition, D would be the bounding region of the points like box or called a quadrate sometime, and representing a matrix region locations for the ranges of the coordinates. The pattern distribution of points Within each sub-region, as shown in figure 4, Random distribution that any point occur at any place in closing area may be applied quadrate technique to limited the events for analysis which taken cluster distribution status, Uniform distribution for every point will be taken same position shape of points distribution that distance measured of neighbor points similarly in large area expose include very few events or points, and Cluster distribution of points are concentrated close together which the distance measured at less than type of distribution, (9) and (10)

Geographical Information Systems (GIS), PPA has been used with increasing frequency in a range of applications including identification point's patterns of Radon distribution.

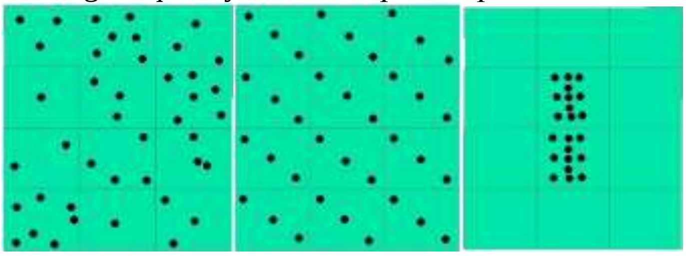


Figure 4. Three types of different pattern points distributions, Randomly, Uniformly, and clustery distribution to be sequence.

Assumption, that closely area (continuous surface), the formula that distributed the correlation of point's pattern is finding by standard z-value, which the point pattern distribution is type:

$$Z = \frac{\overline{\bar{d}-E(\bar{d})}}{SD} \quad \ldots, (1)$$

Where; d the distance average, E(d) is the expected distance value and sd is the standard deviation, they can be found in equation;

$$\bar{\boldsymbol{d}} = \frac{\sum_{i=1}^{n} d_i}{n} \quad \ldots, (2)$$

Where; d_i number of distance for each point and n is number of point which represent Radon gas measured

$$E(\bar{d}) = 0.5\sqrt{\frac{50}{10}} \quad \ldots, (3)$$

Where; A is the area represent study area, n number of point represent Radon gas measured.

$$SD = \sqrt{\langle \frac{1}{4tan^{-1}1} - \frac{1}{4} \rangle \frac{A}{n^2}} = \frac{0.26136}{\sqrt{n^2/A}} \quad \ldots, (4)$$

When, if the z-value result equal for +1.95 value the distribution is uniform, equal or less -1.95 value the distribution is cluster and the value between those values the distribution is randomly, as shown in figure 5.

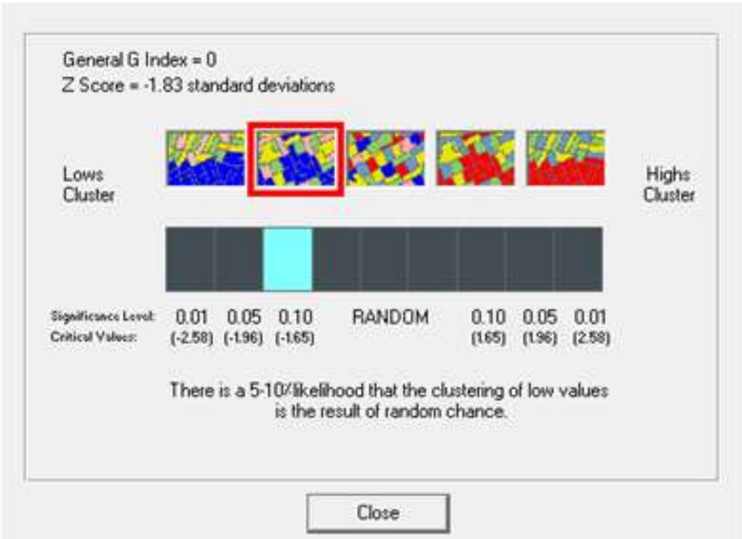


Figure 5. Illustration, the radon distribution type according to z-value, which represent cluster type.

