

A STUDY ON MIGRATION IN SUDAN USING GEOGRAPHIC INFORMATION SYSTEMS TECHNOLOGY

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ABSTRACT:

Migration between countries is not a fresh problem; it has occurred since the dawn of time, but little research has been conducted on it, particularly by employing effective technologies such as Geographic Information Systems (GIS). As a result, the purpose of this paper was to investigate the migration of Sudanese to other countries and vice versa, as well as the migration of students of higher education from Sudan to other countries. To study all this, the ArcGIS 10.8 program was used, and in it inserted and created all the relevant data from shapefiles and attribute data. The Add XY Coordinates, XY To Line, and Time Slider tools were also used. Migration lines showing migration from and to Sudan in 2015 were drawn based on the nine most prominent countries for each, and a video of an interactive time map illustrating students' migration to fifteen foreign countries from 1998 to 2015 was created. Graphs that show the relationship between countries and the number of immigrants were also created, and they are considered a good means of comprehension even by non-geographic information systems specialists.

1. INTRODUCTION

Migration is defined as the movement of individuals from one location to another to live or work. International migration has a significant amount of academic interest, and as a result of this trend, the migration literature continues to develop. However, when compared to other branches of international trade, migration theorization is lacking.

In the scientific literature, there is widespread agreement that worker migration harms the exporting country and its people while benefiting the receiving country. However, the situation is more complicated, and any evaluation should take into account all potentially positive and negative variables (Aluttis, Bishaw, and Frank, 2014).

Migration is rarely a two-way street; it usually occurs in one direction, from impoverished to prosperous countries. Migrants do not choose their destination; instead, receiving countries select migrants based on their criteria, selecting the finest. This results in significant human capital loss and brain drain in sending countries.

A considerable number of young men and women under-

take long and perilous overland treks across deserts and seas to reach destination nations in the face of difficult socioeconomic and political situations in the country, which are worsened by very restricted alternatives for legal international migration. In Sudan, protracted violence is the primary source of migration, which includes displaced people, refugees, and, to a lesser extent, economic migrants (Assal, 2011).

Sudan is a migration source, transit, and destination country. Sudanese migrants include refugees and asylum seekers, economic migrants, and foreign students to a lesser extent. Men between the ages of 25 and 40 make up the majority, and they come from a variety of socioeconomic and educational backgrounds. The majority of refugees and asylum seekers are in neighboring nations, whereas the Gulf States employs approximately 500,000 economic migrants. Sudanese migrants are also found in lower numbers in Western countries, with 16,901 residence permit holders in European Union countries as of the end of 2014. Sudan, at least in some sectors, is thought to be suffering from brain drain, the health and education sectors are the most notable (Strachan, 2016).

Sudanese immigrants are largely from nearby countries, and they represent an unusual case of migration.

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Because of the informal character of human mobility from adjacent countries and the presence of an irregular migration phenomenon in Sudan, the total number of foreign nationals in the country could be significantly higher. However, the actual number of refugees from South Sudan, Ethiopia, Eritrea, Syria, and other countries is estimated to be around 5 million, all of them are considered refugees. A handful of asylum seekers and an unspecified number of irregular migrants from neighboring countries are residing in Sudan and traveling through the country on their way to Libya, Egypt, and the Red Sea. Because Sudan has 35 universities and colleges with over 200000 graduates every year, the majority of Sudanese are migrating for work. So many of them migrate as a means of survival; the majority of the others have poor abilities.

Money is transported through irregular channels due to sanctions and a lack of incentives, hence no particular financial data is accessible. However, Sudanese households' usage of financial remittances from outside has a considerable impact on daily consumption, housing, education, and health care (Ministry of the Cabinet, 2021). Historical geography is a branch of geography that studies past geographies by imaginatively reconstructing observable facts and events that occurred in a specific location or society.

It has become important to refer to this period as the "information revolution," particularly in light of the massive rise in the flow of information in all disciplines, making it difficult to deal with, absorb, and benefit from it manually. All of this led to the development of geographic information systems, which allow people to organize, classify, and summarize data (Mohieldeen, 2021). A geographic information system is a computer-based method for mapping and analyzing data and events. Database operations are combined with the benefits of map viewing and geographic analysis in GIS technology. Digital maps based on GIS can use the power of human vision to reveal patterns that are frequently difficult to see in numerical summaries of data (Mohieldeen, 2021). Although map drawing and geographic analysis are not new, a GIS performs these tasks more effectively and quickly than manual approaches. And, before GIS technology, only a few people have the abilities required to use geographic data to aid decision-making and problem-solving.

