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Tales of Archaeological Places: Visualizing Mayan Pre-Colonial Settlement Patterns

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TALES OF ARCHAEOLOGICAL PLACES: VISUALIZING MAYAN PRE-COLONIAL SETTLEMENT PATTERNS

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TALES OF ARCHAEOLOGICAL PLACES:
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ABSTRACT

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In order to visualize ancient Mayan settlement patterns and demography through time, data derived from 26 published archaeological sites were collected and plotted onto three discrete map media. These data were subdivided into six time periods ranging from Pre-Classic to Post-Classic, and were simulated for each map medium. Specific attention was given during the selection of geographical locations, natural landscape features, map annotation, layers and coordinates. Tabulated information were site names, coordinates, site founding dates, site decline/abandonment dates, and estimated population. Combined with existing country base map layers downloaded from online geographical sources and time series animation (an animated map), the data show ancient Mayan settlement patterns and demography during the time period spanning from 1500 BC to AD 1542. This pilot study demonstrated that of the three applied map media (static, interactive, and animated), it is the animated version that best represents data visualization changes in ancient Mayan settlement patterns, demography, and potential causes of decline/abandonment.

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Introduction: Ancient Maya

The Mayan civilization was one of the most dominant indigenous societies of Mesoamerica in the Pre-Colonial era (Essential Humanities, 2015). There is archaeological evidence of this preserved at many sites distributed within the present-day countries of southern Mexico, Guatemala, Belize, Honduras, and northern El Salvador (Sabloff, 1994). The evidence of Mayan civilization manifests in the form of ruins and monuments representing ancestral ceremonial centers and sites. Over the past century, scholars and other experts have identified, explored, and excavated many of these Mayan sites (Chase et al., 2014). As evidence has been uncovered, many scholars have forwarded various interpretations about the evolution of Mayan civilization complexities and settlement patterns (Hammond, 1974a; Rivet, 1960; Zaccagnini, 2003). Other scholars have disagreed and offered alternative interpretations about the nature of ancient Mayan settlement and subsistence patterns, and population rise and decline, ultimately postulating reasons for abandonment (Sheets, 2002; Scherer, 2007). Included in this pilot study are perspectives that address the intensification and eventual abandonment of these large centralized ceremonial centers.

The present study specifically addressed the temporal changes of selected Mayan sites where data are available and then plotted those data through the use and development of three different types of mapping media. This study also considered the following information/data plotted onto a simplified temporal scheme, including 1) founding dates of the sites, 2) estimated peak populations at the height of settlement, 3) abandonment dates of the sites, and 4) possible reasons for decline/abandonment.

Archaeological field methods for documenting and describing the settlement patterns were employed, including 1) applications of LIDAR (light detection and ranging) to the natural landscapes surrounding Mayan ruins, and 2) reconstructing political affiliations by using epigraphic models (interpretation of Mayan hieroglyphics on stelae and other monuments) (Chase et al., 2014). Such methods produce results for only one time period at specific sites or regional areas.

A comprehensive review of online and published sources uncovered no specific reports employing computational interactive or animation map media that addressed the different temporal periods of Mayan settlements and ceremonial centers during the Pre-Colonial era. Thus, the purpose of this pilot study was to acquire the available data from 26 documented Mayan archaeological sites, plot those data onto the three types of map media (static, interactive, and animated), and present visual representations of the founding and decline/abandonment dates of these sites as a final product.

Research Question

Do representations of ancient sites' founding and abandonment dates incorporated into animated (as opposed to static and interactive) maps enable researchers to better understand changes in population size and settlement patterns? In order to address this question, the following Phase I methodology was developed as part of this research that included the mapping of 26 recorded Mayan geographical locations in chronological order, resulting in the generation of 37 individual static maps. These 37 static maps served as a baseline plot in order to develop the next phase of mapping. Phase II methodology involved the mapping and transfer of those plotted data sets from the static

maps to an animated map. The geographical locations of each site are found in Appendix A.

The Mayan archaeological sites considered in this study were first grouped into three general established time periods (Pre-Classic, Classic, and Post-Classic) presented in Table 1. After the sites were plotted, the three time periods were further subdivided into six temporal periods, for purposes of a more refined analysis. As part of the overall methodology, these plotted data were evaluated and presented in 1) tables, 2) figures, 3) static maps, 4) an Environmental Systems Research Institute (ESRI) Story Interactive Map, and 5) an animated map. The static maps and the animated map are presented at the same scale for comparability while the interactive map has a variable scale.

Two different approaches were employed to answer the research question. First, a basic cartographic assessment was completed for the three different map media. Second, in order to arrive at an understanding of Mayan settlement patterns, an analysis addressing the expansion of the population at its height was conducted for all 26 sites, with those data factored into the mapping and charting of evidence. Criteria and data were derived from various sources. The results were analyzed to formally answer the question of whether animated maps versus static or interactive maps enable researchers to successfully evaluate plotted geographical, temporal, and population data addressing changing settlement patterns through time.

Definitions and Assumptions

The key terms and concepts used in this research are as follows:

Study Area: the extent used to define a focus area for a map.

Cultural Geography: the field of geography concerning the spatial distribution and patterns created by human cultures and their effects on the earth.

Settlement Archaeology: the study of societal relationships using archaeological data.

Time Series Visualization Map: a type of map that contains records, each of which is specific to both individual coordinates and to a single point of time.

Mercator Projection: a cylindrical map projection of the earth.

One of the assumptions in this study was that ancient settlement patterns may have been affected by various natural and cultural conditions. For example, drought, exhaustion of nutrients in the land, clear cutting of forests, warfare, and civil strife are potential explanations for shifting settlement patterns. There are many theories behind the decline/abandonment of the Mayan civilization. Archaeologists have hypothesized that the sites collapsed due to wars, climate change, volcanic eruptions, excessive population, resource competition, or for other as yet unknown reasons. Appendix B presents some of the hypotheses for the decline/abandonment of each site.

Another assumption incorporated into this study was that plotting settlement patterns through an animated map can lend support to some generally accepted theories. Based upon available published sources, the selected sample of the 26 archaeological sites was incorporated into an animated map. The end result of the generated animated map provides support for map animation as a useful analytical tool for researchers to plot

and visualize changes in ancient Mayan settlement patterns and population fluctuations through time.

The final predicted outcome was that students and scholars can independently apply the methodologies and principles behind the plotting of data sets onto all three mapping media in order to gain greater insight into the changing dynamics of other ancient civilizations.

Literature Review

A brief review of a few key terms and concepts related to static, interactive, and animated maps as well as some history of the Ancient Mayan archaeological sites and civilization were completed to provide background information for this research. The literature review is divided into the following subsections: the first subsection introduces a brief history of Ancient Mayan civilization, the second subsection provides a comparison of the three map media, and the last subsection presents four static maps of the area under study.

History of Ancient Maya

The highlights of ancestral Mayan civilization include a variety of complex social, political, ceremonial, educational, and scientific developments. This includes the development of a multiyear calendar, a form of hieroglyphic writing and numeral notation, astronomical observatories and ceremonial temples, ballgame arenas, and ritual sacrifice. The ancient Mayan civilization's geographical territory extended over a large area that encompassed the present-day countries of Honduras, El Salvador, Guatemala, Belize, and much of southern Mexico (Sabloff, 1994). Based on the most likely reasons behind decline and abandonment of the sites ascertained from findings in research papers, there was communication between chiefdoms and ceremonial centers (e.g., Calakmul and Tikal) through complex transportation and communication networks (National Geographic, 2010). However, though the civilization had inner conflicts and declined for various reasons, the ancient Mayan civilization did not completely disappear after the collapse of its ceremonial centers. In the ensuing centuries, the Mayan communities

seem to have reformulated adaptive settlement and subsistence patterns. Their descendants still live within their respective historic and linguistic territories (Suter & Buell, 2015).

Zaccagnini (2003) hypothesized that the selected geographical locations of founding sites and ceremonial centers, also tied temporally to specific time periods, factored into the cosmological beliefs of the ancient Maya. Based upon the archaeological evidence, the establishment of ritualized ballgame arenas, temples, and other residential structures representing day-to-day activities factored into Zaccagnini's analysis.

