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# GIS applications in science and engineering research: Case study of the Graduate College University of Khartoum

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**Abstract:** New trends and developments in science and research urged not less than many disciplines, such as science and engineering, to revisit their methods and practices to become more IT-oriented and spatially referenced by using Geographical Information Systems/Science (GIS). GIS, as a geo-technology/science, is one of the most growing three professions in the recent decades besides bio and Nano technologies. Currently, universities and enterprises, to inject advanced spatial analysis and modelling methods and tools in their disciplines and projects, are increasingly demanding GIS. GIS integrates hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. The technology works on different levels and sizes of databases and uses various types of tools and models to obtain results usable in research, applications and decision support. This paper aims first at previewing the different practices and applications of GIS and related geo-technologies in science and engineering research. With some examples from the literature, this paper will explain where and how GIS tools are applied. The tools and operations may include spatial statistics, spatial modelling, mapping and tracking, geo-referencing and geo-coding, digital elevation modelling (or 3-D analysis) and network analysis. The second objective of this paper, however, is to urge and draw attention of graduate and research students in science, engineering and environmental fields in University of Khartoum to the application of spatial technology in their thesis' works. As thesis topics are varying, the use of GIS technology data management, spatial analysis and result presentation, will no doubt, develop and improve the graduate's studies and practice in these vital fields for better living conditions and sustainable development in the Sudan. To achieve its objectives, the paper relied on data from Basic Sciences and Engineering Studies Board (BSESB) master and doctoral theses and abstracts during the period 2000-2011. In addition, applications published in relevant professional journals, web sites, symposia, engineering solution firms, and consulting agencies are examined. Results show that a few postgraduate researches in the University of Khartoum have used GIS and spatial technology and analysis in the field of science, engineering and environmental studies during the period. The reasons are many. They include, to mention some, unawareness, incapability, or lack of concern by the postgraduates about this very vital geo-technology and its spatial analysis and modelling functions.

**Keywords**: GIS technology, basic science, engineering, environmental studies, spatial data, spatial modelling, graduate studies

مستخلص: حثت الاتجاهات الجديدة والتطورات العامية الحديثة العديد من العلوم والتخصصات بما فيها العلوم الأساسية والهندسية والبيئية على مراجعة مناهجها وممارساتها البحثية والادوات المستخدمة خاصة فيما يتعلق بالمعلوماتية والتحليل والنمذجة المكانية. بلغ ذروة هذه التوجهات تعلم واستخدام نظم المعلومات الجغرافية وعلومها (*GIS*) وبناء قواعد بياناتها المكانية. وتعد تقنية نظم المعلومات الجغرافية المتطورة إحدى الثلاثة اخناصات ، إلى جانب التقنيات الحيوية والنانوية، الأكثر احتياجا واستخداما وفقا لتقرير سابق لوزارة العمل الأمريكية. حاليا، تتبنى العديد من الجامعات والشركات برامج تعليمية وتدريبية متسارعة لادخال مناهج التحلل المكاني وطرقه والنمذجة المكانية وأدواتها المتقدمة في مناهجها وبرامجها ومشروعاتها. تعمل هذه النظم عى دمج البنى الجهازية والبرامجية والبيانات والخطط من خلال تحصيل البيانات وادارتها وتحليلها وعرضها في إطار المرجعية الجغرافية أو المكانية. تعمل هذه التقنية على مستويات واحجام متعددة من قواعد البيانات وتستخدم أدوات ومناهج ونماذج تحليلية مكانية كثيرة تساعد على معلومات ونتائج تستخدم في البحوث والتطبيقات ودعم القرار. تهدف هذه الورقة، أولا، إلى عمل مراجعة واستعراض عام لاستخدامات وتتطبيقات نظم المعلومات الجغرافية ورصيفاتها من التقنيات الجغرافية في دراسات العلوم الأساسية والهندسية والبيئية. كما تسعى الورقة، باستخدام بعض الأمثلة من المنشور، إلى توضيح أدوات مجالات وكيفية الاستخدام والتطبيق. وتشمل الأدوات والعمليات التطبيقية، على سبيل المثال، الاحصاء المكاني والنمذجةالمكانية وإعداد الخرائط والربط المرجعي المكاني والعنونة والنمذجة الارتفاعية (المجسمة) وتحليل الشبكات. أما الهدف الثاني لهذه الورقة البحثية فيرمي إلى حث طلاب الدراسات العليا في مجال العلوم الأساسية والهندسية والدراسات البيئية بجامعة الخرطوم وترغيبهم في استخدام هذه التقنية والمنهجية المتطورة في انجاز رسائلهم العلمية وأعمالها. وبما أن موضوعات هذه الرسائل متعددة ومتباينة فإن استخدام تقنيات وعلوم نظم المعلومات الجغرافية المتمثلة في والتحليل المكاني و إدارة البيانات وعرضها، ستؤدي بلا شك إلى تحسين وتطوير هذه الدراسات ورسائلها لفائدة الجامعة والمجتمع. ولنحقيق هذه الاهداف، اعتمدت الورقة على بيانات رسائل الماجستير والدكتوراه ومستخلصاتها في مجالات الدراسات الأساسية والهندسية والبيئية التي قدمت للاجازة في جامعة الخرطوم في الفترة من 2000م و2011 م. كما فحصت ،إضافة، المنشور في تطبيقات نظم المعلومات الجغرافية في العلوم الأساسية والهندسة والبيئة في الدوريات والمواقع والملتقيات ومؤسسات وشركات الحلول والاستشارات الهنسية المتخصصة. وتشير الدلائل إلى قلة الرسائل العلمية التي انتبهت لهذه التقنية المتطورة واستخدمتها واستفادت منها في ذات الفترة بالنسبة للدراسات الأساسية والهندسية والبيئية. الأسباب متعددة ولكنها تشمل في بعضها عدم الاهتمام أو عدم الالمام بأهمية نظم المعلومات الجغرافية وقدراتها، وعدم السعي إلى اكتسابهامعرفيا وتقنيا.

