



# Developing an Active Tool in GIS for Population Projection: Ninevah Governorate and USA Population Data as a Model

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This research aimed to develop a population projection tool in ArcGIS Desktop10.x which is very popular GIS software. The tool is based on the geometric mean equation, and it was developed by deconstructing a set of tools available in the Data Management Tools application of ArcGIS Desktop10.x, then reconstructing them in a special environment known as the Model Builder. The idea is based on the premise that the aim can be achieved by developing an easy-to-use tool that works with high speed and accuracy, utilising the automating calculation of population projection in the feature linked Attribute table. The research succeeded in developing a population projection tool and testing it on the population projection data for Nineveh Governorate, Iraq and the United States of America.

**Key words:** *Active Tool in GIS, Population Projection, Nineveh Governorate, USA Population*

## Introduction

In view of the tremendous developments witnessed by the world in digital record systems and the use of geographical information on the one hand, and the current trends to efficiently utilise the resources of effort, time, and money on the other, GIS and its applications have become an integrated solution that can be used in various scientific and research fields. However, GIS and their applications still lack many tools that can support different applications, such as population projection. Population projection is one of the important sources upon which economic and social service plans and programs are built. Population projection results are used to identify the future population needs in terms of education opportunities, the potential workforce that will enter the labour market, as well as the demand

for various goods and services. Estimating the future population is one of the most important stages in many geographical and planning studies. The research addresses the problem of the lack of a tool for population projection in GIS Software. Users of GIS, when population projections are required in their research, have to rely on manual methods for projection while entering the results in the attribute table of the investigated features in GIS. This means they rely on a calculator and a pen and paper. The effort required for this manual process increases with the number of spatial units, which in turn increases the risk of errors in the population projection.

The main source of error stems from entering projection results manually into the feature linked Attribute table in GIS. The research aims to develop a special population projection tool in ESRI ArcGIS Desktop10.x, the most popular geographic information systems software at the global level, to bridge the gap in the software by delivering a population projection tool for its users (Maguire et al., 1991). This goal is based on the idea of developing an easy-to-use tool that works on automating the calculation of population projection in the Attribute table linked to map features, with high speed and accuracy. Highlighting spatial relationships and linking them with population variables is what distinguishes the geography of the population from the demography that addresses the population digitally and as a separate topic from the environment and location. Demography is concerned with numbers and statistical methods. For the Population Geography researcher, it links these numbers to the environment and place, and its analysis depends on multiple maps. It is not possible to separate the population geography and demography (Amudo and Inanga, 2009). There is an integrative relationship between them, as the demography deals with the digital and geography side the analytical side to determine the correct spatial framework and clarify the various factors that govern relations between residents of their environment within the limits of this framework. The composition of the population by age and gender is the most common type of structure. Among the important population characteristics in the field of population structure are way of life (rural or urban), marital status, profession, education, religion, language, each of which is linked to the number of births, deaths and immigration. Studies of the population not only examine the population structure at a certain time, but also deals with the extent of the changes that occur in this composition or the reasons for the changes and their impact on society. The research used the inductive scientific method, starting from the basic units of the tool and developing it in a way that serves the aim of the research. The research used the population data for the districts of Nineveh and the counties of the USA as an application model for the research process.

### **The Concept of Population Projection**

Population projection expresses purely demographic implications based on the data available in a specific spatial and temporal space (Clarke, 1972). The United Nations defines



population projection as a set of calculations that aim to assess the future quantitative development of the population based on assumptions that may or may not be achieved (United nation, 2010), meaning that it represents numerical outputs based on a set of assumptions related to the numerical value of a variable. As population projection is a direct measure of current and past conditions that can be measured directly, it also includes an assumption that population trends may change gradually and not abruptly, as there are no sudden, unaccounted developments. The goal of most population projections is to provide a near-future population forecast, calculated on the basis of the assumption of a reasonable future continuity of trends affecting demographic population variables. The results of population projections are used to calculate human needs in relevant economic, social and political areas (Aísa and Pueyo, 2006).

The study of the population depends mainly on the numbers derived from its various sources. However, the number itself is not relevant and must be linked to other numbers. Its resources and its economic and social level, for studying the population mathematically and measuring its indicators related to size, distribution, fertility, mortality and immigration, leads us to a specialised branch called "Demography". The definition of demography is a mathematical statistical science that is concerned with studying the size, distribution, and composition of the population and the components of horizontal and vertical change in these three elements, such as births, deaths, and migration, and then the social change of the individual in society in its multiple social, cultural and economic forms. Population geography can be defined as a modern science of the branches of human geography interested in studying the multiple relationships that exist between man and the environment. The geography of the population is concerned with understanding the variation in demographic variables and linking numbers with places depending on the maps. The general definition of population geography is the branch of human geography that addresses the spatial differences of the demographic characteristics of population societies and studies the socio-economic consequences resulting from the interaction between them and the geographical conditions existing in a particular survey unit.

### **The Projection Method Used in the Research**

The population projection method, based on the geometric mean equation for calculating population change and growth, is one of the best mathematical methods from the population geography perspective. This is especially the case when population projection is implemented for a short period (less than ten years) after the last census. The average annual population change, determined by the geometric mean equation, gives an average rate of population change between two censuses and thus removes the need to delve into the details of the population census dates. This method is adopted by the United Nations Population Division (U.N, 1984), and it is based on the following equation (Clarke, 1968):

$$r = \left( \sqrt[t]{\frac{P_1}{P_0}} - 1 \right) \times 100$$

In this:

$r$  = The annual rate of change.

$P_1$  = The population in the next census.

$P_0$  = The population in the previous census.

$t$  = The number of years between the two censuses.

Population projection is carried out based on the geometric mean equation above, according to the following equation:

$$p = (r)^{n-1} \times (P_1)$$

In this:

$p$  = The expected population.

$r$  = The annual rate of change.