Kernal density functions

Kernel Density technique mapping may be defining hotspot region for geographic aggregation for points pattern, and the best manner for transfer discrete surface from 2-dimension to 3-dimension continuous surface or area smooth, it can calculates the distance by differential bandwidth (sigma (cumulate density) or radii) for each point to estimate suitable density region around each point of Radon pollution, (11). For determined the density (concentration) of point pattern of objects as radon gas is sigma that represented the bandwidth (cumulative density smooth) of the kernel technique, the density of cumulate value can be determined by sum sigma value chosen to reached satisfaction function fulfillment. Hence, the spatial analysis context, kernel technique density behavior that has doing 3-Dimensions, which represented weight factor for a sphere that based influence on their point distance to form point pattern of

Radon gas concentering estimation, the kernel technique equation is, (12].

$$\lambda(x,y) = \frac{1}{nh^2}\sum_{i=1}^{n} \kappa \frac{(x_i,y_i)}{h} \quad \ldots, (5)$$

Where;

λ(x, y) is a density of the point pattern location (**x_i, y_i**) is the observed at *ith* points, ***k*** is the kernel weighting value function, ***h*** is the sigma or bandwidth, and ***n*** is number of events (points). The functions simplest of the kernel density is sophisticated forward to easy target function, which able estimation point pattern intensity λ(x, y) is representing circle centered at point density location that can be estimating, (13]. Mathematically, this case is compute;

$$\lambda(x,y) = \frac{no.[S\in C(\boldsymbol{P},r)]}{\pi r^2}\,\mathrm{S} \quad \ldots, (6)$$

Where

The number of points pattern ***S*** to be related to C (***p***, *r*), a circle of radius ***r*** centered at the point pattern location is represent ***P***, shown figure 6.

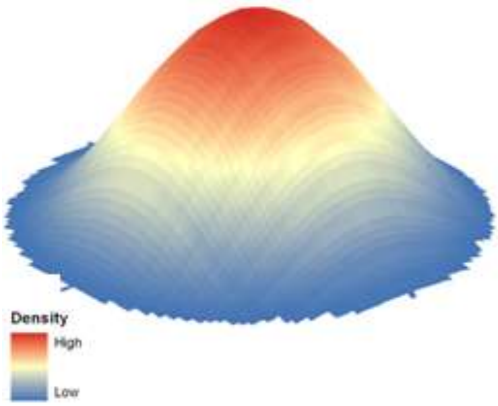


Figure 6. Illustration, 3-Dimensions of Kernel Density Estimation (KDE) technique derive from 2-Dimension currently, (14).

The value in equation (πr^2) represented the circle area. Pictorial continuous surface at all a study area, the surfaces may be using also to moderate density functions to a sum variety of local sample density.

Density estimation

It is processing appraisement the density distribution for data n-Dimension stretched continuous surface smoothing, and to make a condition testing nonparametric from any point arrived a target confirmation KDE technique, and performance the shape has interesting geographic concentration aggregation. Manually to choice adjustment bandwidth avoid point redundant to reduce the space of n-Dimension and roughness surface, in figure 7, illustration the method use GIS programming to extract variable (choose distance manually), (15).

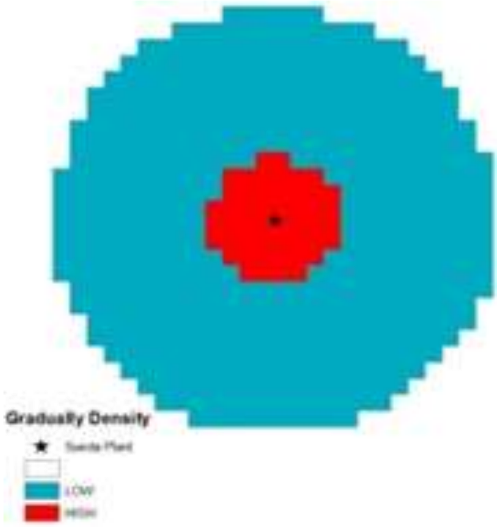


Figure 7. Illustration, Density Estimation for Radon gas location in 2D, which is representing density distribution function, and can be reducing n-dimensional spaces, (15).