1.1 Previous Studies

Ayalew, Adugna, and Deshingkar (2018) conducted a study to discuss the migration processes from Ethiopia to Sudan and brokering practices that occur, relying on field data collected in three months and using a traditional qualitative research technique. They concluded that migration thrives in border areas because people smugglers transfer the benefits of smuggling to the economically challenged local community, generating social and community support for smuggling (Ayalew, Adugna, and Deshingkar, 2018).

Wickramasinghe and Wimalaratana (2016) wrote a paper focusing on theoretical perspectives of international migration, and they found that there is a plethora of theories on migration that explain various dimensions of the phenomenon in detail, but there is a lack of a holistic approach to migration that would allow

for a better understanding of the issue (Wickramasinghe and Wimalaratana, 2016).

Lagman (2015) conducted research to identify possible trends in the characteristics of Filipinos who migrated to specific areas in Manila, as well as potential disparities in the quantity and kind of migrants attracted. He used geographic information systems to determine variances and similarities among these migrants in terms of a) their origin provinces, b) their ages, c) gender, and d) their listed vocations (Lagman, 2015).

The authors agreed with previous studies in the study of migration, but there are clear differences and uniqueness, as the first and second studies focused solely on the theoretical study of migration, and the third study focused on assessing demographic and spatial characteristics using GIS. The authors, on the other hand, used GIS technology to study migration lines from and to Sudan, as well as to create an interactive time map of the students' migration.

1.2 Research Objectives

The primary motive for migration from less developed countries to countries with higher economies is economic, although migration can also be because of the desire for better education, wars, or natural disasters such as drought, desertification, and floods. This paper was conducted to study the migration lines from and to Sudan to the most prominent nine countries in 2015 and also the migration of higher education students abroad in several years by creating a video of an interactive time map showing the variation in migration for each year.

2. METHODOLOGY

Most of the previous studies focus on a theoretical study of migration, and even a few of them that used GIS dealt with the analysis methodology that focuses on numerical based on the geodatabase, but this study used a different methodology, which is the study of migration lines and also the creation of a video showing an interactive time map of student migration using the ArcGIS 10.8 program, based on many measures that were taken within the program.

2.1 Study Area

The Sudan Republic (Figure 1) is Africa's third largest country (1,886,068 km²), physically located at the crossroads of Sub-Saharan Africa and the Middle East, and stretching as far east as the Red Sea. Libya, Egypt, Chad, the Central African Republic, South Sudan, Ethiopia, and Eritrea are its neighbors. Khartoum, Sudan's capital, is where the White and Blue Niles meet. Extremely dry desert areas, such as the Nubian Desert and the Bayuda Desert, can be found in Sudan's central and northern regions. People in northern and western semi-desert areas still rely on scarce rainfall for rudimentary agriculture, and many are nomadic, following ancient seasonal migration routes with their livestock. In 2019, Sudan's population was 42,813,238 people. Sudan is home to about 150 major ethnic groupings, as well as over 400 languages and dialects. Around 52% of the population is black, 39% Arab, 6% Beja, 2% immigrants, and 1% other ethnic groupings (Migrants and Refugees Section, 2021).



Figure 1. Sudan Location Map (Source: <https://www.britannica.com/place/Sudan>)

The Republic of Sudan is an origin, transit, and destination country, strategically located along the main migration routes from West and East Africa to Europe. Due to ongoing hostilities and attendant insecurity, as well as a stalled economic condition typified by widespread unemployment, Sudan is a migration hotspot also because it is a popular tourist destination for tourists traveling from surrounding nations and West Africa in general, thanks to the existence of trade and pilgrimage routes. Sudan is simultaneously a temporary and long-term host country for a huge number of refugees and asylum seekers. Sudan is a country where various ethnic groups, tribes, faiths, and cultures have come together and coexisted.

2.2 Data and Software

The data used to study the migration lines are the numbers of migrants from (Table 1) and to (Table 2) Sudan to the most prominent nine countries in 2015 for each of them, got from the United Nations, Department of Economic and Social Affairs, Population Section, 2015 (Escwa, 2017). While the data used to create an interactive time map of student migration is the number of students migrating from Sudan to fifteen countries from the year 1998 to 2007 (Table 3) was got from the International Organization for Migration, 2011.