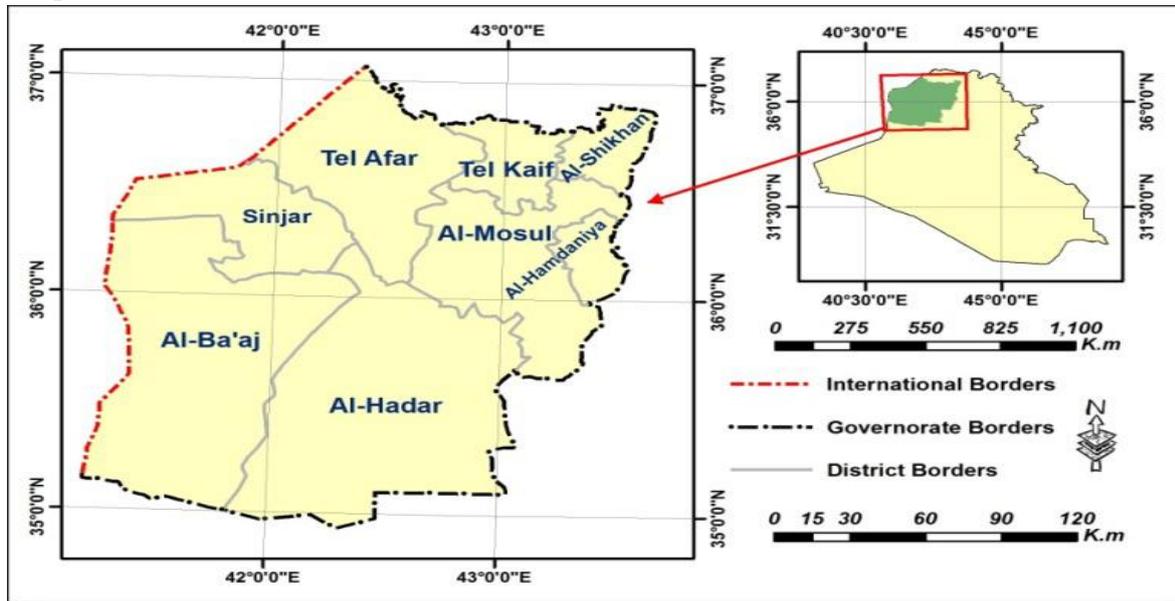
$n$  = The number of years between the next census and the target year.

$p_1$  = The population in the next census.

### **The Software and Data**

The research was based on ArcGIS Desktop 10.x, which consists of a software package that performs the tasks of geographic information systems at all scales and levels, from building a geodatabase to editing data, and from research and inquiry at the level of MapQuery to cartographic production and advanced geographical analysis (Booth and Mitchell, 2005). The administrative map of the districts of Nineveh governorate was used to implement the projection on the software Attribute table. The population data used for population projection of the districts of the Nineveh governorate in the research was based on the last two censuses issued in Iraq in 1987 and 1997, as shown in Map 1. It is worth stating that no censuses followed that of 1997 in Iraq. Population data used in the projection process are shown in Table 1 and Maps 1 and 2.