Bandwidth (sigma) kernel density estimation

The base employee the kernel density estimation by chosen various bandwidth on spatial point platform using adaptive bandwidth for data value each discrete surface case, such as Radon gas concentration pollution, the notice this case, if the small area extended the point densities impact forward a high or small, that depend on chose number of bandwidth for any case, requirement decided execute the target of search, (16), see figure 8.

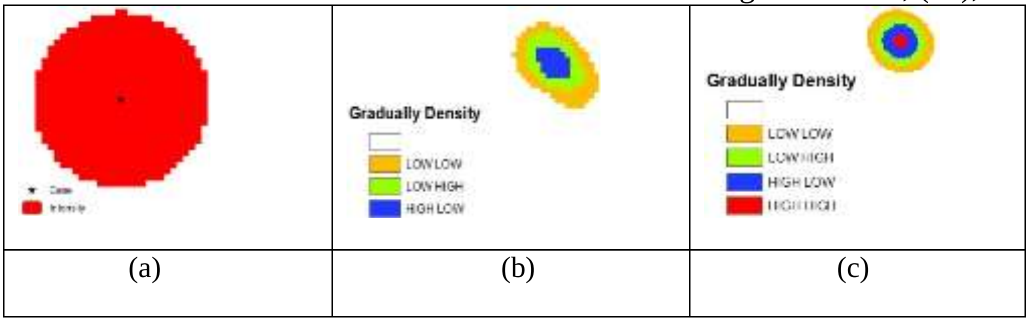


Figure 8. Illustration, (a) the circle surround the spatial point (case) marked black star in circle center, (b) and (c) choose two cases of point density surface, which represented two type bandwidth (sigma= 1 to 3 km^2) consecutively, (17) and (1).

The adaptive processing is calculated as follows;

$$f(x,y) = \sum_{i=1}^{n} K\left(\frac{d_i}{p(u,v)}\right) \quad \text{... (7)}$$

Where

$p(u,v) = nh^2$, represent bandwidth; This study uses a simple form

There are vary choose for K function;

$$\begin{cases} K\left(\frac{d}{h}\right) = \left(1 - \frac{d^2}{h^2}\right) if\ d < h \\ K\left(\frac{d}{h}\right) = 0\ otherwise \end{cases}$$

The influence case will harmony to another. For bandwidth obtained optimal results, that can use this equation;