Destination Country	Immigrants Number
South Sudan	552,391
Saudi Arabia	364,304
United Arab Emirates	86,981
Chad	363,465
Kuwait	45,525
Uganda	164,136
United States of America	42,306
Egypt	31,589
Yemen	27,082

Table 1. Migration from Sudan (Source: "United Nations, Department of Economic and Social Affairs, Population Section, 2015")

Original Country	Arrivals Number
Eritrea	159,748
South Sudan	135,558

Chad	74,514
Ethiopia	60,734
Nigeria	14,828
Egypt	13,423
Central Africa	13,489
Kenya	2,575
India	1,277

Table 2. Migration to Sudan (Source: "United Nations, Department of Economic and Social Affairs, Population Section, 2015")

Destination Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Canada	0	0	0	0	0	0	221	0	303	270
United States of America	294	300	327	317	378	431	279	303	320	328
Australia	0	0	0	0	0	0	6	10	10	36
Belgium	0	15	15	11	9	10	11	17	19	13
Denmark	9	10	3	5	6	15	14	9	13	16
Germany	542	554	602	587	572	781	542	460	397	373
Greece	0	0	0	0	19	17	21	22	78	81
Spain	2	6	8	2	2	3	4	4	3	4
France	73	6	11	12	54	55	54	52	49	42
Italy	22	20	13	18	17	18	17	18	22	19
Hungary	20	14	0	10	14	4	3	4	2	6
Holland	0	25	56	71	99	76	72	71	61	53

Austria	54	52	54	50	27	32	25	24	20	19
Finland	14	21	17	13	12	8	12	16	15	18
Sweden	35	42	44	53	45	48	53	44	62	60

Table 3. Student Migration (Source: "International Organization for Migration, 2011")

Each of these tables was placed in an excel file and was later joined with the layers in the ArcGIS program.

ArcGIS Desktop is a collection of connected programs. ArcMap is the most widely used mapping software, allowing users to generate maps, query attributes, analyze spatial relationships, and layout final projects. ArcCatalog organizes spatial data on computers and other devices, allowing users to search, preview, and add data to ArcMap, as well as manage metadata and set up address finder services (geocoding). ArcToolbox is ArcGIS Desktop's third application, and it includes geoprocessing, data conversion, coordinate systems, projections, and other tools (Mckeldin Library, 2012).

ArcView, ArcEditor, and ArcInfo are the three software product levels that makeup ArcMap. These items have a similar architecture but offer progressively more features. The mapping and analysis tools are provided by ArcView. ArcEditor has all of the features of ArcView plus additional processing and advanced editing. ArcInfo has all of the features of ArcEditor plus enhanced analysis and processing.

There are a variety of GIS file types from them: geodatabase, the personal geodatabase, also known as a geographic database file, is the "contemporary container for GIS data" and is unique to ArcGIS, all types of data that can be used in ArcGIS are defined, managed, processed, and stored in geodatabases (i.e., feature, rasters, relationships, measurements, attributes, etc). Shapefiles, the ArcGIS shapefile format is a widely used standard that consists of three or more files, they'll have several file extensions, including .shp, .shx, and .dbf, among others. Layer, the layer file (.lyr) stores symbology, symbology classifications, labeling characteristics, scale dependencies, and definition, according to esri, Colors, and other features are saved, unlike with shapefiles. Coverages, coverage is a collection of thematically related data that is stored as a single unit, soils, waterways, roads, and land use are all examples of single layers. Features are kept in coverage as both primary and secondary features (points, arcs, and polygons) (tics, links, annotation). Computer-Aided Design (CAD), a computer-based method for graphical information design, drafting, and display, these files can be utilized in a GIS, albeit they are most typically used to support engineering, planning, and illustrating activities. ArcGIS supports and uses a wide range of image formats (.tiff, .jpg, .jpeg, .png, etc). Text documents (with x, y coordinates).

In ArcGIS, two types of data may be viewed: vector and raster. Points, lines, and polygons are used to represent real-world objects on the earth's surface, such as an address location, a street,

or a zip code area, in vector data. Raster data, like an aerial or satellite image, is a continuous image of a piece of the earth's surface made up of grid cells or pixels. Both vector and raster data can be utilized in the same view if they are georeferenced to the same location.