**Map 1.** Nineveh Governorate Districts

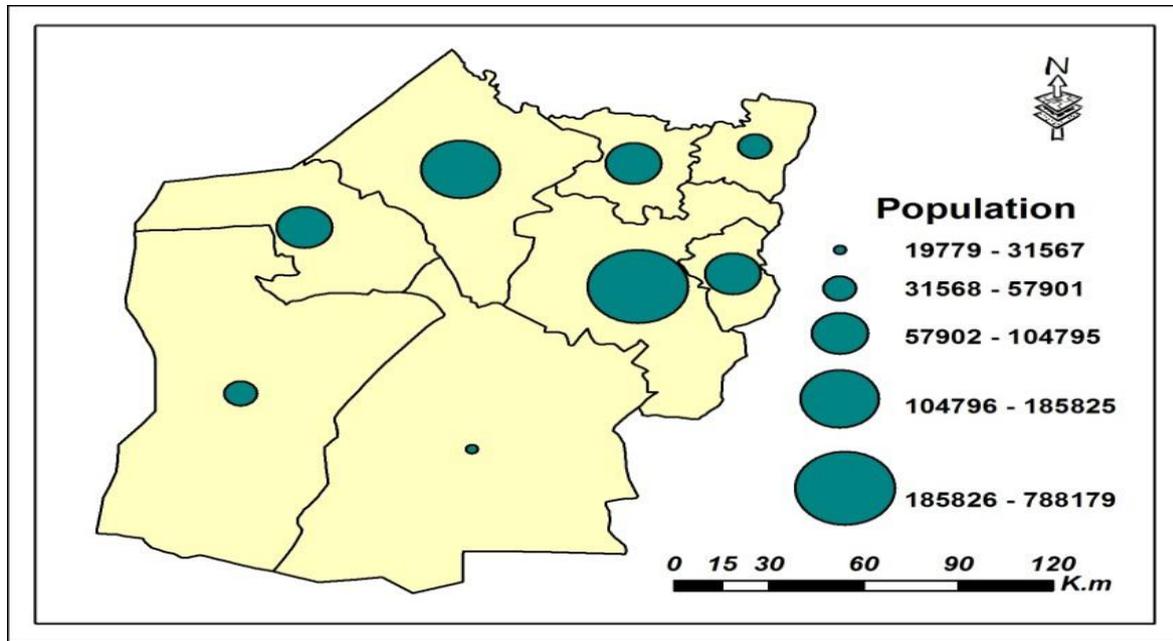


**Source:** Compiled by researcher based on Nineveh Agriculture Directorate /GIS Division 2009.

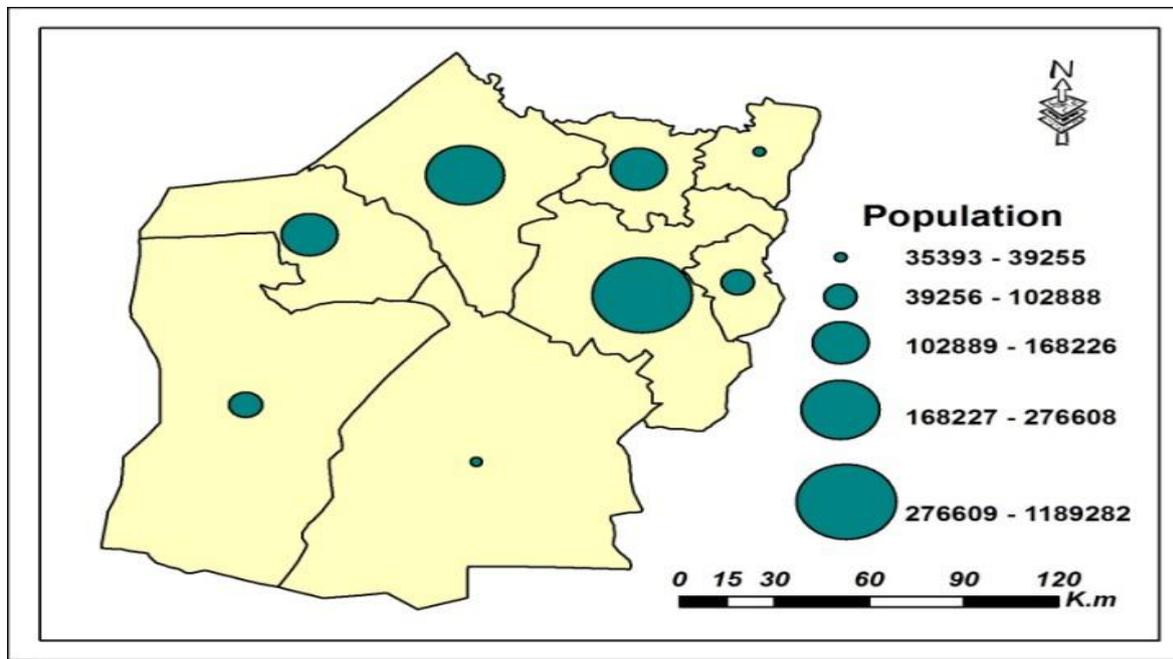
**Table 1:** Population of Nineveh Governorate Districts Based on the Censuses of 1987 and 1997(Ministry of Planning).

District	Population	
	1987	1997
Al-Mosul	185825	276608
Al-Hamdaniya	78810	102888
Tel Kaif	97108	136687
Al-Shikhan	54559	35393
Tel Afar	185825	276608
Sinjar	104795	168226
Al-Ba'aj	57901	94513
Al-Hadar	19779	39255

**Map 2.** Distribution of Population According to the Districts of Nineveh Governorate for the Year 1987



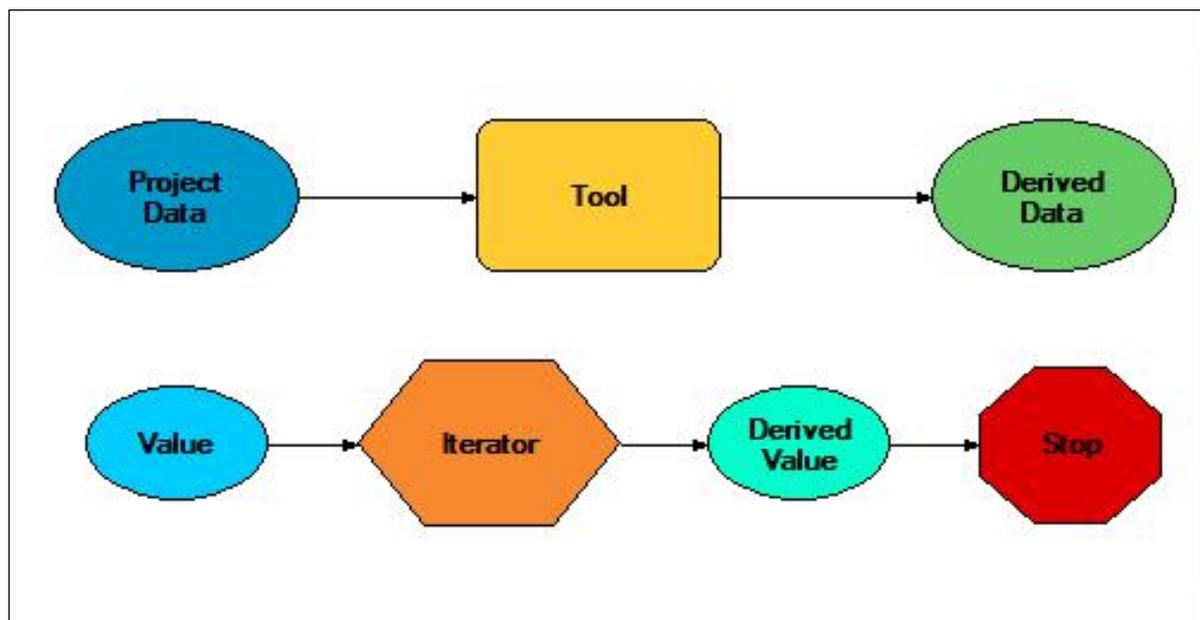
**Map 3.** Distribution of Population According to the Districts of Nineveh Governorate for the Year 1997



## Building the Executive Model

An executive model is defined as a graphic that describes the internal manipulation mechanism of geographic features represented in the form of layers in the GIS software. It is considered a product, designed and implemented without the need for following a specific methodology (Parrish, 2005), and it is an antecedent for a later process of tool development. In building the executive model of the population projection, a set of general functions in ArcGIS 10.x were converted into graphs in a special environment called the Model Builder. The Model builder is generally defined as a graphical tool for designing, simulating and analysing models that comprise a system (Gillette, 2011). For ArcGIS Desktop, the model builder is an application for creating, editing, and managing executive models and it consists of a series of geoprocessing tools that express workflow tasks. In other words, the model builder can be considered a visual programming language for the procedural workflow in geographic information systems (See Figure 1).