**كلمات مفتاحية:** نظم المعلومات الجغرافية، الدراسات الأساسية والهندسية والبيئية، رسائل الماجستير والدكتوراه، التحليل المكاني والنمذجة المكانية

## 1- Introduction:

Geographical Information Systems/ Science (GIS) integrate hardware, software, and data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. The technology works on different levels and sizes of databases and uses various types of programs and software. Spatially, the technology can help in answering questions (queries) about location, occurrence, adjacency, and reason of happening "if", in addition to mapping, integration of information, visualization scenarios, and handling complex issues and develop effective solutions for the process of decision and operation support (Burrough, 1986); (Maguire *et al*, 1993).

The new trends and rapid developments in research and spatial technologies, have urged many disciplines including basic sciences, engineering and environmental studies, to revisit their methods and practices to become more information technology-oriented and spatially referenced by using GIS (Fotheringham and Rogerson 1993). Moreover, GIS, as a geo-technology /science, is one of the most growing three professions in the recent decades besides bio and nano technologies, (Gwen, 2004)

With regard to current changes, developments and hot environmental issues in the world, research in science and engineering is becoming very vital and rather complex. Epistemologically, Science deals with the understanding and explanation of the real world (black box -white box modelling), while engineering works to develop solutions to man-real-world problems using scientific explanations and laws about the real world (Abler, *et al*, 1971)

In such complex and difficult to understand man-real-world relationships and interactions, GIS and remote sensing have become actual and potential tools for many science and engineering branches and applications. GIS is widely used to generate applied models by integrating the information about real world with those about natural resources, demographic and socio-economic data. The tools used include spatial statistics, spatial modelling, geo-referencing, geo-coding, digital elevation modelling (or 3-d analysis) and network analysis. Applications in the area of engineering and basic sciences include, for example, housing, sanitation, power, water supply, urban growth, irrigation, highway and road alignment etc. (Benenson and Torrens, 2004).

GIS is frequently labeled as an enabling technology that focuses with analysis on spatial relationships and interactions. Spatial analysis has arisen with the early attempts at cartography and surveying, but many fields have contributed to its second rise in modern form. In science, biology contributed through botanical studies of global plant distributions and local plant locations, ethological studies of animal movement, landscape ecological studies of vegetation blocks, ecological studies of spatial population dynamics, and the study of biogeography. Epidemiology contributed with early works on disease mapping, while statistics has contributed greatly through applications of spatial statistics.