According to the Association for Belizean Archaeology, the temporal periods subdivided into Archaic, Formative, Classic, Post-Classic, and Colonial provide the synthesized, interpretive, and temporal framework utilized for the present study (Cubola Productions, 2015). The revised temporal framework has been simplified and reduced to three general time periods for ancient Mayan civilization: 1) Pre-Classic, 2) Classic, and 3) Post-Classic (see Table 1).

As mentioned above, a total of 26 sites were selected for inclusion in this study based upon the availability of published data. According to available information on these sites, the dates were placed into the generalized three-part temporal period scheme developed for this region (see Table 1). The Pre-Classic Period includes 14 sites, 2 of which were no longer occupied before the end of this period (see Table 2); 8 of these sites were abandoned during the Classic Period, 3 others ended their occupation during the Post-Classic Period, and one collapsed in the Colonial Period (see Table 2). The

Classic Period involves 9 sites, with 6 of them abandoned during this period, and the remaining 3 abandoned sometime during the Post-Classic Period (see Table 3). The Post-Classic Period involves 3 sites; 2 of which were abandoned during this time period, while the third ended during the Pre-Colonial time period (see Table 4). The temporal ranges of occupation of these sites are presented in the methodology section of this paper, in Tables 2-4.

Table 1. Ancient Mayan Time Periods

Time Periods	**Approximate Dates**
Post-Classic Period	AD 900-AD 1542
Classic Period	AD 250-AD 900
Pre-Classic Period	2000 BC-AD 250

(Source: Cubola Productions, (2015))

"The Mayan civilization only entered history at the beginning of the Christian era" (Rivet, 1960). Rivet explained further that these people of the Mayan civilization were originally organized into nomadic tribes. They lived for centuries by hunting, fishing, and food gathering for centuries, with no apparent agricultural activity until 1000 BC. At the time that Rivet's book, *Maya Cities,* was published in 1960, there were already disagreements between prominent archeologists such as Morley and Caso with regard to authenticity of the evidence of the first Mayan city. For purposes of this study, the earliest identified site is Cuello, located in present-day Belize (Hammond, 1973a). By the time of Cuello's founding in approximately 2500 BC, the Mayan civilization had thrived during the formative period of socio-cultural complexity and architecture of

formative complex non-city-state chiefdoms, but engaged in pre-agricultural subsistence activities. Therefore, although some of the earliest Mayan sites were established during the Pre-Classic Period, those factors influenced the civilization's settlement patterns.

A Comparison of Map Media

Within this subsection, three map media types are discussed: 1) static, 2) interactive, and 3) animated. Static maps are individual maps visually showing the plotted data with accompanying legends or information in text format. Interactive maps consist of an end-user, a computer, iPad or smart phone, and graphic user interface for display and analysis of plotted data. Animated cartography is similar to an interactive interface, with the exception of an allotted time frame to view the data with the option of pausing the animation.

The Great American History Machine, created in 1988, was one of the first publically available interactive maps, requiring more than 2 minutes for the end-user to fully download (Peterson, 1995). Over the years, changes in computing and integrative mapping technology have enhanced the ability of researchers to conduct detailed and comprehensive geographical and population analyses.

In recent years, Esri's Story Map and Google Tour engine offer a much shorter download time. Furthermore, during the period of The Great History Machine in the 1980s, there were limits on map file sizes. Currently, most data are stored on cloud services, readily accessible for download at any time. There are different integrative categories for the end products of those maps based on the type of data stored and

available. Peterson (1995) divided map interaction into three categories: electronic atlases, maps for navigation, and data analysis.

Esri's Story Map (in the data analysis category) was used to represent the data employed in the present study. The Esri Story Map Gallery holds certain published story maps, created by StoryMaps, Community_examples (Esri's vocabulary word used to describe joint work), and registered members of Esri. Three story maps provide data and locations within Mesoamerica: "Indigenous People of Mexico," "Historical Monuments of Mexico," and "Maya Archaeological Sites in Belize" (Esri, 2015). It is important to note that this gallery does not contain all of the possible published story maps dedicated to the theme of Mayan archaeological sites. Rather, the gallery only contains those maps that were submitted to the Esri team (based in Redlands, California). The authors of these submitted story maps have a choice of having their maps displayed in the gallery or not.

None of the above discussed maps included complete or even sufficient archaeological data. As a result, this study included development of a complete set of static maps compiled into one single interactive and one single animated map.

Griffin et al. (2006) tried to address some concerns from a study by Tversky et al. (2002), involving an experimental design with the same maps in animated form and static-multiple forms, using a within-subjects experimental design and small-multiple condition, given to 24 students. "The experiment tested each participant on three coherence levels (no patterns, subtle pattern, and strong pattern) and at four distinct paces (5, 7, 9, and 11 sec)" (Griffin et al., 2006, p.744). Results of the experiment showed that

participants identified patterns correctly more often using the animation than they did using the static-multiple small maps. The participants completed the experiment more quickly when using the animation portion.

As a result of this study, static maps showing founding and decline/abandonment dates plotted within the three proposed time periods are limited in terms of visual representation. Using static maps for a small population is manageable; however, using static maps to learn about patterns of change for a large population would increase the overall number of maps, thus creating a larger potential margin for error. After a while, the end-user may give up attempting to find those patterns, due to the number of maps. Furthermore, along with the maps, the end-user would need to independently view information in table and text format, especially if the static map did not internally provide it. In an interactive map, the end-user has tables and images as well as the map itself to view various data sets. The amount of time needed to go through an interactive map is faster than static maps; however, animation maps or a Time Series Visualization Map as an end product ultimately saves research time over both static and interactive maps.

Static Maps: Profile of the Study Area

In order to provide baseline information including boundaries of countries (see Figure 1), distribution of sites by 6 time periods (see Figure 2), distribution of the sites by countries (see Figure 3), and sites by probable reasons of decline/abandonment (see Figure 4), the static maps below were generated, with data derived from information in Appendix A and Tables 2-4.

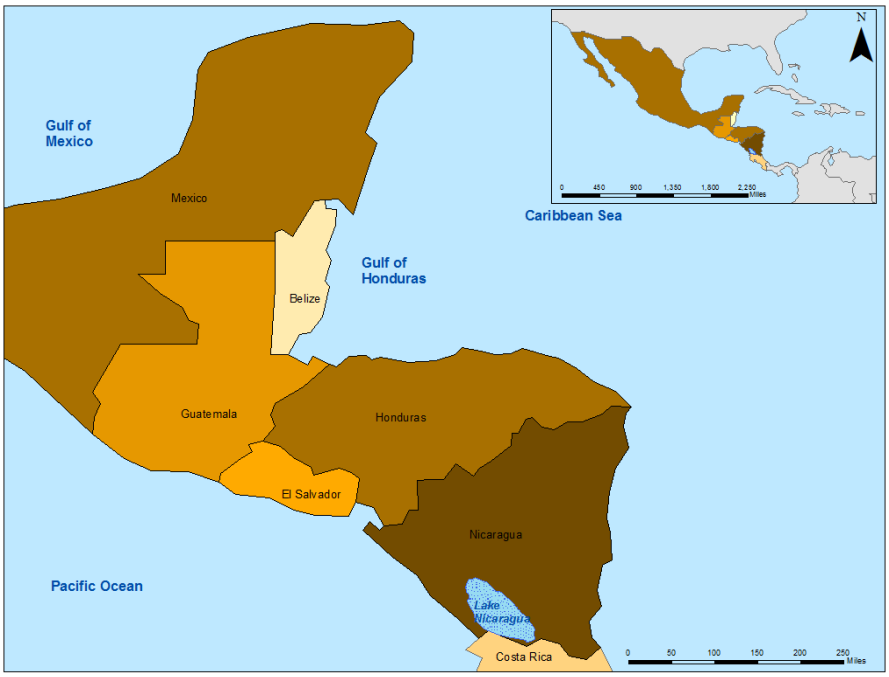

*Figure 1.*Study area: Mexico, Guatemala, Belize, El Salvador, and Honduras. (Source: ArcMap 10.2.2 country base layer map)