**Figure 1.** ArcGIS Desktop 10.x Executive Model building Units

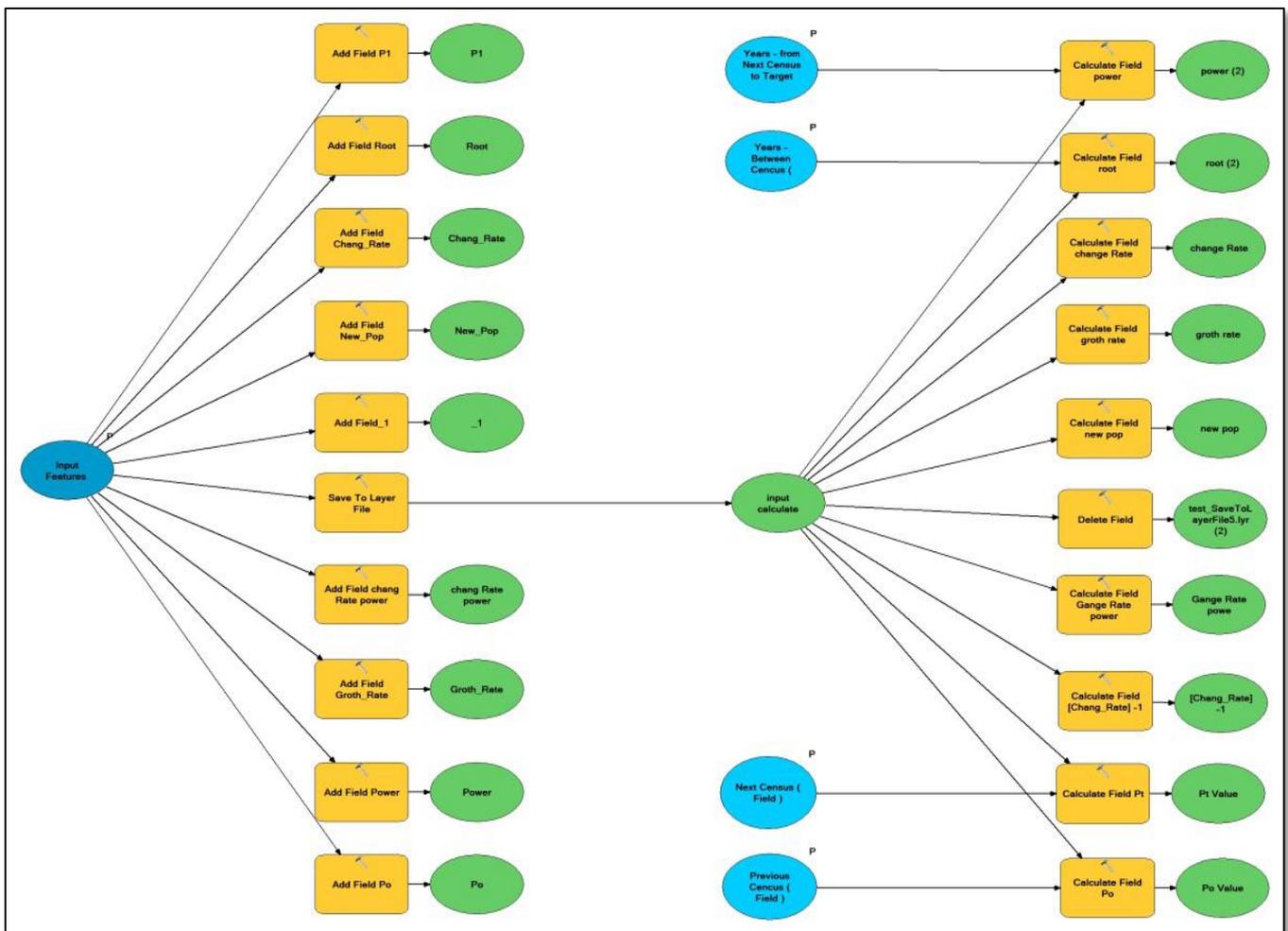


From this standpoint, the researcher decided while building the executive model for the population projection to name it based on its intended function, which is "Population Projection". The Executive model was built from a number of relative functions in the Data Management Tools application as follows:

- Add Field.
- Save to layer File.
- Calculate Field.
- Delete Field.

The “Add Field” function was repeated nine times in the structure of the model in order to create the necessary fields in which the stages of applying the geometric mean equations will be saved to extract the annual change rate and population projection. The “Save to layer File” function was repeated once in the model structure, as its task was to define the fields added to the “Attribute Table” to be dealt with in the field calculation stage. This stage was conducted using the “Calculate Field function,” which was repeated nine times in order to perform the successive calculations necessary to reach the population projection for the year specified by the user. The model ends using the “Delete Field” function, which was repeated once in its structure, in order to delete the transient fields between the information that is to be obtained from the idea of building the executive model (See Figure 2).