GIS, however, is currently presenting itself as a major player, thanks to the advancing position and importance of geospatial systems in modern analytic tool chain. Remote sensing, as a spatial observation technology, has contributed extensively to morphometric and clustering analysis. Computer technology and

science has contributed extensively through the study of algorithms- notably in computational geometry. Vital to GIS development and modelling, mathematics continues to provide fundamental tools for analysis and modelling (simplification and abstraction) of the complexity of the spatial realm, i.e. with its work on fractals and scale invariance. Scientific modelling provides a useful framework for other approaches (Wikipedia, 2016; Fotheringham and O'Kelly, 1989).

Environmental research, impact assessment, planning and management have grown increasingly reliant on computer-based approaches in the past few decades. GIS, remote sensing, dynamic-simulation modelling and statistics, for example, are utilized in a variety of scientific and professional endeavors, ranging from forestry, landscape mapping and watershed ecology to archaeology, pollution detection and geology. Universities and enterprises are currently demanding GIS for advanced spatial analysis and modelling in many disciplines and projects.

**2- Spatial Analysis and Modelling in GIS:**

A GIS is a technological tool for comprehending geography and making intelligent decisions. GIS application relies on what is called the *Geographic Approach* which describes a high-level vision for using geospatial technology as a key method in finding answers to problems. The approach involves five steps that ask, acquire, examine, analyze and act. In this manner, many problems such as climate change can be considered as geographic problems (Dangermond and Artz, 2008). As regards to space itself, a mathematical space exists whenever we have a set of observations and quantitative measures of their attributes. In spatial analysis, we are concerned with specific types of mathematical spaces, namely, geo-spaces. A geo-space is one where the observations correspond to locations in a spatial measurement framework that captures their proximity in the real world. Hence, GIS application relates to fundamentals of the geo-space and its spatial components, relationships and interactions. Central to the application of GIS is spatial analysis and spatial modelling. Spatial Modelling is an analytical procedures applied with a GIS (geometric, coincidence and adjacency models). Spatial analysis, on the other hand, refers to the formal techniques used in various fields of research, which study entities using their topological, geometric, or geographic properties (Wikipedia, 2011) Table (1).

Spatial analysis varies depending on the approaches and goals of the large number research involved, techniques and data used. Fundamental to spatial analysis is common errors often arise due to the mathematics of space; the ways data are presented spatially, and the tools, which are available (Wikpedia, 2011). When results are presented as maps, the presentation combines the spatial data which is generally very accurate with analytic results which may be grossly inaccurate. Respectively, spatial analysis faces many fundamental issues such as spatial characterization, spatial dependency or auto-correlation, scaling and sampling. (Fotheringham e*t al* 1989; Fotheringham, 1993; Abler, 2004; Miller, 2004)

Table (1) GIS (static and dynamic) can offer different levels of sophistication for spatial analysis and modelling

| No | GIS Task-Operation | spatial solutions Fields |
|---|---|---|
| 1 | spatial data manipulation or classic GIS capabilities (spatial queries & measurement, buffering, map layer overlay-raster/grid analysis etc ), | Civil engineering transportation, water resources, facilities management, urban planning, construction and E-business, environmental information systems, natural resources management, irrigation an and modelling, pollution monitoring, environmental impact studies, terrain visualization and geospatial database infrastructure, soils, hydrology, and vegetation to, wildlife habitat needs, restoration of degraded ecosystems and land and resource management. |
| 2 | spatial data analysis or descriptive and exploratory GIS (visualization through data manipulation and mapping) | |
| 3 | spatial statistical analysis (geostatistical analysis tools) and spatial modelling and prediction of processes and patterns (surface analysis, network analysis, point pattern analysis, single/multi-layer modellng, fuzzy spatial analysis) | |
| 4 | General: (a) links observations and measurements to specific locations and specifies the relationships, actual or inferred, between data points; (b) handles different data types and allow quantitative analysis of information; (c) integrates remotely sensed images with data collected traditionally such as field surveys of vegetation patterns and water quality measures and; (d) Extrapolates from limited sample locations to larger areas | |

Source: Based on ([7] Bansal, 2007).