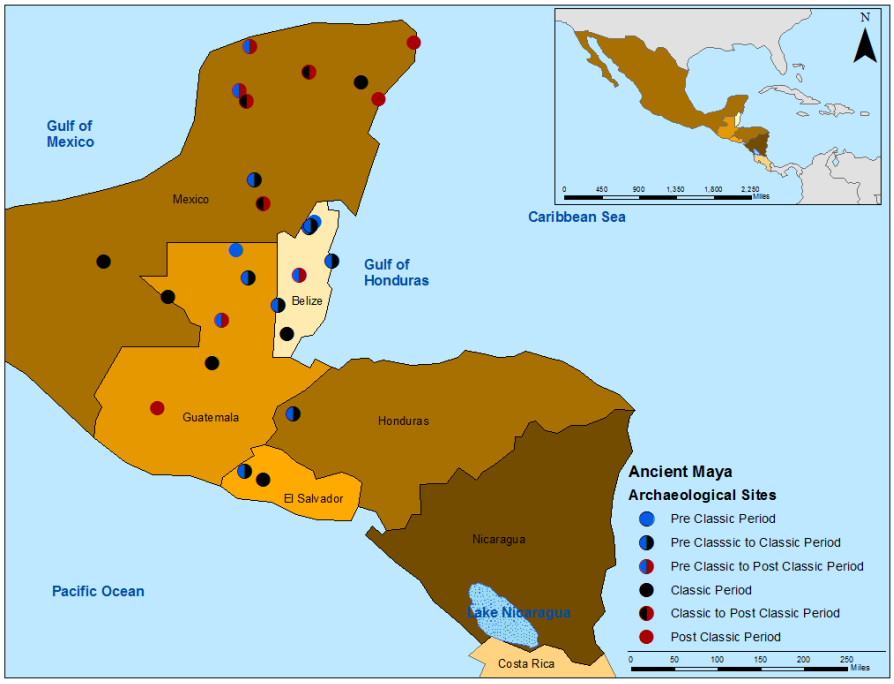

*Figure 2.*Mayan archaeological sites divided into six sub-time periods. (Source: ArcMap 10.2.2 country base layer)

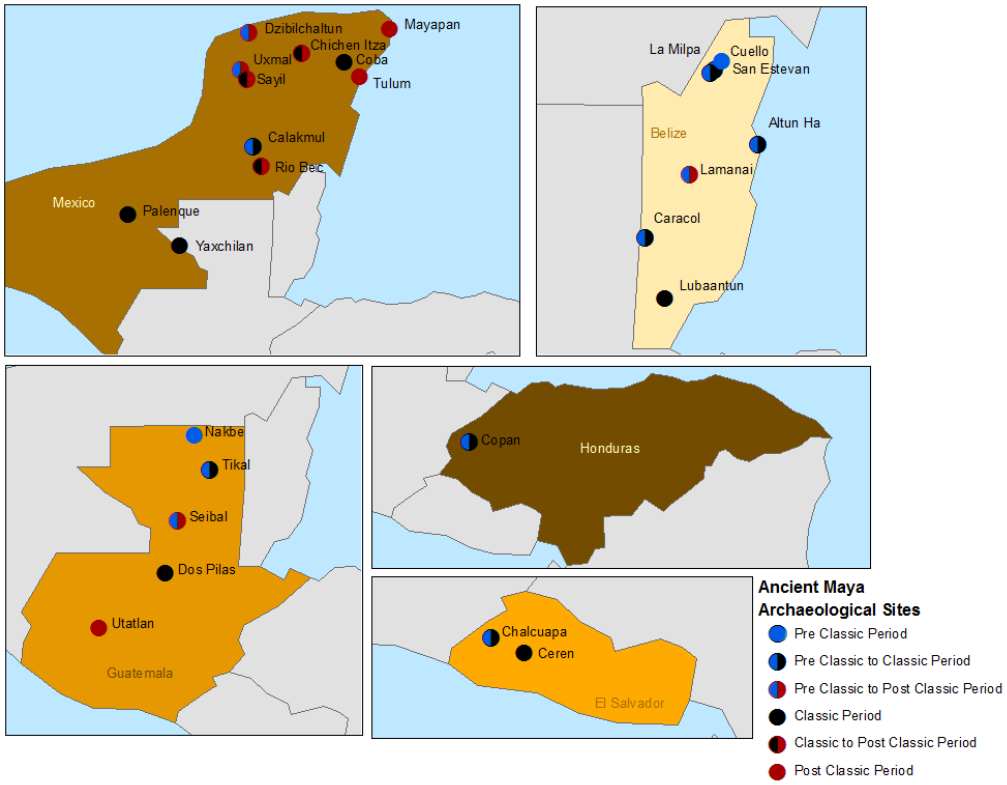

Figure 3. Distribution of 26 Mayan archaeological sites by country.
(Source: ArcMap 10.2.2 country base layer)

Figure 4. Distribution of the 26 Mayan archaeological sites by probable decline.
(Source: ArcMap 10.2.2 country base layer)

Methodology

The data collected from several sources were evaluated, using ArcGIS 10.2.2 and Photoshop programs. Quantitative rankings for the research sources were scored one through six, with one as the lowest rank and six the highest. Quantitative rankings were based on the visibility of the data imported onto multi static maps, an interactive map, and an animated map.

Study Area

The study area for this research consisted of 26 archaeological site locations at two different spatial scales located in present-day countries of Honduras, El Salvador, Guatemala, Belize, and southern Mexico. The spatial scales included one mid-scale regional study area and five large-scale local study areas (see Figures 2 and 3 above). The mid-scale regional study area includes the five present-day countries mentioned above. The two most heavily populated areas in Ancient Mayan civilization correspond to what is now Mexico and Belize.

The study area is located south of the Tropic of Cancer and north of the equator (23 degrees 27 minutes). Sierra Madre de Chiapas, Cordillera Isabelia Mountains, Sierra Maestra Mountains, Lucayan Archipelago, Greater Antilles, Lesser Antilles, Isthmus of Panama are some of major geographical features within this area of Central America.

The first of the five present-day countries is Honduras, located in the north-central part of Central America. Its key geographic features include the Caribbean in the north and Pacific Ocean to the south; Guatemala to the west; El Salvador to the south; and Nicaragua to the east. The second largest country in Central America, Honduras is a

mountainous region, characterized by fertile plateaus, river valleys, and narrow coastal plains.

The second present-day country in the study region is El Salvador, which borders the North Pacific Ocean, situated between Guatemala and Honduras. The terrain is tropical on the coast and temperate in the uplands. El Salvador is known as the "Land of Volcanoes," because of the Apaneca Range and the Cerro Singuil, Izalco, Santa Ana, Coatepeque, San Diero, San Salvador, and 13 other volcanoes (VolcanoDiscovery, 2015).

The third present-day country in the study region is Guatemala, bordered by Mexico on the north and west, with Honduras, El Salvador, and Belize to the east. The country has three types of environments: cool highlands, tropics along the Pacific and Caribbean coasts, and the tropical rainforest in the northern lowlands.

The fourth present-day country in the study region is Belize. Belize lies along the Caribbean Sea, nestled to the right of the northern border between Mexico and Guatemala. The environment is thickly forested with hardwood trees. Swamps and cays along the caves transition into hills and mountains away from the coast.

The last present-day country in the study region is Mexico. Mexico is bordered by the United States to the north, with Guatemala and Belize to the southeast. A high plateau runs through its center with mountain chains on the east and the west. Mexico is divided into several states, with only a portion of present-day Mexico falling within this study area: parts of Quintana Roo, Yucatan, Campeche, and Oaxaca.