$$h_{opt} = \left[\frac{2}{3n}\right]^{\frac{1}{4}} \sigma$$

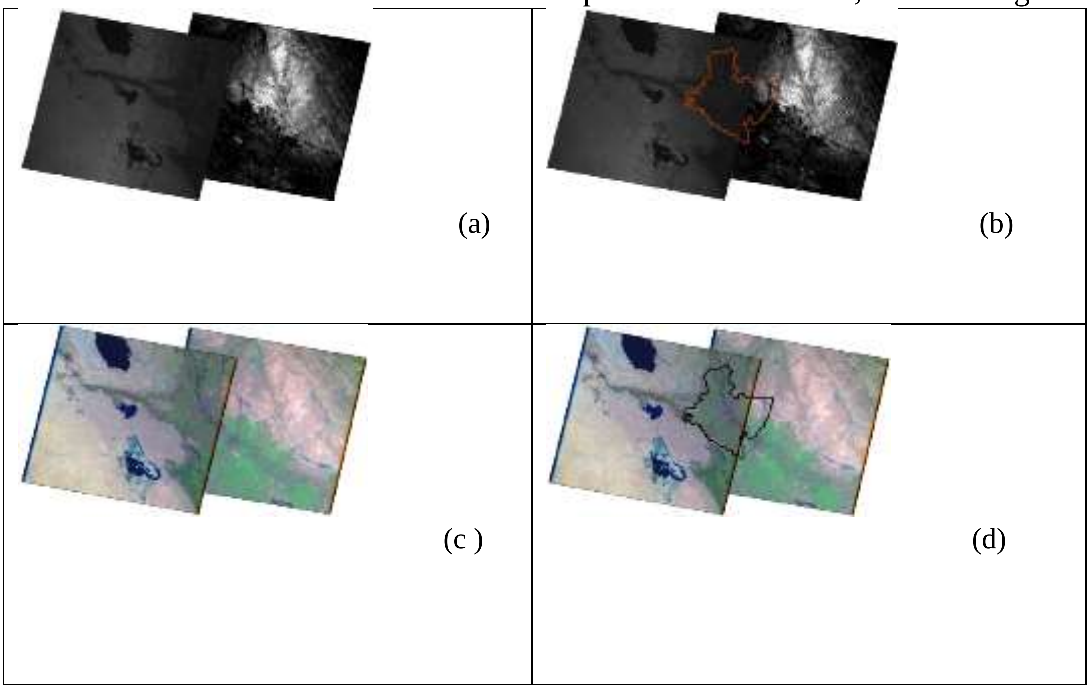
Where

$\boldsymbol{h_{opt}}$ optimal bandwidth

$\boldsymbol{n}$ number of samples and $\boldsymbol{\sigma}$ standard deviation, (17).

RESULTS AND DOSCUSSION

In this search using remote sensing techniques in order to finding and monitoring the change of landcover and landuse for Baghdad city influence on release Radon gas concentration pollution distribution, shown in figure 9.



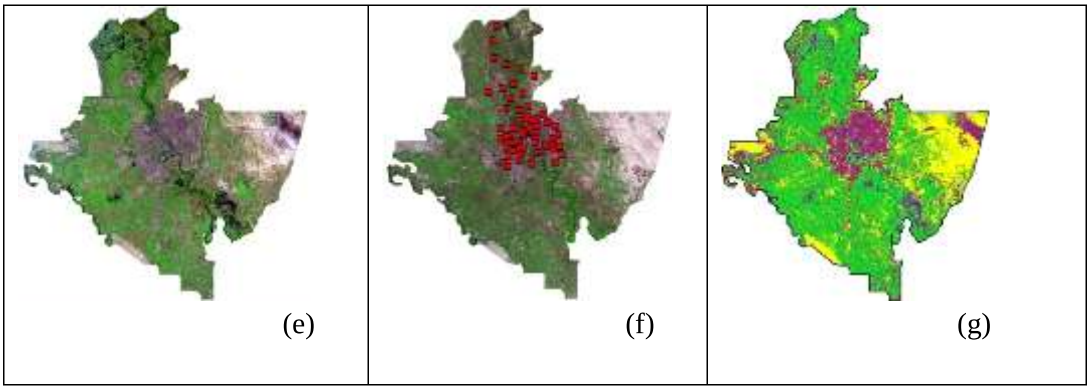


Figure 9. Illustration. Using remote sensing techniques, by apply landsate satellite imagery ETM+ producing 21\8\2017, (a) and (b) manipulation the dataset and processing, using many bands (NIR+RED+GREEN) produce physical scene representing the study area (Landcover, Landuse), (e), (f) and (g) classification types show the features base of Baghdad city and drop the point pattern of Radon Gas concentration.

Classification supervisor type process to find elementary of Baghdad city features which can be exposure the Radon gas concentration and finding proportion for each feature, shown figure 10 and table 3.