**Figure 2.** The Executive Model for Population Projection in ArcGIS Desktop 10.x

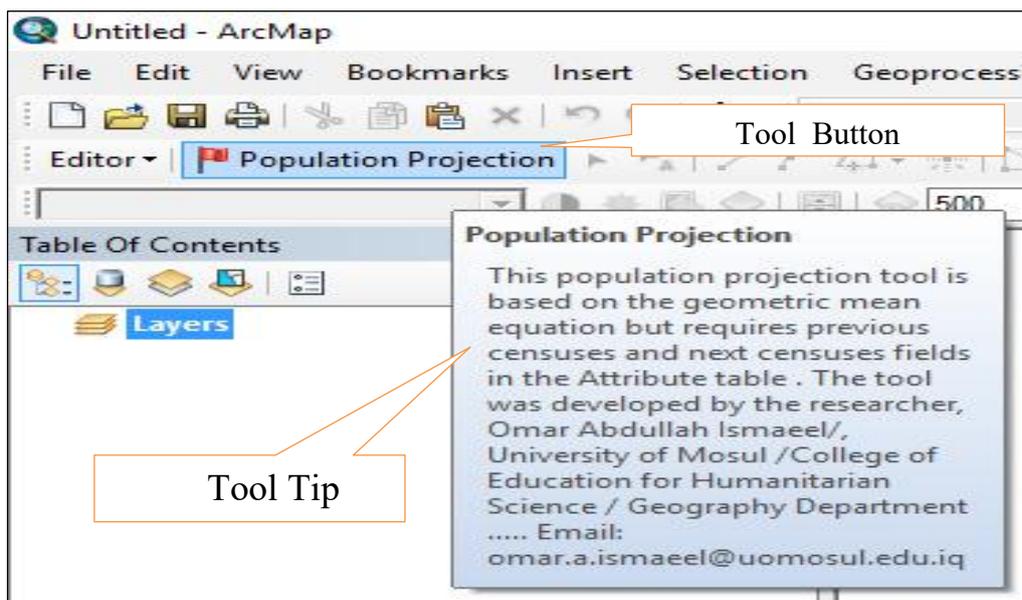


## Transforming the Executive Model into a Tool

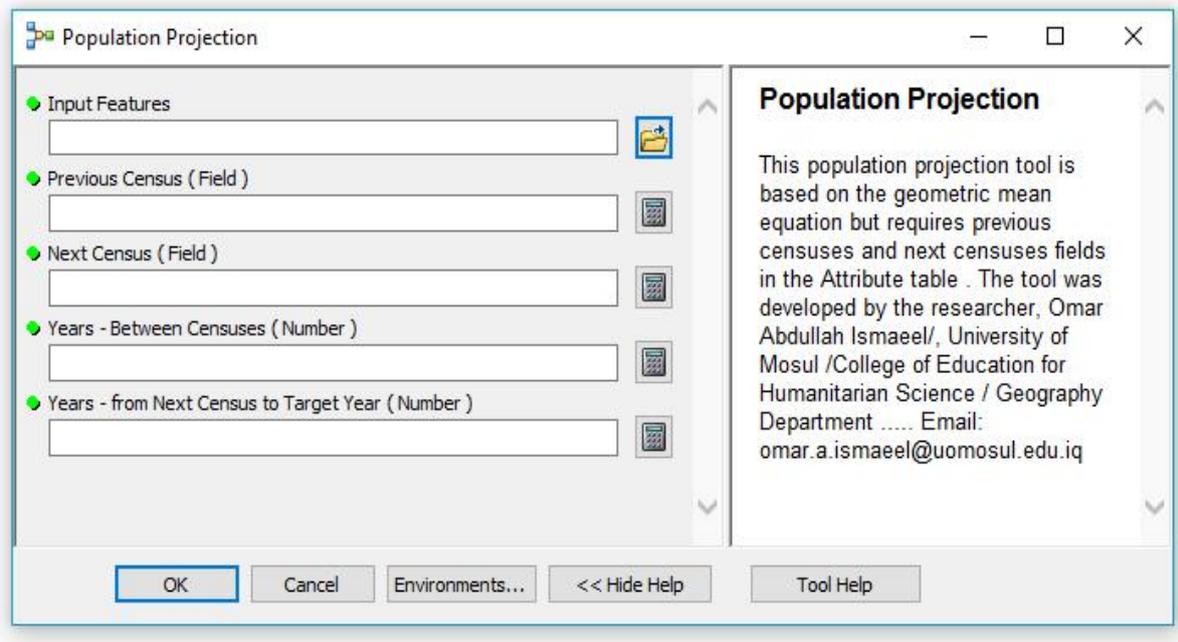
Converting the executive model into a tool requires knowledge of the necessary parameters that must be made available to the user so that he can control the model process in a comprehensive manner, while leaving the task of internal manipulations and the logical sequence of functions, included in the model structure, to the tool that performs the necessary treatments based on the included parameters. Therefore, the following parameters were selected in the development of the population projection tool:

- 1- The parameters termed “Input Features,” from which Shapefile or Feature Class data are entered in the Geodatabase through a table containing a previous and next population census.
- 2- The parameters termed “Previous Census,” from which the field for the previous census is entered.
- 3- The parameters termed “Next Census,” from which the field for the next census is entered.
- 4- The parameters termed “Years - Between Censuses,” from which the number of years is entered between the two censuses.
- 5- The parameters termed “Years - From next Census to Target Year,” from which the number of years between the last census and the target year for which population estimates are to be obtained is entered (See Figure 3 , 4, and 5).

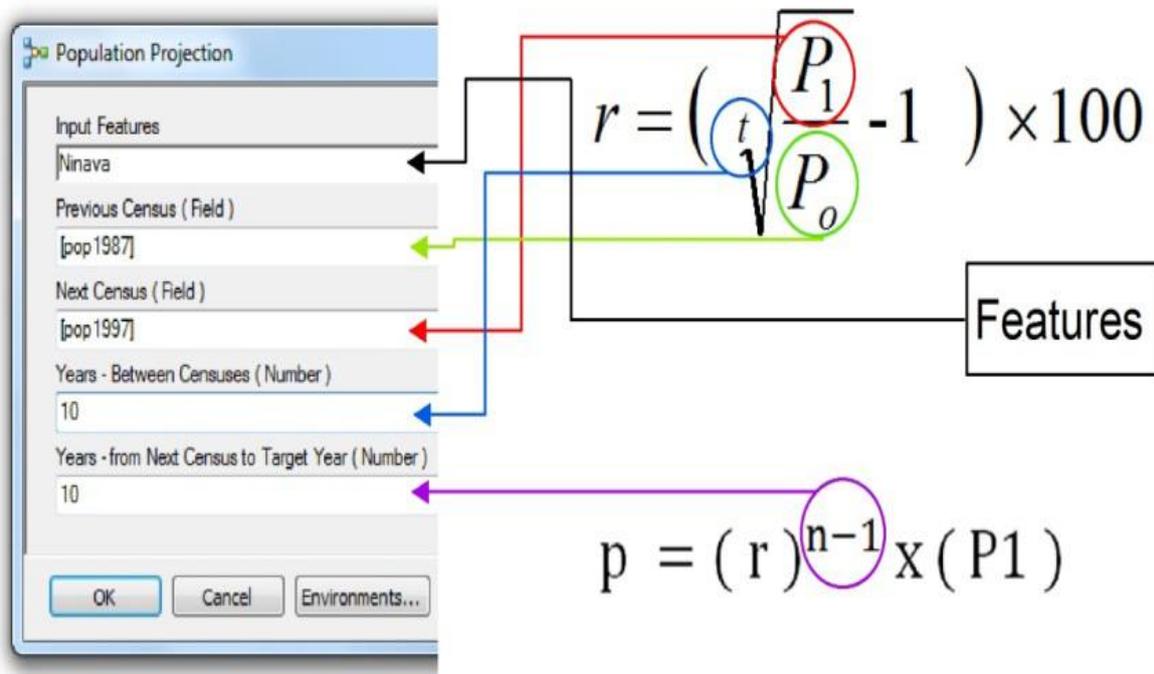
**Figure 3.** Population Projection Tool Button and Population Projection Tool Tip in ArcGIS Desktop 10.x



**Figure 4.** Population Projection Tool Interface



**Figure 5.** The Relationship Between the Developed Tool's Parameters, the Geometric Mean Equation, and the Population Projection



## Running and Testing the Tool

In order to test its functioning, the developed tool was used to estimate the population of Nineveh governorate according to its districts for the year 2007, after preparing the results obtained from the 1987 and 1997 censuses. Running the tool led to the automated addition of 3 additional Fields to the Attribute table:

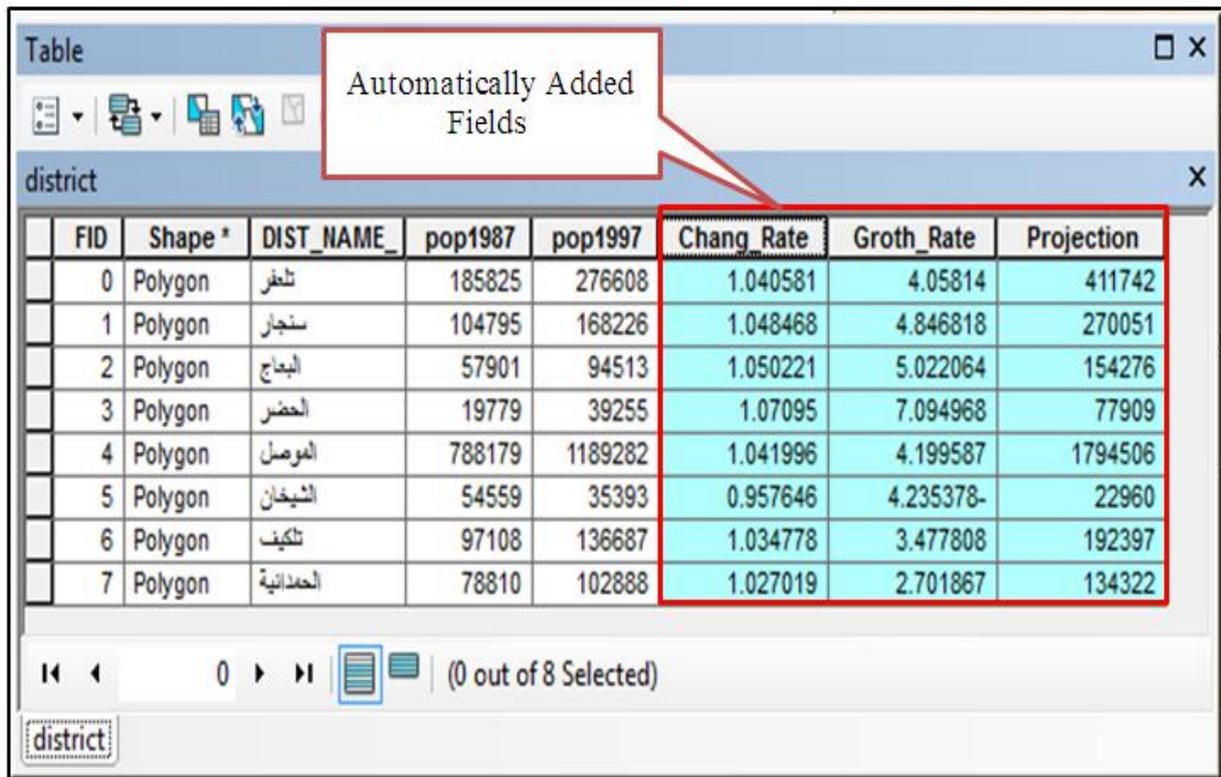
A- The Change Rate field, which reflects the annual change rate according to the spatial units (governorate districts).

B- The Growth Rate field, which indicates the annual growth rate according to the spatial units.

C- The Projection field, which embodies the population estimates for the year 2007 according to the spatial units.

It is worth noting that the field designations remain constant when using the population projection tool on a different spatial space (See Figure 6 and Table 2 as well as Map 3).

**Figure 6.** Population Projection Data in the Form of Fields Automatically Added to the Attribute Table in ArcGIS Desktop 10.x.

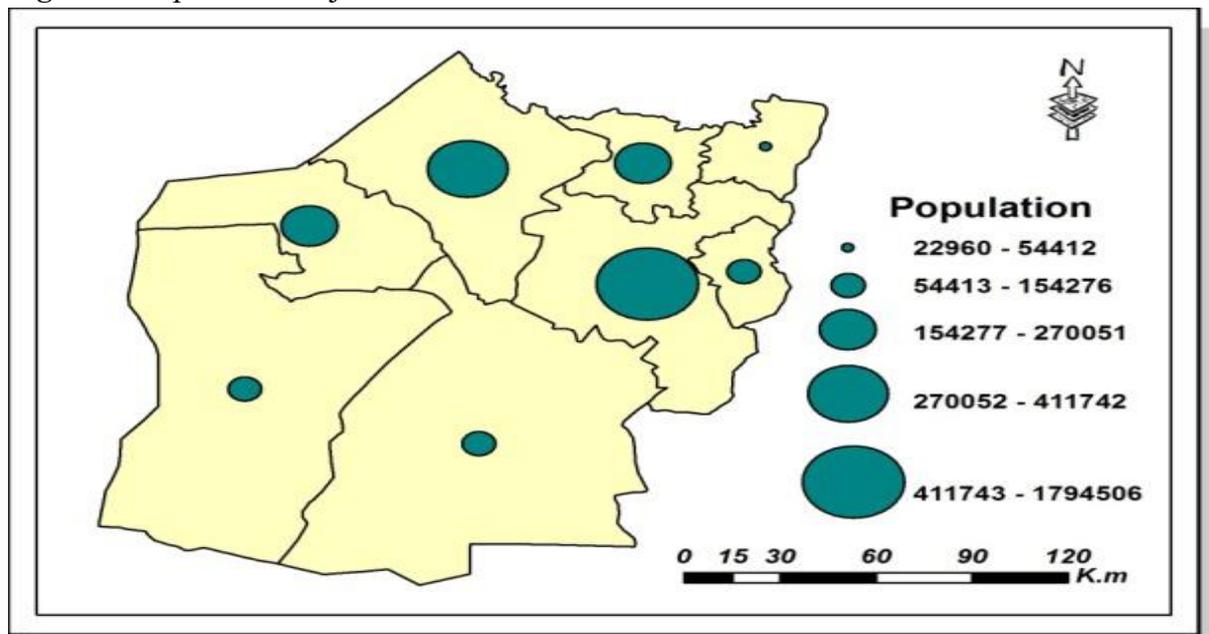


FID	Shape *	DIST_NAME_	pop1987	pop1997	Chang_Rate	Groth_Rate	Projection
0	Polygon	تلعفر	185825	276608	1.040581	4.05814	411742
1	Polygon	سنجار	104795	168226	1.048468	4.846818	270051
2	Polygon	البعاج	57901	94513	1.050221	5.022064	154276
3	Polygon	الحضر	19779	39255	1.07095	7.094968	77909
4	Polygon	الفرصل	788179	1189282	1.041996	4.199587	1794506
5	Polygon	الشيخان	54559	35393	0.957646	4.235378-	22960
6	Polygon	تلكيف	97108	136687	1.034778	3.477808	192397
7	Polygon	الحدانية	78810	102888	1.027019	2.701867	134322