Spatial analysis is used in many fields of study to assess causal relations and understand patterns. Spatial analysis typically can be performed in one of three approaches: Inductive (examines evidence in search of spatial patterns), deductive (testing known theories against observational data) and normative (develop or prescribe new designs and their potential impact). Understanding the spatial distribution of data from phenomena that occur in space constitutes today a great challenge to the elucidation of central questions in many areas of knowledge, be it in health, in environment, in geology, in agronomy, among many others**.**

Types of spatial analysis may include spatial autocorrelation (statistics measure and analyze the degree of dependency among observations in a geo-space), spatial Interpolation (methods, such as kriging, estimate the variables at unobserved locations in geo-space based on the values at observed locations), and spatial regression (methods capture spatial dependency in regression analysis). Other types of spatial analysis include spatial interaction (or gravity models estimate the flow of people, material or information between locations in geo-space) and; simulation and modelling (alternative modelling perspective representing the system at the highest possible level of disaggregation, and study the bottom-up emergence of complex patterns and relationships from behavior and interactions at the individual level Table (2).

Modelling, i.e. scientific modelling is the process of generating abstract or conceptual models. Science offers a growing collection of methods, techniques and theory about all kinds of specialized scientific modelling. Some general theory about scientific modelling is offered by the philosophy of science, the systems theory and new fields like knowledge visualization (Wikipedia, 2016). Spatial modelling is the Analytical procedures applied with a GIS. There are three categories of spatial modelling functions that can be applied to geographic features within a GIS: 1, geometric models, such as calculating the Euclidean distance between features, generating buffers, calculating areas and perimeters; 2, coincidence models, such as overlays; and 3, adjacency models (pathfinding, redistricting, and

allocation). All three model categories support operations on spatial data such as points, lines, polygons, tins, and grids

Table 2: Types of Spatial Analysis

| No. | Type | Type |
|---|---|---|
| 1 | Spatial autocorrelation | statistics measure and analyze the degree of dependency among observations in a geo-space |
| 2 | Spatial Interpolation | methods, such as kriging, estimate the variables at unobserved locations in geo-space based on the values at observed locations |
| 3 | Spatial regression | (methods capture spatial dependency in regression analysis |
| 4 | Spatial interaction | spatial interaction (or gravity models estimate the flow of people, material or information between locations in geo-space |
| 5 | Simulation and modelling | alternative modelling perspective representing the system at the highest possible level of disaggregation, and study the bottom-up emergence of complex patterns and relationships from behavior and interactions at the individual level |

Sources: (Wikipedia, 2011), O'Sullivan, D. and D. Unwin (2002).

**3- GIS applications in basic sciences and Engineering:**

Basic sciences research covers a wide range of fields such as mathematics, chemistry, biology, physics, geology and botany. On the other hand, fields of engineering cover areas of research in civil, mechanical, chemical, electrical, electronics, telecom, bio and agricultural engineering.

The good use and application of GIS in these areas of research in science and engineering would not be possible without understanding the fundamentals of the geo-space and its spatial components, relationships and interactions. This will maximize the use of GIS from a mere mapping tool to analytical and modelling engine of the spatial effect in science and engineering. However, GIS is methodologically and technically enabled to offer procedure and analytical tasks that are particularly useful for spatial analysis such as:

a) Single layer operations
b) Multi layer operations/ Topological overlay
c) Spatial modelling
d) Geometric modelling
e) Calculating the distance between geographic features
f) Calculating area, length and perimeter
g) Geometric buffers.
h) Point pattern analysis
i) Network analysis
j) Surface analysis
k) Raster/Grid analysis
l) Fuzzy Spatial Analysis
m) Geostatistical Tools for Spatial Analysis

Matthew C. Redmond, President and CEO The TSR Group Inc. considers GIS as an approach that transforms the traditional engineering design project lifecycle by synthesizing drawing data, planning applications based on ESRI's ArcGIS and ArcSDE software, design workflows and methodologies, and applying this approach creatively to the existing process. The result is a centralized and organized data store that may be distributed quickly, efficiently and digitally to reduce project costs and duration (Bansal, 2007).

Many engineering solution firms use GIS and geospatial technology in research and other related activities such as inspection, analysis, design, construction supervision of new structures, and rehabilitation of existing facilities. In dam-reservoir/flood storage engineering services, spatial methods and tools offered by GIS have been used in feasibility studies, hydrological and hydraulic analyses, detailed design, construction supervision, flood assessments, dam safety inspections, quantitative risk analysis, inundation mapping, *dambreak* analysis, emergency planning and dam remedial works.