Background Information

The 26 ancient Mayan archaeological sites were identified and generated in ArcMap 10.2.2. The site geographical locations were added to the land cover layer (country base map) of the mid-scale regional study area. These archaeological sites were selected on the basis of their confirmed geographical locations, as well as their ties to the ancient Mayan population. The founding and decline/abandonment dates (BC and AD) were reported in Tables 2-4. Estimated populations at the height of settlement period were researched for each site; their importance was to show expansion of the population not just geographically but also politically. However, not all sites had population data; if no population data were available, this was noted as "unknown" and presented as a break on the line graph for the animation. For the postulated reasons for Mayan site abandonment, see Appendix B.

Table 2 provides the names of selected sites, founding dates, abandonment dates, and population peaks for the Pre-Classic Period.

Table 2. Pre-Classic Period Ancient Mayan Archaeological Sites

Site Name	**Founding Date**	**Abandonment Date**	**Population Peak**
Cuello	2500 BC	AD 500	Unknown
Copan	2000 BC	AD 300	22,500
Lamanai	1500 BC	AD 1680	35,000
San Estevan	800 BC	AD 200	Unknown
Chalcuapa	800 BC	AD 400	Unknown
Uxmal	800 BC	AD 1000	25,000
Tikal	600 BC	AD 900	62,000
Caracol	600 BC	AD 900	115,000
Dzibilchaltun	500 BC	AD 1500	200,000
Calakmul	400 BC	AD 900	50,000
La Milpa	400 BC	AD 900	46,000
Nakbe	300 BC	AD 150	Unknown
Seibal	300 BC	AD 950	7,577
Altun Ha	200 BC	AD 550	2,733

(Sources, by order of date of founding: Association for Belizean Archaeology (2015), UNESCO (2015c), Rosenswig (2008), Sharer (1969a), UNESCO (2015e), UNESCO (2015h), Chase & Spencer (2014), Maya World Expeditions (2014), UNESCO (2015a), Tourellot (1999), Hanson (2002), World Monument Fund (2015), and Institute of Archaeology (2015a))

Table 3 provides the names of selected sites, founding dates, abandonment dates, and population peaks for the Classic Period.

Table 3. Classic Period Ancient Mayan Archaeological Sites

Site Name	**Founding Date**	**Abandonment Date**	**Population Peak**
Palenque	AD 325	AD 900	Unknown
Chichen Itza	AD 415	AD 1500	50,000
Ceren	AD 470	AD 595	200
Coba	AD 500	AD 900	50,000
Rio Bec	AD 600	AD 1000	Unknown
Dos Pilas	AD 670	AD800	3,000
Lubaantun	AD 730	AD 890	600
Yaxchilan	AD 741	AD 771	Unknown
Sayil	AD 800	AD 1000	Unknown

(Sources, by order of date of founding: Scherer (2007), UNESCO (2015f), UNESCO (2015b), Hacienda Tres Rios (2011), Holloway (2014), Houston (1985), Institute of Archaeology (2015b), Tate (1992), and Smith & Dore (1992))

Table 4 provides the names of selected sites, founding dates, abandonment dates, and population peaks for the Post-Classic Period.

Table 4. Post-Classic Period Ancient Mayan Archaeological Sites

Site Name	Founding Date	Abandonment Date	Population Peak
Mayapan	AD 1100	AD 1450	17,000
Tulum	AD 1200	AD 1520	1,600
Utatlan	AD 1400	AD 1529	15,000

(Sources, by order of date of founding: Hammond (1974a), Mayapan Archaeology (2015), Loco Gringo (2014), and Babcock (2012))

The United Nations Educational, Scientific and Cultural Organization (UNESCO) website was consulted to determine which Mayan sites in the selected sample are included in the "World Heritage List." Only 7 out of 26 Mayan archaeological sites were determined to be part of UNESCO's Word Heritage List. These archaeological site geographic locations were taken from the UNESCO website and converted using the Federal Communications Commission (FCC) Degrees, Minutes, Seconds to/from Decimal Degrees Converter. UNESCO has developed specific criteria for a site to be included on the World Heritage List: "[t]he sites must be of outstanding universal value and meet at least one out of ten selection criteria" (UNESCO, 2015g).

These 7 archaeological sites met a variety of UNESCO criteria. Each site met two or more criteria out of ten, with each site having an individual page with the following information: 1) present-day country location, 2) photographs, 3) synopsis, and 4) historical summary. Table 5 provides the Mayan site name and the various coded criteria assigned to each site. Appendix C provides summarized descriptions of these

criteria derived from the UNESCO website. The UNESCO website data were selected based upon a high degree of geographic reliability, as well as other related criteria.

Table 5. Archaeological Sites under UNESCO Criteria included in This Study

Site Name	**Criteria**
Calakmul	i, ii, iii, iv, vi, ix, and x
Ceren	iii, and iv
Chichen Itza	i, ii, and iii
Copan	iv and vi
Palenque	i, ii, iii, and iv
Tikal	i, iii, iv, ix, and x
Uxmal	i, ii, and iii

(Source: UNESCO, 2015g)

Limitations of this Study

The limitations encountered during the acquisition of comparable data for the development of all three maps representing the ancient Mayan archaeological sites, estimated populations, and explanations of decline and abandonment presented several challenges. One of these limitations was that the estimated populations at the height of settlement as well as the founding and decline dates were derived from several sources, which provided differing, often conflicting information. During the course of this study, the archaeological site locations were carefully analyzed in conjunction with selected population data. Even though there are more than 26 sites associated with the ancient Mayan civilization, not all those recorded sites are represented in this study, for several

reasons. These reasons include: 1) many of the archaeological sites were not clearly identified in the various archaeological publications, 2) although identified on previously published maps, during the course of this research, no specific information was available on many of these sites, and 3) the available sources that had many of the sites identified were limited to tourist-type information, and therefore were not acceptable in terms of the criteria implemented for this study. Furthermore, although scholars often disagree and offer various interpretations about the factors contributing to the rise, decline, and abandonment of Mayan civilization, a decision was nonetheless made on the basis of study area to utilize the data derived from the various available published sources for inclusion in this pilot study. Another constraint was developing an adequate standard for representational symbols indicating the location of the 26 sites, temporal periods, and the factors contributing to the decline and abandonment (e.g., volcanism). Constant representational symbols had to be established for all the three map media (static, interactive, and animated). Furthermore, the sites had to be represented by the following symbols: (1) name, (2) location, and (3) assigned temporal period(s).

The static and animation maps displayed the representational symbols; however, the interactive Esri Story Map did not have the ability to display these symbols. Instead, three colors — blue, red, and purple were used in the interactive Esri Story Map to represent only the founding dates and locations. The colors selected for the static and animated maps were blue, black, and red. In order to follow the consistency of the representing symbols, the media image for each site on the interactive map displays one of the five large-scale study areas with a corresponding legend. The interactive map is

able to show the factors contributing to the decline and abandonment dates only in text format.

The country base map served as the foundation for the static and animated maps while the interactive Esri Story Map relied upon the National Geographic base map. The same base map was chosen for static and animated maps, in order to display variables about population dynamics (rise and decline). Esri's database provides several base maps in an interactive environment, including the National Geographic base map, which was selected for its basic geographical features such as boundaries of countries, oceans, lakes, rivers, and mountain ranges.

Reliability Criteria for Sources

A comprehensive literature search was conducted for published sources providing suitable and reliable data sets. The following criteria were considered for reliability: (1) publisher, (2) author's credentials, (3) accuracy of data, (4) currency of information, (5) possible bias, and (6) audience.

Publisher: This refers to the individual or organization that published or sponsored work the author. Many factors contribute to credible research, both the public and private sector, including accessibility of the publisher, and recognition by others in the field.

Author's credentials: This refers to the individuals or organization(s) engaged in the research and publication. Who was the author or authors? What is their professional background? What were their qualifications for writing about the topic? Credentials help determine the source's credibility in the field being researched.

Accuracy of data: This refers to the quality of the written material within the source or study. Can the data be verified by others? Is there a bibliography that can lend documentation to the research? Do the authors have credibility in the field of study?

Currency of information: This relates to the published date of the study. Does the source reflect current trends in the discipline? Most websites, for instance, do not offer a publication date for their data, making it difficult to assess this criterion.

Possible bias: This refers to the author's position relative to the material. Is the author's analysis objective, with testable hypotheses? Does the author provide verifiable facts and statistical analyses? If there is indeed evidence of bias, does it bear upon the accuracy of the data?