**Table 2:** Output of the developed projection tool for population projection in the Tabular form

District	Average annual change	Average annual growth	Estimation of Population numbers in 2007
Al-Mosul	1.0419	4.19	1794506
Al-Hamdaniya	1.0270	2.7	134322
Tel Kaif	1.0347	3.47	192397
Al-Shikhan	0.9576	-4.23	22960
Tel Afar	1.0405	4.05	411742
Sinjar	1.0484	4.84	270051
Al-Ba'aj	1.0502	5.02	154276
Al-Hadar	1.0709	7.09	77909

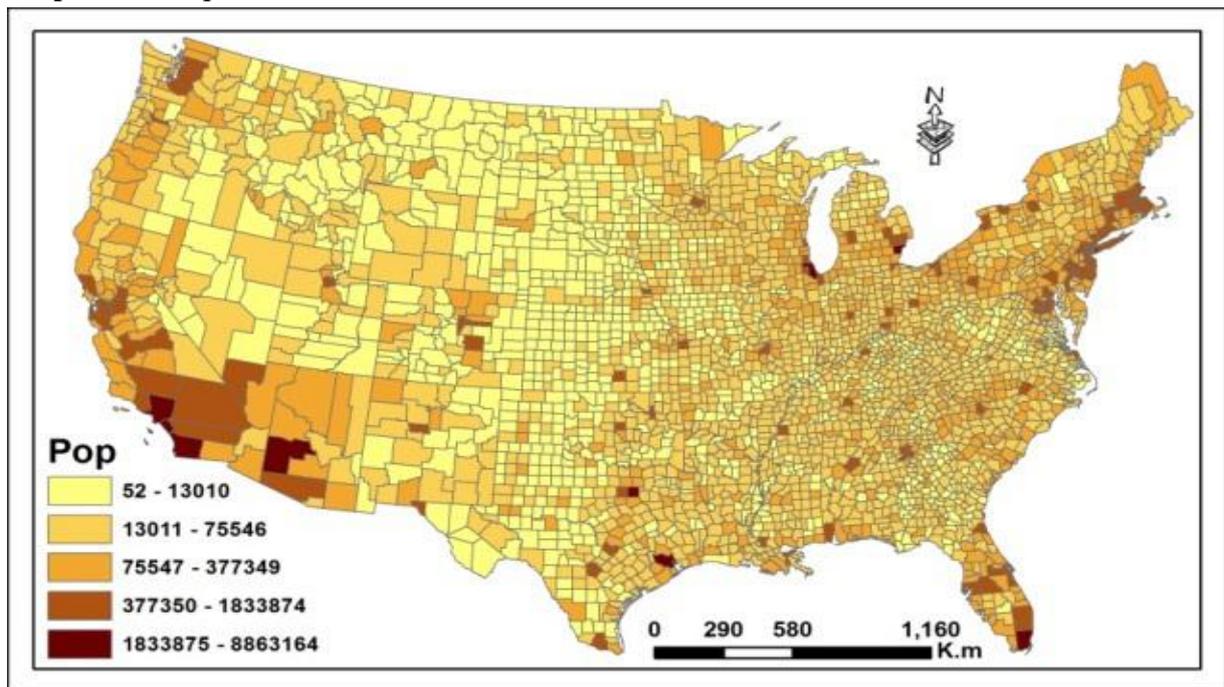
**Figure 6.** Population Projection of Nineveh Districts in 2007.



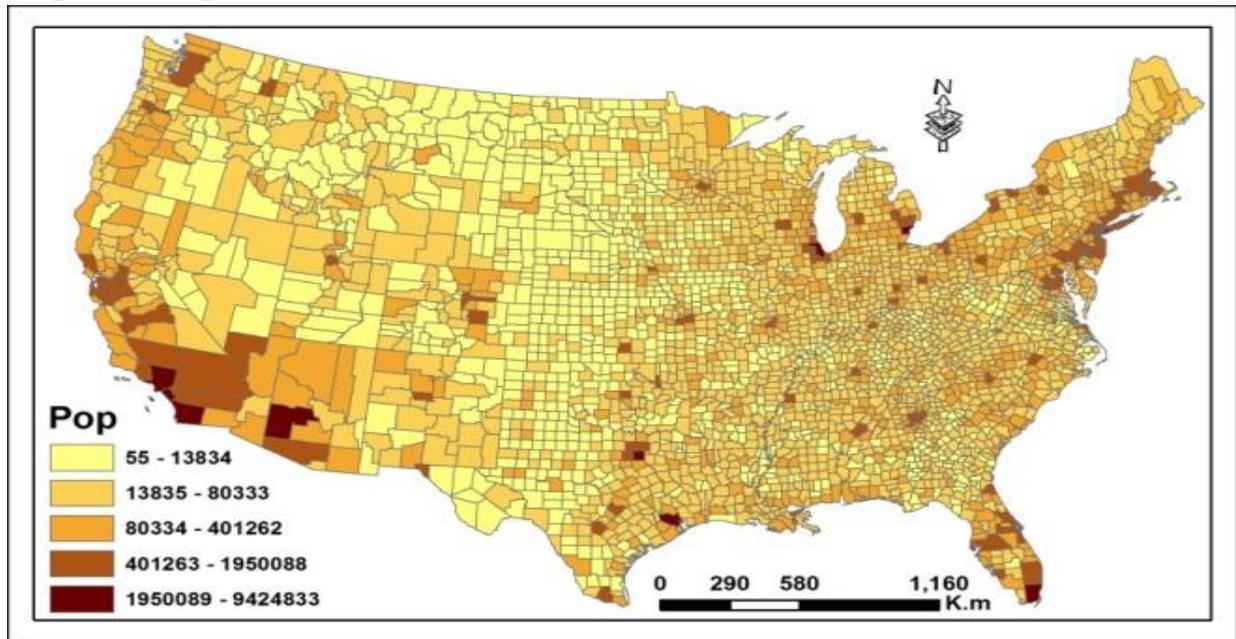
In order to verify the functioning of the developed tool in more than one place, it was used with the population projection of counties of the United States of America based on the censuses of 1990 and 2000. The projection was successful for the year 2010. The 1990 and 2000 Censuses, as well as the population projection for the United States, were represented by the choropleth method, instead of Graduated Symbols as in the representation of the population censuses and the population projection for Nineveh Governorate. The reason for this is that Nineveh consists of 8 spatial units, which allows cartographers to use size variation in the mapping process. In contrast, the United States includes 3111 spatial units, excluding the states of Alaska and Hawaii. The huge number of spatial units of the USA

required the use of a very small map scale for practical reasons allowed by the scope of the search pages. For this reason, the researcher was limited to the choropleth style in the process of data representation for cartographic reasons. On the other hand, the geometric interval method was used in classifying the maps of USA, because there is a large difference between the population of some counties, and this method is optimal for that type of data (Dent, 1999) (See map 4, 5 and 6).