Elsewhere, the U.S. Army Corps of Engineers uses GIS, for example, for complete analysis of category 5 hurricane

protection. The Corps of Engineers scientists determined potential surge and wave elevations for both frequent and infrequent events based on critical factors, such as wind speed relationships, central pressure, forward speed, and landfalling location. At the Corps' center, in Florida, GIS specialists work with research scientists to create databases, develop map layers, assess data relationships, and design predictive modelling methods. Data from contributing agencies' databases and remote data, such as lidar, are input into GIS, which completes calculations and creates data visualizations on an intelligent map.

Data can also be run in models. For example, the team used GIS to visualize the Advanced Circulation Model for coastal circulation and storm surge that outputs maps for analyzing hurricane surge and flooding events. Data from various sources, such as the National Hurricane Center, was downloaded to the model. Then the team used GIS to generate situation maps. Output reflected a variety of factors used to predict how often and how severely the region could expect to be inundated during future hurricanes.

Reviewing GIS use and application in Postgraduate Theses anchored at Massachusetts Institute of Technology's (MIT) *Dspace* (2003-2010), some areas of research such as water distribution system, household water treatment… etc., have used or approached GIS and its spatial analysis stronghold (MIT Dspace).

*A GIS was* applied *in* transportation planning study in Riyadh City, the capital of Saudi Arabia. Specifically, the study used GIS to identify deficient facilities (i.e., tolerable, moderate, moderate to heavy and heavy road deficiencies) in the vital area within Riyadh's Ring Road. The deficiency analysis process is utilized to highlight streets where demand exceeds capacity. The link volumes, resulting from the travel demand forecasting, were incorporated into the network attribute table in GIS. For the short range planning, the study aimed to illustrate how GIS can be used in identifying projects on the network using dynamic segmentation, and preparing network link tables for travel demand planning. Moreover, the integration of GIS into the travel demands analysis process intended to identify future areas of congestion. Shortest path and travel time allocation of major activity centres analyses are also investigated (Alterkawi, 2001).

GIS applications in biology, as a basic sciences, and ecology include, among many, analysis of habitat protection and habitat changes over time. The spatial technology and science can help also in species tracking and identification of migration patterns and track encroachment of invasive species. As for GIS-environmental applications, attention should be given to the type of connection established between the environmental model and the GIS software. In addition, the type of GIS software used is a concern.

Documenting earlier efforts in GIS applications and integration to various models, Tim and Jolly (1994) present an overview of three types of model interfaces possible with GIS (Figure -1). Their paper describes the three levels of integration as 1) ad hoc integration, 2) partial integration, and 3) complete integration. In the first level, the GIS data structure and environmental model are developed independently. The data is extracted from GIS, the model run separately, and the output analyzed at the

user's discretion. The second level results in GIS playing more of an integrated role in the modelling. GIS supplies the data and then accepts the modelling results for processing and presentation. The third level consists of complete model development within the GIS software. The user has a single operating environment, where the data stored in the GIS is structured to meet the demands of the model and vice versa.

The author would like to note that there are, since 1994, unprecedented development if numerous types of GIS software that offer special software extensions and programming and model builders, and that is just a tip of an iceberg (professional and popular GIS websites, groups, publications and newsletters).

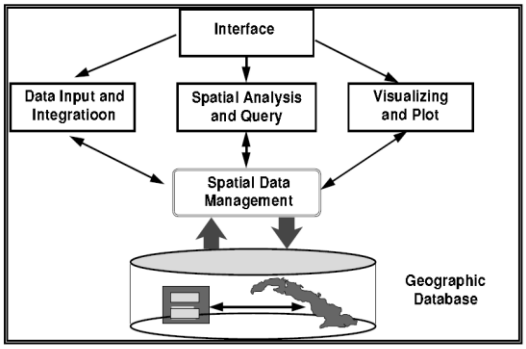


Fig (1): the architecture and components of a GIS
Source: (Tim and Jolly, 1994).

**4- Hypotheses and objectives:**

A few master and PhD theses examined at the Graduate College U of K used GIS and related spatial technologies as an analysis method or a tool. Several reasons including unawareness, incapability, or lack of concern by the postgraduates about this GIS and its spatial analysis and modelling functions hypothesized. Accordingly, objectives were defined to:

1- Review of practice and application methods analysis of GIS and related geo-technologies in fields of science, engineering and environmental research.
2- Review specifically, the use and application of these geo-technologies in basic sciences, engineering and environmental postgraduate studies in University of Khartoum during the period 2000-2011.
3- List and discuss the benefits, difficulties and the future of using the technology in postgraduate studies in the University of Khartoum.
4- Set recommendations in the benefit of GIS applications in future BESB postgraduate research.