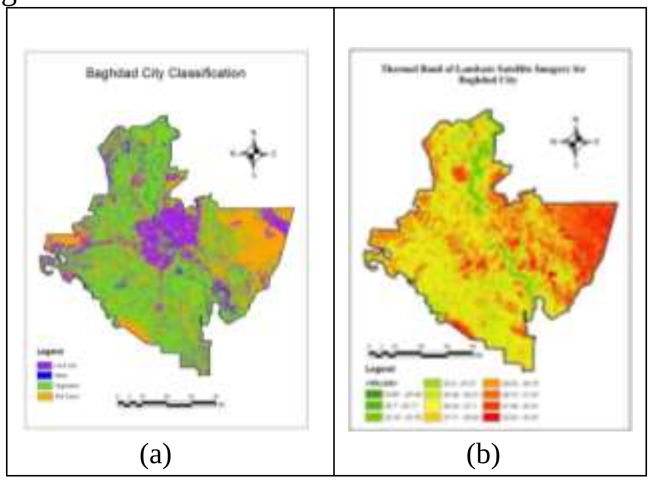


Figure 10. Illustration, (a) classification supervisor for study area show fundamental of features (Landuse, Vegetation, Water and Soils Type, (b) using Thermal Band show various temperatures degree at all Baghdad area.

Table 3. Illustration, compute statistical of feature types for Baghdad city using Landsate satellite imagery analysis producing 21\8\2017

NO	Study Area Features Type	Sum Area km^2	Number of Pixel	Mean center	Standard Deviation
1	Land Use	1137.37	126373	9487.5195	1099.1
2	Water	70.76	78631	5329.73	199.01
3	Vegetation	2874.23	319247	8899.5898	1059.41
4	Soil Types	1139.87	126652	11771.2	1434.32

In this search, spatial patterns of radon gas study region at continuous area closely apply normalizing kernel densities technique by using experiment density to compute bandwidth (sigma) per area basis. Then, hypothesize here choose different radii value (bandwidth) for determine of suitable density visualization such as 1250, 1750, 2250 and 2750 meters by choosing 500 meter for any high stage, shown figure 11.