2.3 Procedures

Inside the ArcGIS 10.8 program, countries' administrative borders shapefile was used as a basemap, which was got from the site <https://www.naturalearthdata.com>. Three shapefiles of point type were created, a shapefile representing the countries to which Sudanese immigrate besides Sudan, a shapefile for countries whose citizens immigrate to Sudan besides Sudan, and a shapefile for countries that Sudanese students go to for education.

The attributes data that represents the number of immigrants from and to Sudan in 2015 to the most prominent nine countries and the number of immigrant students from 1998 to 2007 to the most prominent fifteen countries were got and were placed in excel files. Excel files were joined with each related layer. The number of immigrants was added equal to zero to the Sudan feature in the first two shapefiles. Thus, geodatabases of countries and immigrants were got.

To create the migration lines from Sudan, the X and Y coordinates for each country were added using the Add XY Coordinates tool in the ArcToolbox, Start X and Start Y fields were added, and the X and Y coordinates for Sudan were inserted into them, after that the migration lines were created using the XY To Line tool, and thus a new layer was got and symbolized.

Also, using the ArcToolbox's Add XY Coordinates tool, the coordinates of each country were added, and Start X and Start Y fields were created for each country, which represents the coordinates for Sudan. By using the XY To Line tool, the migration lines were created and symbolized.

It is possible to use, create, and share maps, scenes, apps, layers, analytics, and data with ArcGIS Online, a collaborative web GIS. You can add objects, publish web layers, and make maps, apps, and scenes with the content in the ArcGIS Living Atlas of the World, ArcGIS apps, and cloud infrastructure.

The Time Slider widget enables viewing temporal layers in a map and playing the animation to see how the data changes over time. Using this widget, you can control the animation of the data with buttons to play and pause, go to the previous period, and go to the next period.

The student migration countries shapefile was symbolized, and by using the Time Slider tool, an interactive time map was created for years from 1998 to 2007 for fifteen countries, and then a video was created for it. It shows the increase and decreases in the number of immigrant students for each country over time as the size of the circle's increases and decreases.

Graphs were made for immigrants from and to Sudan based on the most prominent nine countries for the year 2015 and also for immigrant students from Sudan to abroad base on the most prominent fifteen countries from 1998 to 2007. The graphs provide an overview of the number of immigrants to the countries

in question, and thus, they are considered a good means of comprehension even by non-specialists in the field of GIS.

3. RESULT, ANALYSIS, AND DISCUSSION

Countries' administrative borders shapefile was got and made it as a basemap for the study shapefiles. A destination country shapefile was created which represents the countries that the Sudanese go to, also the original country shapefile which represents the countries whose citizens come to Sudan. The student migration countries shapefile also was created, which contains the countries to which Sudanese students of higher

education migrate. Attributes data was inserted for each shapefile and thus geodatabases were got.

The X and Y coordinates were added to the destination country shapefile, and the Start X and Start Y fields, which represent the coordinates of Sudan, were added (Table 4). After that, migration lines were established from Sudan to the destination countries (Figure 2). And they were classified into five classes, the South Sudan country occupies the first place among the countries to which migration takes place, where the greater the thickness of the line this indicates many migrants to the concerned country.

Country	Number	Point-X	Point-Y	Start-X	Start-Y
South Sudan	552,391	30.0057501381	6.82857257869	29.7908815059	15.4783036961
Saudi Arabia	364,304	44.1067771042	23.8413023472	29.7908815059	15.4783036961
United Arab Emirates	86,981	54.4704868814	23.68419225	29.7908815059	15.4783036961
Chad	363,465	18.3304488208	15.2631273214	29.7908815059	15.4783036961
Kuwait	45,525	47.509849601	29.3587308567	29.7908815059	15.4783036961
Uganda	164,136	32.429356874	1.24112812981	29.7908815059	15.4783036961
United States of America	42,306	-98.8043962482	39.1170532168	29.7908815059	15.4783036961
Egypt	31,589	29.6645547284	26.4876672843	29.7908815059	15.4783036961
Yemen	27,082	47.7008691526	15.6373250977	29.7908815059	15.4783036961
Sudan	0	29.7908815059	15.4783036961	29.7908815059	15.4783036961