**5-Data and analysis:**

To achieve these objectives, the paper relied on data from BSES Board theses records and abstracts from 2000 to 2011. Current GIS literature and applications availed from reputable spatial technology journals institutions and solution companies. As a member of the basic Sciences and Engineering Studies Board (BSESB) Board and a GIS specialist, the author's experience in GIS learning, teaching, supervision, research, training and consultancy in relation to universities in home, Scandinavia, Arabia was accompanied (as a participant observer). The ESRI, world largest GIS developer and vendor, web contents and publications (Arc news, Arc Users) were examined. Proceedings and publications of the National GIS Symposia in Saudi Arabia were reviewed. Recent developments and applications of GIS from public and private engineering institutions and firms, in addition to GIS client enterprise experience in the internet were assessed (ESRI 2016) (National GIS Symposia KSA, 2015).

**6- Results and future of GIS applications in research of G C- U. of K**

The results obtained by the study are presented in three folds including review and analysis of example GIS applications, GIS applications in (BSESB) U. of K postgraduate research and the analysis of current and future GIS applications in fields of research within basic sciences and engineering.

The study performed a geographic statistical analysis of the data about graduate theses completed during the period (2000 to 2011) (Figures 2, 3, 4, 5, 6).

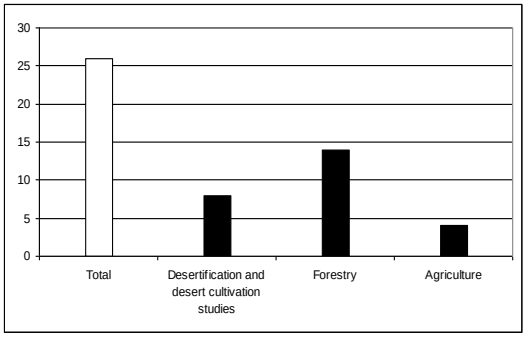


Figure 2: Theses examined from Agricultural and Veterinary Studies Board- Graduate College U of K.

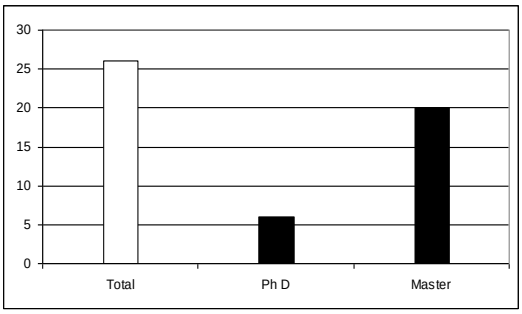


Figure 3: Number and types of theses examined- Graduate College U of K.

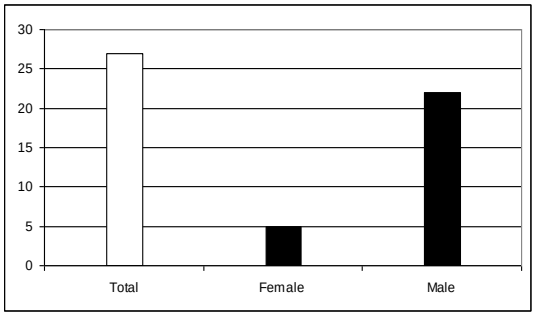


Figure 4: Number and gender of Students - theses examined- Graduate College U of K.

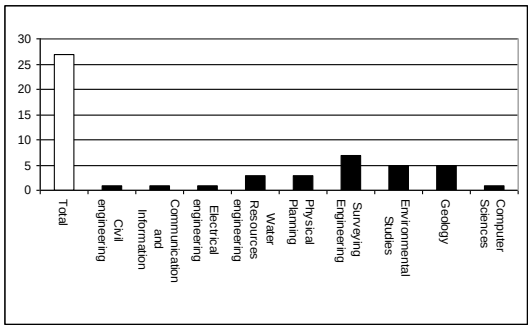


Figure 5: Research fields covered by theses examined.