Audience: This refers to the intended readers. Is the source intended for a specific readership (e.g., high school students, university students, professors, or scholars within related disciplines)?

Each criterion was individually rated either 0 (if it was deemed unacceptable) or 1 (if it was deemed to be up to standard). With one point possible for each of six criteria, then, the highest possible cumulative score was 6. The number of research sources scored by criteria was then organized by their respective temporal periods, as shown in Table 6.

Table 6 also shows the availability of plotted data relating to ancient Mayan sites for this study, reflecting the variation of sources with regard to credibility and reliability. Some of the information was not verifiable (e.g., population at peak). Every source was issued a score of 1 for the publisher because the publisher could be verified. There were 2 sources that did not show the author's credentials and 3 sources that were unrated. The earliest date of research was Peterson (1995), about interactive and animated maps. A source was not deemed to be credible if it was assigned a value of 0 in the bias category (e.g., tourist-type). Of the 14 Pre-Classic sources, 9 received 6 out of 6 points for all the criteria. Of the 9 Classic sources, 6 received 6 out of 6 points for all criteria. Finally, of the 3 Post-Classic sources, 2 received 6 out of 6 points for all criteria.

Table 6. Research Sources Used in This Study, Scored by Criteria

Temporal Period	**1**	**2**	**3**	**4**	**5**	**6**	**Total Sites**
Pre Classic	0	1	0	3	1	9	14
Classic	0	1	0	1	1	6	9
Post Classic	0	1	0	0	0	2	3

Data and Processing: Static Maps

The archaeological site data were derived from multiple sources, including both paper and digital publications of various kinds, all cited in the attached bibliography. The map layers were downloaded from the accommodating data disk for the software ArcMap 10.2.2 (Natural Earth, 2015). The archaeological site variables processed were 1) approximate founding date, 2) approximate date of decline or abandonment, 3) estimated

peak populations at height of settlement, and 4) possible reasons for decline/ abandonment. All data were plotted onto a Mercator projection as a base map for this pilot study.

Each site was merged with the base map layer with the aid of the "Add XY Data tool" in ArcMap 10.2.2, in order to create a visual representation of the ancient Mayan sites at their approximate locations. The "Add XY Data tool" imports the latitude and longitude of each geographic location from the Excel data sheet file to create the point layer for the map. Each site's symbol was then edited to show a specific time period, found in Figure 5. Multiple runs were done to minimize error relating to time period. The colors below were chosen for their visual effectiveness in terms of showing up on the country base layer, which is five shades of brown.

Figure 5. Time periods of the Mayan archaeological sites.

As discussed above, Figure 2 shows all 26 sites, while Figure 3 displays the sites located in the five present-day countries. This base map was developed in order to show only the boundaries of the present-day countries, to reflect the previous research on the location of the Ancient Mayan civilization. No other layers, such as mountains or rivers, were included.

Figure 6 shows the symbols used to define the probable reasons for the decline and abandonment of each site. These reasons include: (1) site abandonment, (2) being buried under ash after a volcano eruption, (3) depopulation due to migration or war, (4) depletion of artistic resources, (5) conquest by the Spanish empire, (6) inter-tribal wars and regional conflicts, (7) collapse because of the rise of a rival city, and (8) sudden collapse for unknown reasons.

Figure 6. Symbols for the probable decline or abandonment.

Figure 7 juxtaposes a published map showing the distribution of ancient Mayan sites with the map generated for this study.

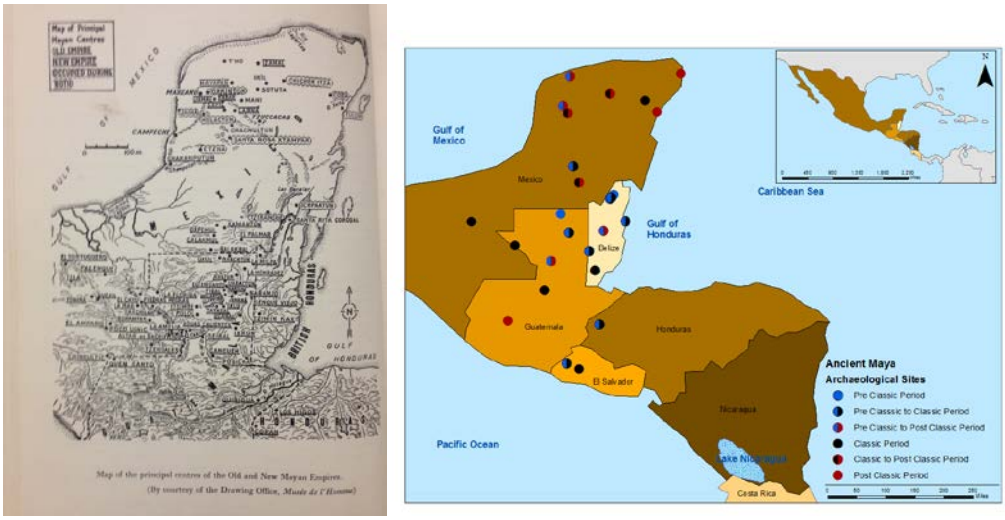

Figure 7. Juxtaposition of a published map from *Maya Cities* with the map developed for this thesis.
(Sources: Rivet (1960), ArcMap 10.2.2 country base layer)

The map published in *Maya Cities* (*Musee de l' Homme)* shown in Figure 7 is a complex map, with clearly more than 26 sites, showing the widespread distribution of recorded ancient Mayan sites throughout the region. Also, the author used three different fonts to represent countries, sites, and water bodies, respectively, without the use of color-coding, making reading it difficult to read. Furthermore, this map does not include a legend or time periods. These types of maps are only useful for showing the general location of the recorded sites, not for showing settlement patterns.

The map that was generated for this study, presented on the right of Figure 7 includes all 26 ancient Mayan sites, a legend, two map scales, and the location of the geographical area within North America. A researcher is able to discern the general locations of the earliest Pre-Classic sites (represented by solid blue circles) populated by the Mayans, which are located in the present-day countries of Guatemala and Belize. Furthermore, the three Post-Classic sites (represented by solid red circles) in this study are at great geographical distances from each other. Based upon this static map and representative sample of the plotted ancient Mayan sites, a researcher can make various determinations about temporal and geographical distribution. Prior to compiling those data points, information had to be plotted onto 37 different static maps. The newly generated map in Figure 7 presented the compilation of the 37 individual maps into a single cartographic representation, which included the temporal and geographical locations. Appendix D presents the 37 static maps in order.

Figure 8 shows two bar graphs, generated for this pilot study, representing the number of the sites by time periods. The bar graph on the left shows 14 Pre-Classic sites,

9 Classic sites, and 3 Post-Classic sites. The bar graph on the right shows the temporal range that includes 2 Pre-Classic sites, 8 Pre-Classic to Classic sites, 4 Pre-Classic to – Post-Classic sites, 6 Classic sites, 3 Classic to Post-Classic sites and 3 Post-Classic sites. The bar graph on the left only shows the founding temporal placement of these sites. The use of the three general time periods is only limited by founding date and therefore is misleading because the data do not include a decline or abandonment date.

The bar graph on the right shows the temporal ranges (founding and decline/ abandonment dates) subdivided into the six sub-time periods. As a result, only 11 out of 26 sites start and end within their respective time periods. Also, it can be discerned that many of the sites continued from the Pre-Classic to the Classic Period.