Table 4. Attribute Table of Destination Country Shapefile

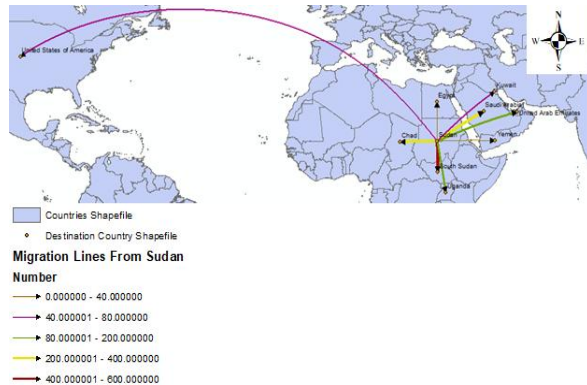


Figure 2. Migration Lines from Sudan

Figure 2 shows the lines of migration of citizens from Sudan to the nine most prominent countries, where the larger line width indicates a greater number of immigrants

The same previous step was repeated for the original country shapefile, and therefore the attribute table was got (Table 5) and the migration lines to Sudan were created (Figure 3). Through the symbology of migration lines to Sudan layer, we find that the migration line to the State of Eritrea country is the largest.

Country	Number	Point-X	Point-Y	Start-X	Start-Y
Eritrea	159,748	38.8687664926	15.3083370805	29.7908815059	15.4783036961
South Sudan	135,558	30.0057501381	6.82857257869	29.7908815059	15.4783036961
Chad	74,514	18.3304488208	15.2631273214	29.7908815059	15.4783036961
Ethiopia	60,734	39.1428804005	8.54178450289	29.7908815059	15.4783036961
Nigeria	14,828	7.86082039514	9.52267764486	29.7908815059	15.4783036961
Egypt	13,423	29.6645547284	26.4876672843	29.7908815059	15.4783036961
Central Africa	13,489	20.0803855947	6.6943512823	29.7908815059	15.4783036961
Kenya	2,575	38.1048027139	0.388779616853	29.7908815059	15.4783036961
India	1,277	79.0873054117	23.3583005329	29.7908815059	15.4783036961
Sudan	0	29.7908815059	15.4783036961	29.7908815059	15.4783036961

Table 5. Attribute Table of Original Country Shapefile

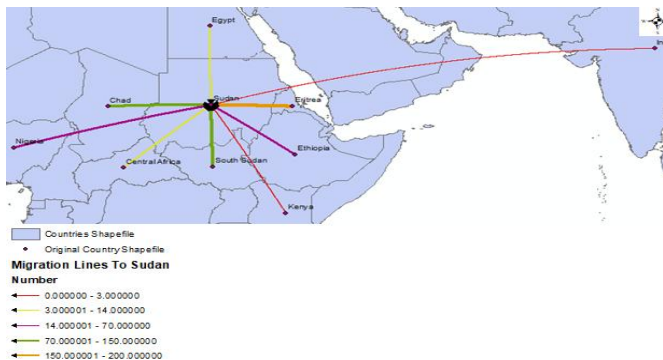


Figure 3. Migration Lines to Sudan

The thicker lines from the figure 3 indicates the largest number of arrivals from the nine most prominent countries to Sudan

Figure 4, shows a sample of the attribute table of student migration countries shapefile. The student migration countries shapefile was symbolized, where Figure 5 shows the symbolizing for the year 2007, and the time property was activated for it depending on the date field and was determined the time interval each year, and through the Time Slider tool in the Tools toolbar, an interactive time map was created so that circles showing the numbers of immigrant students for each country in each year separately, so that the circles get bigger and smaller according to the number of students as shown in the video that was created located in the link <https://youtu.be/poFJhuj5OyY>.

FID	Shape *	Country	Number	Date
0	Point	Canada	0	1/1/1998
1	Point	Canada	0	1/1/1999
2	Point	Canada	0	1/1/2000
3	Point	Canada	0	1/1/2001
4	Point	Canada	0	1/1/2002
5	Point	Canada	0	1/1/2003
6	Point	Canada	221	1/1/2004
7	Point	Canada	0	1/1/2005
8	Point	Canada	303	1/1/2006
9	Point	Canada	270	1/1/2007
10	Point	United States of America	294	1/1/1998
11	Point	United States of America	300	1/1/1999
12	Point	United States of America	327	1/1/2000
13	Point	United States of America	317	1/1/2001
14	Point	United States of America	378	1/1/2002
15	Point	United States of America	431	1/1/2003
16	Point	United States of America	279	1/1/2004
17	Point	United States of America	303	1/1/2005
18	Point	United States of America	320	1/1/2006
19	Point	United States of America	328	1/1/2007
20	Point	Australia	0	1/1/1998
21	Point	Australia	0	1/1/1999
22	Point	Australia	0	1/1/2000
23	Point	Australia	0	1/1/2001
24	Point	Australia	0	1/1/2002
25	Point	Australia	0	1/1/2003
26	Point	Australia	6	1/1/2004
27	Point	Australia	10	1/1/2005
28	Point	Australia	10	1/1/2006
29	Point	Australia	36	1/1/2007
30	Point	Belgium	0	1/1/1998
31	Point	Belgium	15	1/1/1999
32	Point	Belgium	15	1/1/2000