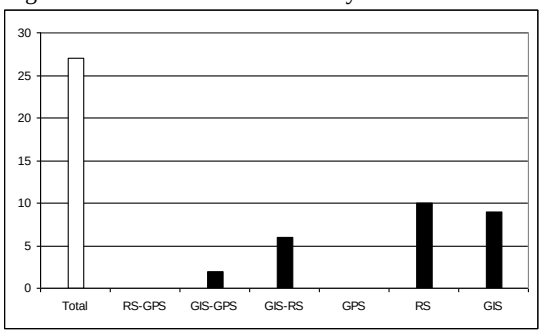


Figure 6: Number and Types of geo-technology methods and tools used by theses.

Results show that a few postgraduate researches in the University of Khartoum have used GIS and spatial technology and analysis in the field of science, engineering and environmental studies during the period (Figure 7).

The application of GIS and related geotechnologies in the postgraduate research of the board covered many faculties and departments including engineering (civil, communication and information systems, electrical, surveying and water resources), architecture (physical planning) and environmental studies. The specialties benefited from GIS are many. They include, for example, GIS models, remote sensing, datum transformation land registration land use planning, vehicle tracking and optimum route selection. In the field of architecture, they study issues in physical planning, greater Khartoum and land use/ land cover mapping. The environmental applications included environmental deterioration and changes, vegetation change and wildlife habitat. In

engineering, dams and Irrigation systems, seasonal water and flood simulation were researched. In basic sciences, geology, mineral exploration, groundwater and hydrogeological investigations were also tackled. Table (3) shows selected titles from thesis' lists in the board (BSESB). The studies were conducted in many areas in Sudan and abroad including Greater Khartoum, Merowe Dam Project, Gash River Basin (Kassala State), Gezira Scheme and Gezira area, Red Sea Hills, River Nile at Dongola in northern Sudan, northeastern Khartoum Basin, central Butana, Sudan. east of Jeddah Saudi Arabia, Rahad Scheme, Eastern Sudan, semi-arid regions in western Kordofan State-Sudan and Al-Radom National Park, southern Darfur (Tables 4, 5).

Table 3: Titles of selected theses used GIS in the field of BS and Engineering.

| **Specialization-Field** | **Thesis title** |
|---|---|
| Surveying Engineering-Datum Transformation | Evaluation of GPS Datum Transformation and GPS/GIS Integration. |
| Physical Planning- Land use Planning | Spatial Development in Land use Planning: References to Use of GIS-Technology: Case Studies of Central Khartoum - Sudan. |
| Surveying Engineering-GIS Mode | Developing A GIS Model for Greater Khartoum Based on Remote Sensing and Artificial Neural Network Techniques. |
| Surveying Engineering-Merowe Dam | Merging of Visual Modelling in GIS with Application to Merowe Dam Project. |
| Surveying Engineering-Optimum Route Selection | Optimum Route Selection for Linear Man-made Features Using GIS Analysis Techniques. |
| Communication and Information systems-Vehicle Tracking | The Application of GIS and GPS Technologies in Vehicle Tracking System. |
| Environmental Studies- Env. Deterioration | Investigation of the Environmental Deterioration in Delta Elgash Area (Kassala State) Based on GIS Techniques. |
| Water Resources engineering-Irrigation System | Monitoring and Operation of an Irrigation System Using GIS (Case of Gezira Scheme). |
| Water Resources engineering-Seasonal Water | Use of Space Technology and GIS in Seasonal Water Course System (Case of Gash River Basin). |
| Computer Sciences-Environmental Changes | Prediction of Environmental Changes and Chemical Impacts Based on Artificial Neural Networks and GIS. |
| Geology-Groundwater and Minerals | Image Interpretation and GIS Techniques in Mapping and Exploration for Groundwater and Minerals, Red Sea Hills, North Eastern, Sudan. |
| Civil engineering-Flood Simulation | A Flood Simulation Model for the River Nile at Dongola Using ANNs and GIS. |
| Environmental Studies-Groundwater | GIS Modelling and Hydrochemical Assessment of the Groundwater in the Gezira Area - Sudan |
| Geology-Groundwater | Application of Remote Sensing and Geophysical Techniques for Groundwater Exploration in Central Butana, Sudan. |
| Geology-Hydrogeological Investigations and Mineral Exploration | Applications of Remote Sensing in Geological Mapping Hydrogeological Investigations and Mineral Exploration in Red Sea Hills. |
| Environmental Studies-Vegetation Change | Detection of Vegetation Change of Khartoum Forests Using the Remote Sensing. |
| Water Resources engineering-Irrigation Water | Irrigation Water Management in the Rahad Scheme Using Remotely Sensed Data. |
| Surveying Engineering-Irrigation Water | Integration Remote Sensing and GIS for Land Use Land Cover Mapping Irrigation Water, Sudan (A Case Study). |
| Environmental Studies-Wildlife Habitat | A Contribution to the Assessment of Wildlife Habitat in Radom National Park based on Remote Sensing and Geographical Information Systems. |
| Remote Sensing | Remote Sensing of the Troposphere Using A Microwave Bridge. |