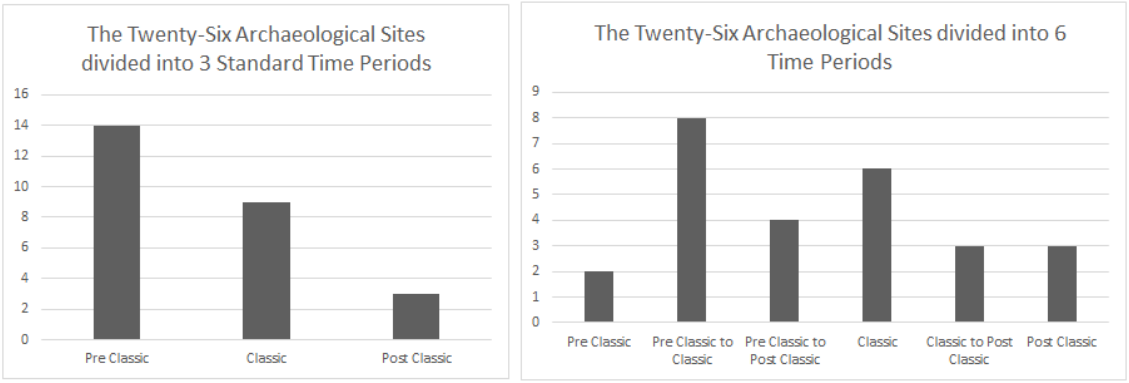

Figure 8. Number of sites by standard time periods and by sub divided time periods

Data and Processing: Interactive Map

In order to generate an interactive map for this project, the archaeological data had to be uploaded as a CSV file into an Esri (Interactive) Story Map template. The research data included the archaeological site name, description, latitude and longitude values, and Photoshop links for the media and thumbnail boxes. After the CSV file was uploaded to the template, the Esri engine plotted the sites to the base map allowing the

project to be editable. After the editing phase of the interactive map, the end-user is able to interact with the plotted data using one ore more of three methods: (1) use a mouse to click through the 26 points representing the site locations, (2) click on the interactive timeline for each site at the bottom of the map, or (3) click one of the arrows found on either side of the accompanying image in order to move to the next site which is ordered by founding date/settlement pattern.

This form of map interaction is organized by founding date chronology and allows the researcher to explore the site settlement pattern more thoroughly than looking at one or multiple static map(s). The end-user may explore the settlement pattern ordered by founding date through the use of multiple static maps, except that this increases the margin of error for order by founding date. If the end-user is provided all the static maps that were used for the animation, an error of placing the static maps showing the declined or abandoned sites may occur, leading the end-user to incorrectly analyze settlement patterns. In the interactive environment, there is no easy way of showing the decline/ abandonment date(s), which is why it is provided in text format. Furthermore, one cannot add a site's data point showing a decline/abandonment date on the timeline, as more than one data point would have two congruent symbols, thus creating a confusing visual view for the user.

Figures 9 and 10 present the finished interactive Mayan Settlement Story Map(s) that were generated as part of this study. Figure 9 was developed to interface with an iPhone.

Figure 10 was generated to graphically interface with computers. To obtain access to these two interactive interfaces, visit http://arcg.is/1JkX8Vm on an iPhone or browser.

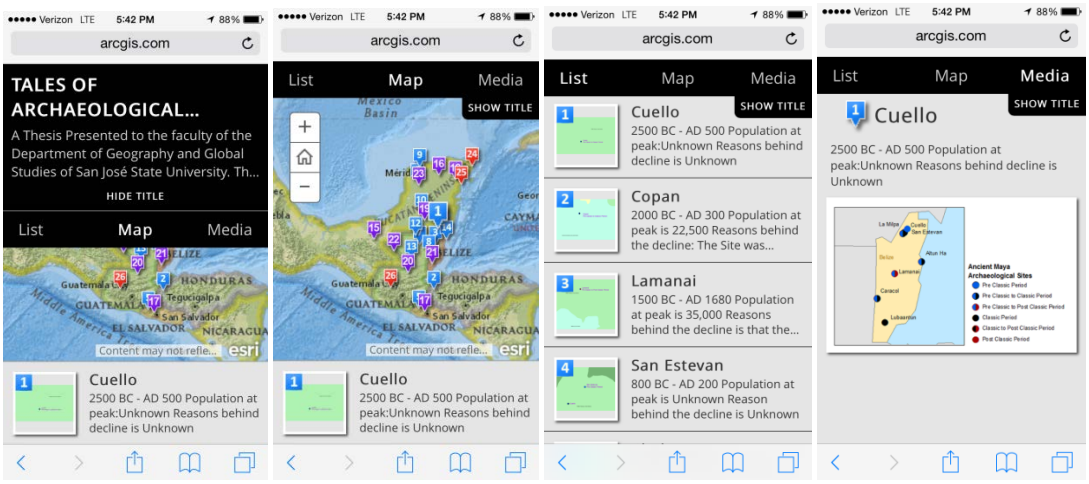

Figure 9. Tales of archaeological places: Visualizing Mayan Pre-Colonial settlement patterns using Esri Story Map on an iPhone.
(Source: Used by permission. Copyright ©2015 Esri, Story Map. All rights reserved.)

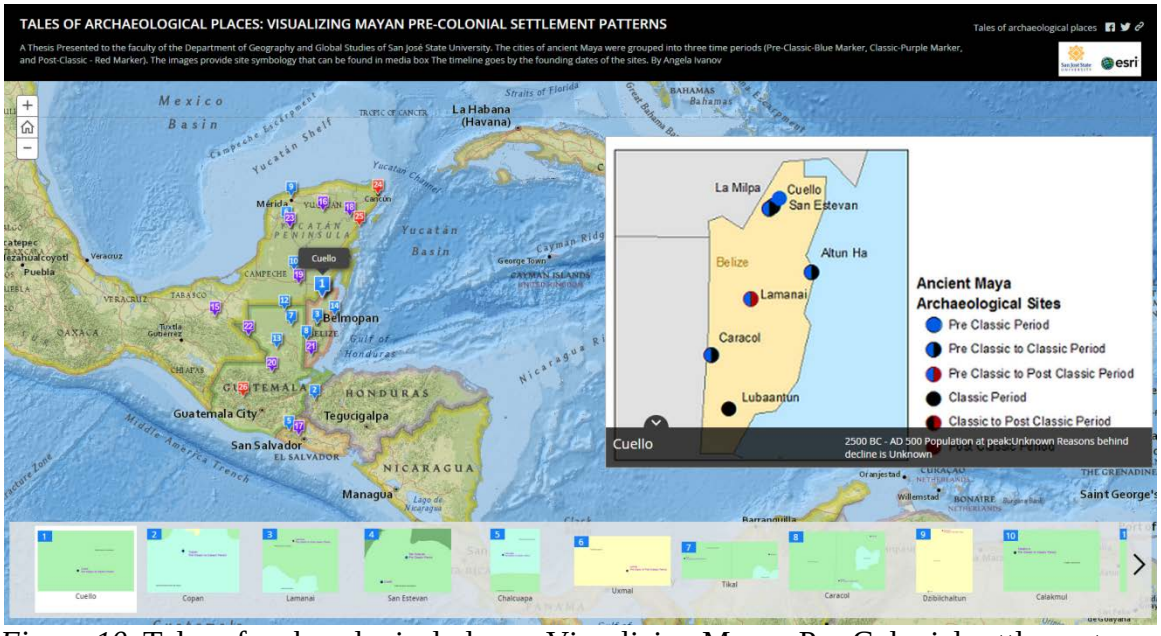

Figure 10. Tales of archaeological places: Visualizing Mayan Pre-Colonial settlement patterns using Esri Story Map on a computer.
(Source: Used by permission. Copyright ©2015 Esri, Story Map. All rights reserved.)

Data and Processing: Animated Map

The steps involving the animation process were much more complicated. As part of this process, 37 static maps were saved at the same scales and loaded into the Adobe Lightroom program for editing. All the images were exported as PNG files to retain some quality of the original image taken from ArcMap 10.2.2. Inside the Adobe Lightroom, the contrast, brightness, hue and sharpness were adjusted for the maximum impact and resolution. The uploaded images then were cropped to show only the study area. All the images were synced together, so they would share the same attributes. All the points would match including: (1) the country boundaries, (2) legends, (3) time graph, (4) map scale and (5) plotted data points. The time graph was edited to match the founding and decline/abandonment dates. Unlike the static maps, the time graph was divided into segments, which appear when an event occurs on the map. The static maps have a constant time graph, mainly done for the end-user's reference. Everything was then exported back into a PNG format, after those edits were completed. Everything was imported into the Adobe Premiere, with titles, music, and credits were added to the animation. The final animation was exported as a 1080 60p footage using the H. 264 codec and CUDA video trans-coding libraries. The video was then uploaded to a YouTube account, located at https://youtu.be/iB2vaVSfM0k. Figure 11 shows the finished animated Mayan Settlement Story Map generated as part of this study.