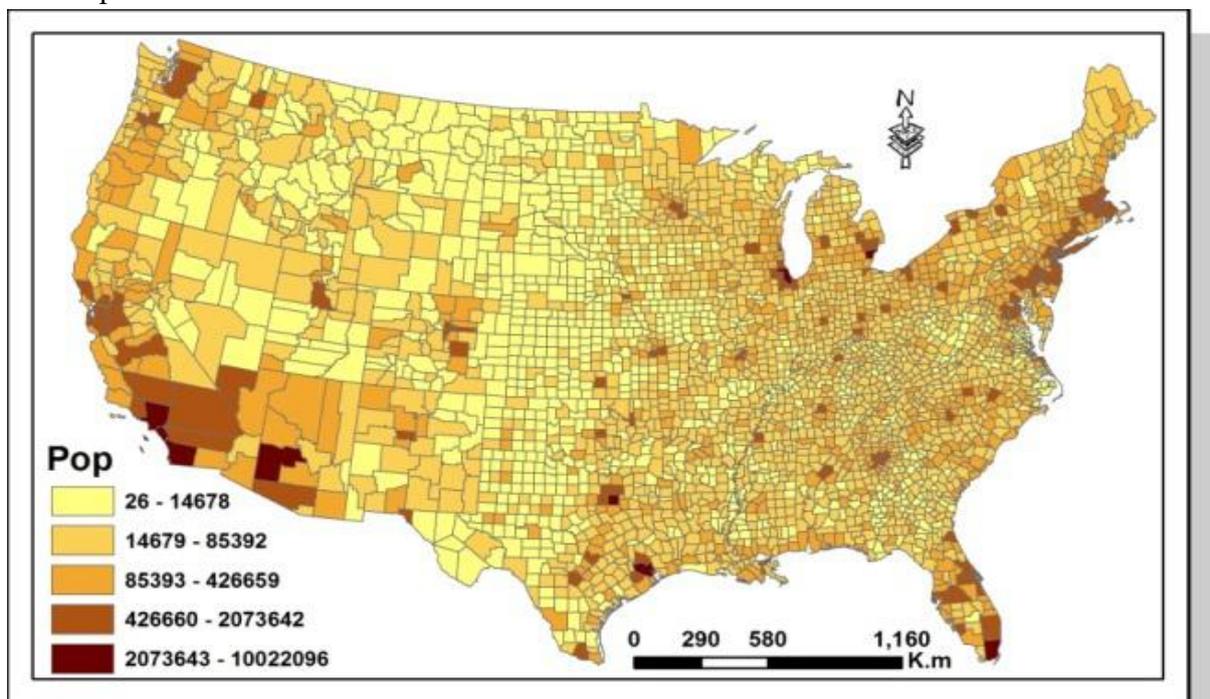
**Map 4.** The Population of USA in the Year 1990 Based on Counties



**Map 5.** The Population of USA in the Year 2000 Based on Counties



**Map 6.** The Projected Population of USA in the Year 2010 Based on Counties Using the Developed Tool





## Summary and Conclusions

The results of the research shows the success in developing a tool for population projection, which is characterised by the tremendous speed in obtaining the projection data as well as the accuracy of the results when compared to the traditional method.

The tool was run in a laptop environment with an Intel (R) Core (™) i5-3230M CPU @ 2.60GHz processor and 6.00 GB RAM Memory.

The population projection of the 8 Nineveh Governorate districts took 3 seconds using the developed tool. This means that the tool reduced the time of population projection by 15.57 minutes compared to the traditional method when using the same data. The average time taken to process a population of one spatial unit using the traditional method takes 2 minutes for experienced researchers and beginners using the traditional methods. This estimated time was determined by the researcher when testing for population projection speed by a sample of researchers consisting of three experienced and three beginner researchers.

A Huge time difference was shown between the use of the developed tool and the traditional method in the population projection of the 3111 USA counties. Projection using the developed tool took 7 seconds for these counties, while the population projection of the same counties using the traditional method was estimated at 6222 minutes, equivalent to 4.3 days of continuous work. The developed tool ads another advantage by providing the user with accurate information about the average annual population change and growth for each spatial unit automatically in the Attribute table linked to the spatial units in ArcGIS desktop 10.x simultaneously with the projection.

The developed tool can be used by researchers provided that their computers are installed with ArcGIS desktop software version 10.x or later. ArcGIS desktop software must be installed with Arc Info and Arc Editor because the developed tool works with the data management tools application available in these two levels only and not available the Arc View level.

The research reached the following conclusions:

- 1- Although ArcGIS desktop 10.x lacks a population projection tool, it does have an environment suitable for modelling and development that can be invested in overcoming this shortcoming.
- 2- The developed tool is characterised by ease of use as well as its high efficiency in population projection, as it contains 5 parameters only and is easy to use by both beginners and advanced users of ArcGIS desktop 10.x.



- 3- The developed population projection tool saves a lot of time and effort compared to the traditional method in the projection process and obtaining data for the annual rate of change and growth. Instead of wasting time and effort using traditional methods, projection with the use of the developed tool is very easy and helps redirect time and effort to other research objectives.
- 4- The accuracy of the results from using the geometric mean equation, in both the traditional method and the tool developed in this research, depends on the accuracy of the censuses. The accuracy of the results increases with shorter time intervals between censuses and vice versa.
- 5- There is no significant difference in processing time when increasing the number of spatial units when projecting population using the developed tool, because the tool deals with field records and not columns. In other words, increasing the number of records (variance of data for spatial units) in a single field does not relatively affect the time taken to complete the work of tools dealing with fields in the Attribute table within ArcGIS desktop 10.x.



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