Source: GC-Uof K (2000-2011).

## 7- Conclusion:

Results show that a few postgraduate researches in the University of Khartoum have used GIS and spatial technology and analysis in the field of science, engineering and environmental studies during the period 2000-2011. The reasons were many. They include, to mention some, unawareness, incapability, or lack of concern by the postgraduates about this very vital geo-technology and its spatial analysis and modelling functions. Moreover, weak inter-faculty and inter-departmental research and supervision ties could have been one of the strongest

reasons that inhibited the surge of GIS application in the field of basic sciences and engineering within the University of Khartoum's Graduate College.

Finally, a quick recent (2017) search into the university *Dspace* signals considerable increase in GIS-tagged research within the fields focused by this paper.

**8- Acknowledgements:**

The author acknowledges the Graduate College for providing the data and statistics about the doctoral and master theses research documents.

Table (4): Review and Analysis of abstracts of the above tables

Table 5: BSEB GIS Applications and percentage

| Faculty and Field of research | Master | Ph. D | Total | GIS theses | % |
|---|---|---|---|---|---|
| Engineering | 544 | 56 | 600 | 13 | 2.17 |
| Science | 415 | 133 | 548 | 6 | 1.09 |
| Architecture | 11 | 3 | 14 | 3 | 21.43 |
| Mathematical Sciences | 7 | 19 | 26 | 0 | 0.00 |
| Institute of Environmental Studies | 140 | 36 | 176 | 5 | 2.84 |
| Road and Building Research Institute | 34 | 3 | 37 | 0 | 0.00 |
| Total | 1151 | 250 | 1401 | 27 | 1.93 |
| GIS theses | 19 | 8 | 27 | | |

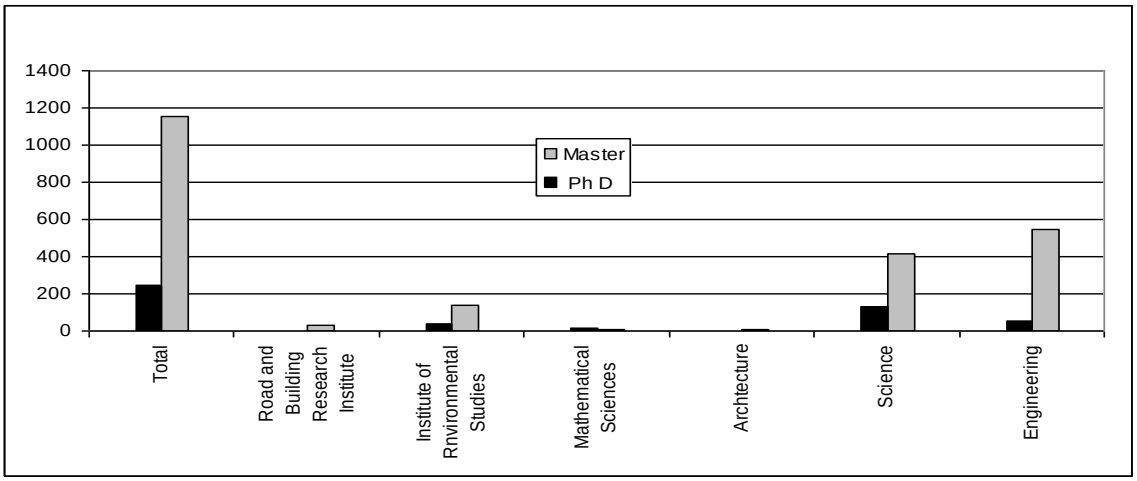


Figure 7 : Number of master and doctoral theses applied GIS in different fields of basic sciences and engineering (Graduate College- U of K ( 2000-2011).

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