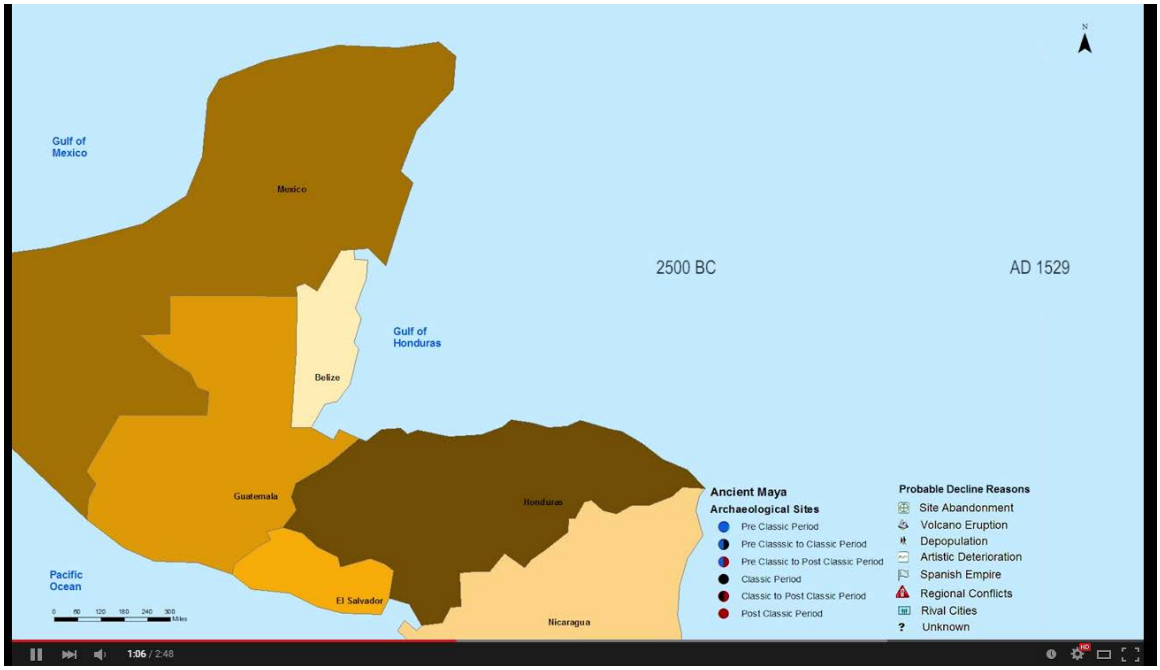

Figure 11. Tales of archaeological places: Visualizing Mayan Pre-Colonial settlement patterns using animated map uploaded to an open access Youtube URL.

Final Analysis

"Maps are abstractions of the world that help us understand our environment" (Peterson, 1995). Most people have a poorly developed mental representation with regard to state of location and its characteristics, especially with modern technology. Today, people enter a destination into a smartphone map app, the app shows the location and how much time will be required to get there, by various modes of transportation. People do not need to analyze the map or prepare a route with a marker on a physical map; the app does everything. Before the iPhone, there was a GPS, now the GPS is embedded into a smart device. With that knowledge, cartographers changed from a physical map medium to a computer medium of interactive and animated maps.

During the data collection phase of this research, the physical map medium presented limitations with regard to the cartographic presentation of ancient Mayan civilization. The limitations only appeared in the physical map medium. Most maps of the ancient Mayan civilization depict only geographic locations of the sites. They do not depict founding, decline/abandonment dates, and population data. Even maps depicting social characteristics through time most often depict only the accepted, predefined time periods, creating a temporal distortion for the end-user.

Cartographers can now create interactive environments, for example, through the use of 'Google Tours' and 'Esri Story Maps.' These interactive displays create tours through time, using whatever data are provided. These maps have text boxes showing the text information and geographic location of each site. Furthermore, they create the tours based upon the imported order of the data sets.

The improvements over static cartography that both the Google and Esri approaches represent, as well as their limited symbology, was the inspiration for developing improved ways of creating an animated map, for purposes of this thesis. The end product of this study makes it possible for a user to see both the founding and decline/abandonment date of each site over time in less than 2 minutes, more realistically than had previously been possible with existing maps. The user can also see the estimated population at peak values on the line graph, along with site name and date. For a site that was abandoned, the site's symbol changes to a probable reason for the decline/abandonment.

Results

The results from the temporal analyses revealed the differences between the three different mapping media. Table 7 presents a simple yes/no tabulation for the visual representation of the plotted data, which includes the following variables: (1) founding date, (2) abandonment date, (3) estimated (population) peak value, and (4) probable reason for decline.

Table 7. Assessment of the Three Map Media

Map Medium	Founding Date	Abandonment Date	Estimated Peak Value	Reason for Decline
Static Map	No	No	No	No
Interactive Map	Yes	No	Yes	Yes
Animated Map	Yes	Yes	Yes	Yes

The 37 static maps in Appendix D show the founding and abandonment dates by geographical location. The maps show the locations by the six subdivided time periods. They do not show the population values or the reasons behind the decline of each site. The static map medium turned out to be the lowest ranked format available for showing temporal settlement patterns.

The interactive map shows the founding dates through a timeline. Abandonment dates, population values, and reasons for decline or abandonment for each site are represented in text format. As a result, researchers rely upon the accompanying text presented in the media image. The interactive map can be used to show temporal patterns through time, though it is not the best analytical tool.

The animated map as an end product for this study shows all the variables. Based on this assessment, the animated map is best option for showing temporal changes because of its presentation of all the data imported into the map.

Discussion

For the purposes of this discussion, the present-day countries were identified in order to analyze the settlement patterns of the 26 ancient Mayan archaeological sites. The plotted sites on the maps generated for this study confirmed Sabloff's (1994) theory of the geographical sphere for this ancient population. These 26 ancient Mayan archaeological sites displayed a wide pattern of geographical distribution and settlement. These sites are usually in close proximity to rivers, large bodies of water, swamps, waterlines, mountains, volcanoes, and forests, as shown by the site maps of individual archaeologists (Gann, 1969, 1917; Anderson, 1957; University of Pennsylvania, 1956). According to UNESCO (2015h), "an inner urban zone of around 400 hectares contains the principal monumental architecture and monuments which include palaces, temples, ceremonial platforms, small and medium sized residences, ball-game courts, terraces, roads, large and small squares." This supports the findings by Zaccagnini (2003), mentioned above in the literature review. Furthermore, there is evidence on preserved decorated surfaces that link Tikal located in present-day Guatemala to Calakmul in present-day Mexico, Copan in present-day Honduras, and Caracol in present-day Belize. This suggests that there was communication between chiefdoms and ceremonial centers through a possible network involving various modes of transportation and communication (UNESCO, 2015h).

Several archaeologists —Gann, Hammond, and Anderson — have created site maps of Lamanai, Cuello, and Altun Ha, respectively, depicting temples and other structures, ball courts, and waterlines (Gann, 1917; Hammond, 1973; Anderson, 1957).

These studies and maps lend support to the argument that each site had important focal points, which might have been connected by well-developed transportation networks that have yet to be clearly identified. The first site in this study, the site of Cuello, located in the present-day country of Belize, had an unknown population density at the height of its settlement; however, the second site, Copan, had a population of about 22,500 at its peak. Although some argue that Guatemala is considered the birthplace of the Mayan civilization and consequently still has a very active Mayan population (Sutter & Buell, 2015), substantial research has hypothesized other theories regarding starting point of ancient Mayan civilization (Cottrill, 2015; Riviera Maya Worldsite, 2002). This study's research on 26 Mayan archaeological sites lends support to the idea that the birthplace of the ancient Mayan civilization was actually Belize, which is congruent with the findings of Hammond (2009b). The largest known approximate population was calculated at 200,000 in Dzibilchaltun, while the smallest known population was estimated at 200 individuals in Ceren. An approximate average population of all the sites included in this study is estimated to be about 39,000.