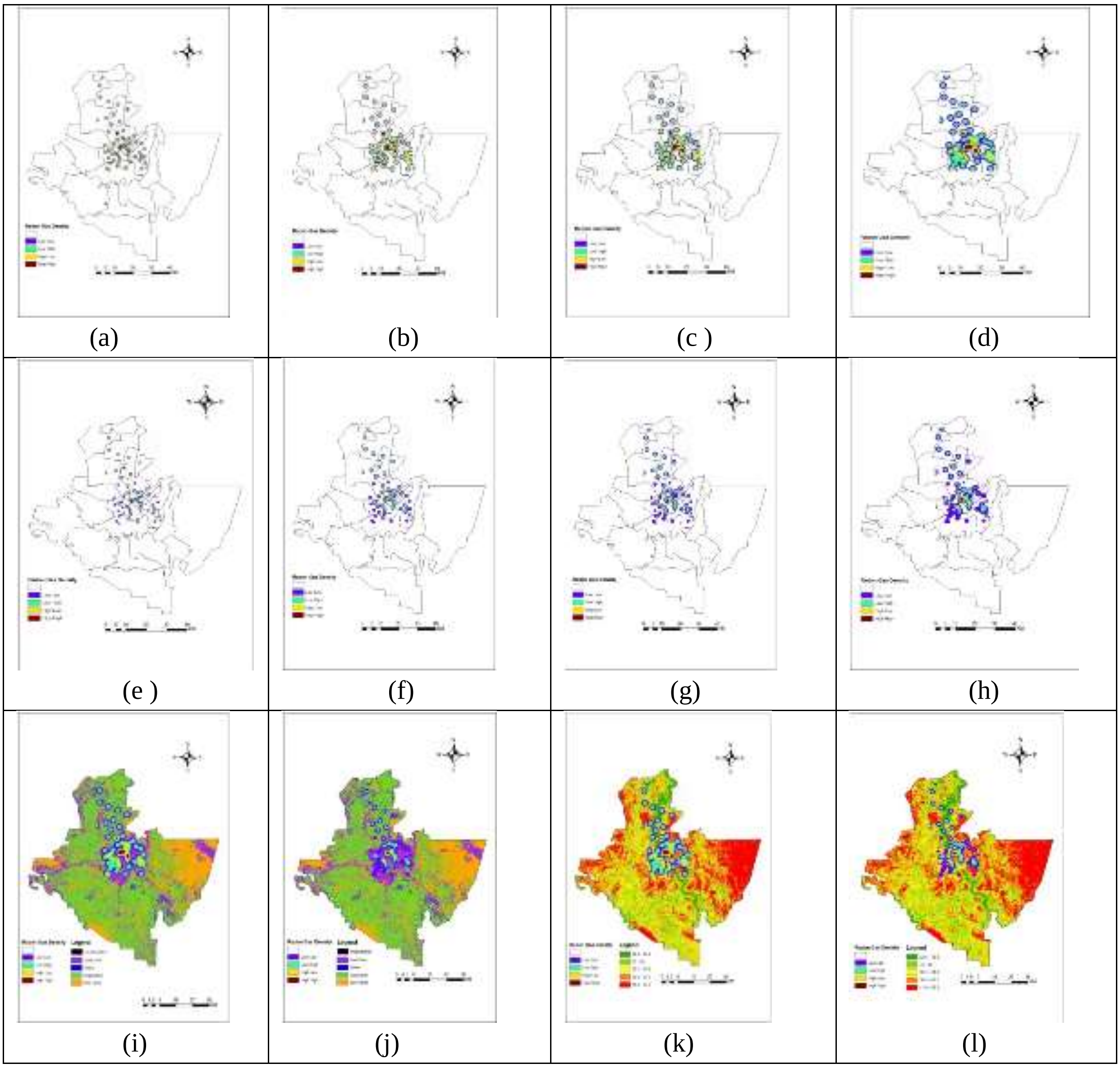


Figure 11. Illustration, different bandwidt using at study area of sigma equal to 1250, 1750, 2250 and 2750 meters respectively, they determined acoording to the points location and points concentration. (a, b, c and d) represente kernal density by using points location, (e, f, g and h) represente kernal densit by using points concentration and (I, j, k and l) represente kernal density on landsate setellite imagery analysis of classification and thermal band for study area.

In figure 11 (a), whene used ArcMap version 9.3 by applied the kernal function tool for study area choice segma equal to 1250 meter first, which represent the distance for each point to neighboore points and observe density chanch in miore shape that conceder the density majore release for any stage (one segma) increased by 500 meters concequently. For arrived to satisfy attainment of idea for Radon concentration distributions as the figure 11 (a) and (e) considered the locations and concentration of points pattren. For obtainment the 3-D continuous surface area might increase the bandwidth several time with 500 meters, show in figure 10 (b), (c), (d) and (f), (g), (h). In figure 11 (i), (j), (k) and (l) illustration the kernal technique application on landsate satellite imagery classifigation for compose in band ratio processing (4, 1, 2, and 3) band and thermal band was processing adjustment to celiluse temperatures for study area. In this study, the choice soils sample location of radon gas concentration according to a place election by using RAD_7 Detector system and they are several measured for each place and extraction points average at less three measuring, then seek of soils type that measured differential of environment for any feature (land use (human activity), water, soil and vegetable) which represent all study area, finding, high concentration of radon gas as measured 185 in Al-Taji district place which all most represented rural region that caused wrong fertilization of arable land for phosphate compound. And lowest concentration measuring was 44 in landuse places, but finding contrast measured in features of study area that discover by using point pattern analysis distribution by apply kernel density estimation, which finding high density in feature of landuse place that neighbor distance of points location more than points concentration, illustration in figure 11 (i) and (j), and density process of points pattern remain would take the density around the same any alone point with last distance which measurement estimated 2750 meters, while, finding two or three points will be contribute the same density if they are inner last distance measuring. All of the processing aiding controlled hazard arising from release radon gas distribution such as lung cancer and deformation of physique, addition to determine and knowledge the radon gas pollution. We can detected relationship the density release of radon gas concentration with some weather factors as temperatures degree, illustration in figure 11 (k) and (l), because of material decay which release radon gas and emitted which cause erosion factors that is development at nature works.