Figure 4. Sample of the Attribute Table of Student Migration Countries Shapefile

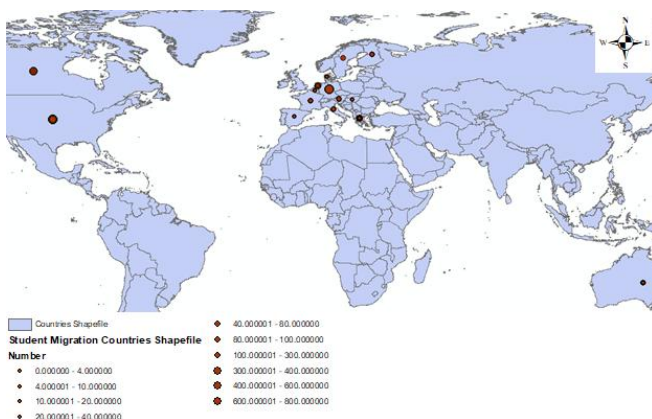


Figure 5. Student Migration Countries Shapefile

This figure displays the countries to which Sudanese students immigrate to receive their education, represented by circles in red.

Figures 6 to 8 show graphs of immigrants from and to Sudan to the most prominent nine countries for the year 2015, as well as Sudanese student immigrants to the most prominent fifteen countries from 1998 to 2007. It is clear that South Sudan has the greatest number of Sudanese immigrants, Eritrea has the greatest number of emigrants to Sudan, and Germany is the country where Sudanese students go to receive knowledge.

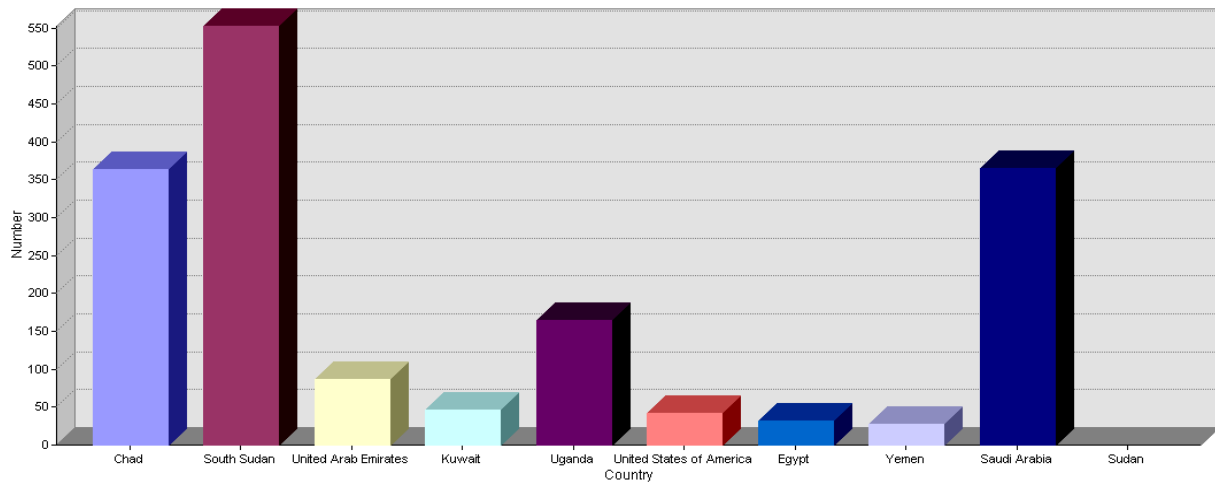


Figure 6. Graph of Destination Countries

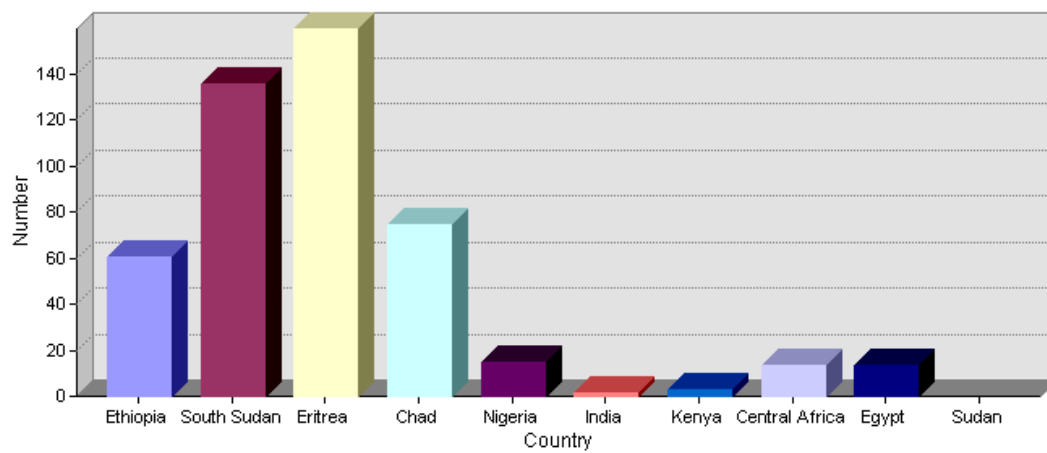


Figure 7. Graph of Original Countries

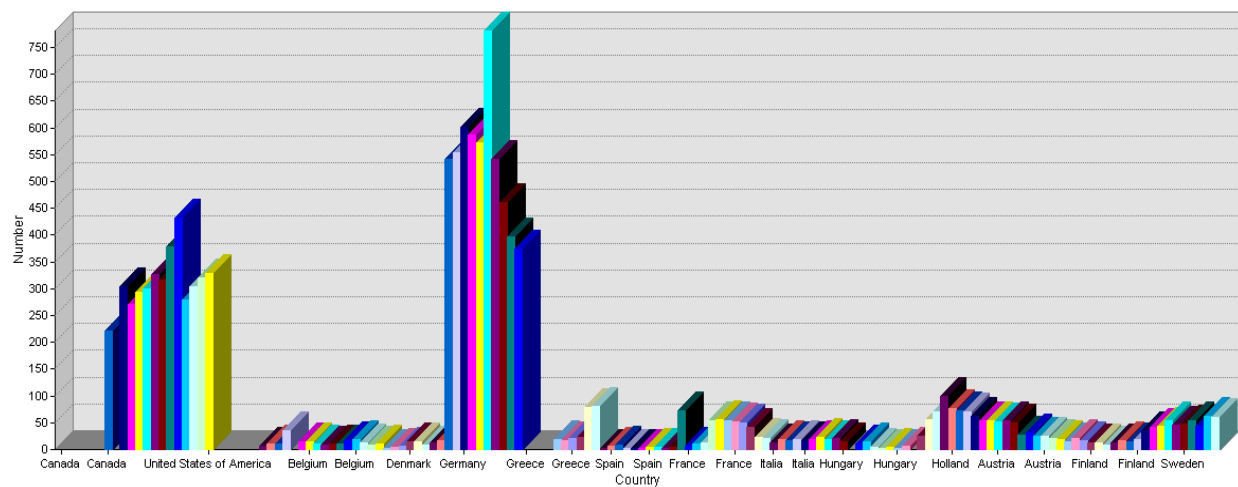


Figure 8. Graph of Student Migration Countries

This study is unique and essential, as a different methodology was used in an applied study of migration between countries, depending on the geodatabase that was created.

4. CONCLUSION

A lot of procedures were done within the ArcGIS 10.8 program to study migration in Sudan, and then:

1. Migration lines were created from Sudan to abroad and it was found that immigration to the South Sudan State is the highest.
2. Migration lines were created from abroad to Sudan, where it was found that migration from the Eritrea State to Sudan is the highest.
3. An interactive time map was created showing the migration of Sudanese students abroad, and it was found that Germany had the most significant number of students in all the years.
4. The relationship between countries and the number of immigrants was illustrated in the above three cases through the creation of graphs. Thus, a clear view was obtained even by non-specialists.

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