REFERENCES

1. Fouad K. M. Al Ramahi and, Z. K. I. Al Bahadly, 2017, Estimation of *Suaeda aegyptiaca* Plant distribution regions at Iraq using RS & GIS Applications, Iraqi Journal of Science, 58 (2A): 767-777

2. Khalid H., L. L., 2006, Estimation the spatial-temporal distribution of Radon releases from the K-65 silos, International Journal of Risk Assessment and Management, 6 (4-6): 1-2

3. Ola A. I., 2018, Determination of Radon Pollution Regions in Baghdad City Using Remote Sensing and Geographic Information System, Requirements for the degree of M.Sc. in Physics (RS&GIS), University of Baghdad, College of Science, Department of physics.

4. Saleh. M. A and F. K. Mashee, 2015, Analyzing the Terrorist Operations in Baghdad Using the RS and GIS Techniques, International Journal of Science and Research (IJSR), 3 (11): 346-351

5. M-pastor, J. N-Navarro, I. G. and M. B. A-Candel, 2011, The use of remote sensing to locate heavy metal as source of Pollution, 7 (1): 225-233

6. Saeed A. D. and R. Ilic, 1997, Radon Measurements by Etched Track Detectors: Applications in Radiation protection, Earth Sciences and the Environment, Editor book, world scientific Amason.com: 20-21

7. Selen A., E. T. Gormus and M. Ekinci, 2018, An efficient pan sharpening via texture based dictionary learning and sparse representation, observations and Remote Sensing Journal , PP (99): 1-13

8. Joseph W., N. E. Malasavage, 2004, Spatial Analysis for Identifying Concentrations of Urban Damage, InTech Europe University Campus STeP RiSlavka Krautzeka 83/A 51000 Rijeka, Croatia

9. Ratcliffe, J. H. and M. J. McCullagh, 1999. Hotbeds of crime and the search for spatial accuracy, Journal of Geographical Systems, 1 (4): 385-398

10. Saleh. M. A. and F. K. Mashee, 2014, Analyzing the terrorist operations in Baghdad using the RS and GIS techniques, International Journal of Science and Research (IJSR), 3 (11): 346-351

11. Plug, C., J. Xia and C. Caulfield, 2011, Spatial and temporal visualization techniques for crash analysis, Accident Analysis and Prevention, 43 (6): 1936-1947

12. Gatrell, A. C., T. C. Bailey, P. J. Diggle and, B. S. Rowlingson, 1996, Spatial point pattern analysis in geographical epidemiology, Transactions of the Institute of British Geographers, 2 (1): 256-274

13. O'Sullivan, D. and, D. J. Unwin, 2003, Geographic Information Analysis, editor book, John Wiley & Sons Inc., 0-471-21176-1, Hoboken, New Jersey

14. Silverman BW, 1986, Density estimation for statistics and data analysis, Editor book, Chapman and Hall, London; New York, pp: 98-111

15. Donald B., J. Dalton, and H. Hoyle, 2004, Spatial forecast methods for terrorist events in urban environments, Springer Verlag Berlin Heidelberg, LNCS 3073: 426–435

16. Shi X., 2009, A geocomputational process for characterizing the spatial pattern of lung cancer incidence in new hampshire, Annuals of the Association of American Geographers, 9 (9): 521–533

17. Waller LA, CA. Gotway, Applied spatial statistics for Public Health Data, Hoboken, N. J. John Wiley & Sons; 2004

18. Fotheringham A. S., C. Brunsdon and M. Charlton, 2000, Quantitative geography perspectives on spatial data, Sage Publication, GIS Module Library Documentation, 2 (13): 270- 275.