During the Pre-Classic Period (2000 BC to AD 250), the earliest Mayan site of Cuello, located in present-day Belize, arose around 2500 BC (see Appendix D, Map 2). About 500 years later, around 2000 BC, the Mayans established themselves in Copan located in present-day Honduras (see Appendix D, Map 3). After another 500 years, around 1500 BC, the Mayans expanded to found the city of Lamanai, in present-day Belize (see Appendix D, Map 4). Subsequently, 700 years later, around 800 BC, they had established the site known as San Estevan, relatively close to the first established site

of Cuello. The Mayans also established a ceremonial center at Chalcuapa in present-day El Salvador, and expanded to a site called Uxmal, in present-day Mexico (see Appendix D, Map 5). Two hundred years later, around 600 BC, they established the major ceremonial center of Tikal in present-day Guatemala, and also founded another site named Caracol, in present-day Belize (see Appendix D, Map 6).

One hundred years later continuing, through the Pre-Classic Period, on the coast of Mexico, the ancient Mayans established the site named Dzibilchaltun around 500 BC (see Appendix D, Map 7). One hundred years later, around 400 BC, the Mayans established Calakmul, in present-day Mexico. At the same time as Calakmul was founded, La Milpa arose in present-day Belize, in close proximity to the first site of Cuello (see Appendix D, Map 8). A100 years later, around 300 BC, Nakbe and Seibal were established in present-day Guatemala (see Appendix D, Map 9). One hundred years later, around 200 BC, Altun Ha was established close to present-day Belize City in Belize (see Appendix D, Map 10).

Nakbe was the first site to be abandoned around the year of AD 150 due to a conflict with El Mirador, a rival city (see Appendix D, Map 11). Fifty years later, around AD 200, San Estevan collapsed for unknown reasons (see Appendix D, Map 12). These were the ceremonial centers and towns established during the Pre-Classic Time Period, with decline and abandoning dates spanning over the three general time periods (Pre-Classic, Classic, and Post-Classic).

During the Classic Period (AD 250 to AD 900), Chalcuapa collapsed due to a volcanic eruption while Copan collapsed for unknown reasons, around AD 300 (see

Appendix D, Map 13). Palenque was the first Classic Period site established approximately AD 325 in present-day Mexico (see Appendix D, Map 14). Ninety years later, around AD 415, Chichen Itza was established in present-day Yucatan, Mexico (see Appendix D, Map 15). Fifty-five years after that, around AD 470, Ceren was established in present-day El Salvador (see Appendix D, Map 16). Thirty years later, around AD 500, Coba was established in present-day Mexico. As Coba was beginning its settlement, Cuello collapsed due to unknown reasons (see Appendix D, Map 17). Fifty years after that, around AD 550, Altun Ha collapsed due to a regional conflict (see Appendix D, Map 18). Forty-five years later, around AD 595, Ceren was buried after the eruption of Laguna Caldera volcano (see Appendix D, Map 19). About five years later, around AD 600, Rio Bec was established in present-day Mexico (see Appendix D, Map 20). Seventy years later, around AD 670, the Mayans expanded into present-day Guatemala to establish Dos Pilas (see Appendix D, Map 21). Years later, Dos Pilas collapsed to a conflict with Calakmul, around AD 800, while Sayil was established in present-day Mexico. Lubaantun was established in present-day Belize, around AD 730 (see Appendix D, Map 22). Eleven years later, Yaxchilan was established in present-day Guatemala, around AD 741 (see Appendix D, Map 23). Yaxchilan collapsed thirty years after its establishment due to war with Palenque, in AD 771 (see Appendix D, Map 24). Twenty-nine years later, Sayil was established in present-day Mexico, around AD 800 (see Appendix D, Map 25). Ninety years later, around AD 890, Lubaantun was abandoned (see Appendix D, Map 26).

Ten years later, about AD 900, the beginning of the Post-Classic Period, six sites collapsed for several probable or unknown reasons. Tikal collapsed because of drought, deforestation, internal strife, which led to depopulation and abandonment. Caracol was abandoned. Calakmul collapsed because of its struggle with Tikal for unknown reasons. La Milpa collapsed for unknown reasons. Palenque was invaded by coastal people of Gulf of Mexico and Coba was conquered by the Spanish Empire (see Appendix D, Map 27).

During the Post-Classic Period (AD 900 to AD 1542), a span of 400 years passed before Mayapan and Tulum were established in present-day Mexico as important ceremonial and trade centers. Around AD 950, Seibal was abandoned after an internal war (see Appendix D, Map 28). Fifty years later, around AD 1000, three sites collapsed for various reasons. Uxmal and Rio Bec were abandoned, while Sayil collapsed due to depopulation (see Appendix D, Map 29). One hundred years later, around AD 1100, Mayapan became the political and cultural capital of the Maya in the present-day Yucatán Peninsula, Mexico and was abandoned after internal and external conflicts and perhaps internal strife around AD 1441 (see Appendix D, Map 30 and Map 33). One hundred years later, around AD 1200, Tulum was established on the present-day Yucatán coast of Mexico (see Appendix D, Map 31). Two hundred years later, around AD 1400, the last site, Utatlan was established in present-day Guatemala and collapsed because of the war with the Spanish Empire, around AD 1529 (see Appendix D, Map 32 and Map 36). Around AD 1500, Dzibilchaltun was conquered by the Spanish Empire, while Chichen Itza lost to a Toltec rival city (see Appendix D, Map 34). Twenty years later,

around AD 1520, Tulum's population was killed off by Spanish diseases (see Appendix D, Map 35). One hundred and fifty-one years later, the last site out of the 26 sites in this study, Lamanai, which was an exception, was abandoned around AD 1680, which continued into the historic Colonial Period (see Appendix D, Map 37). For an animated experience, visit the YouTube link at https://youtu.be/iB2vaVSfM0k.

Conclusion

Three map media were successfully used in this pilot study for the purpose of showing ancient Mayan founding and abandonment dates, along with other variables, incorporated into animated (as opposed to static and interactive) maps, enabling users to address questions about changes in population size and settlement patterns. The success of this pilot study may be traced to several factors. First, the maps (static, interactive, and animated) are easy to use, even for those with minimal experience with plotted data. Second, the user is able to identify the three map media and able to choose the most efficient medium to learn about the 26 ancient Mayan archaeological sites. Third, this pilot study can be replicated by scholars, experts, and users to answer their temporal questions on different topics. The implementation of the principles employed in developing animated maps is suitable for use in settlement pattern archaeology, demography, and other fields relating to geography.

Several findings were arrived at as a result of this study. First, static maps are still very important when analyzing settlement patterns and demographic data. The 37 static maps were used as a basis for the successful animated map. Static maps on their own can be difficult to navigate but can be incorporated into other map media, for analytical purposes. Second, the type of sources one uses for research is important. Reliability criteria for resources should always be evaluated, with regard to the credibility and reliability of published source information. Third, when plotting proposed temporal periods, it is important to evaluate how the accepted temporal periods are implemented. In this pilot study, the 26 sites were placed within the three accepted general time periods

(Pre-Classic, Classic, and Post- Classic) and plotted into histograms in order to understand the temporal distribution of the sites. Furthermore, the three general time periods were subdivided into six temporal periods, for the purpose of showing decline and abandonment dates. Not all sites were abandoned or declined in their individual time period. Fourth, after the map media assessment, the animated map received a "Yes," for all of the plotted data variables. Therefore, the success for the cartographic representation of these variables suggests that the users are able to address questions about changes in population size and settlement patterns relative to the 26 ancient Mayan archaeological sites included in this study.

The hierarchy introduced in this thesis provides a natural guide for future research. Much research remains to be done, to include the sites that were not incorporated into this pilot study. These sites can be added to the maps in order to create a comprehensive animated map, showing ancient Mayan archaeological site settlement and demographic patterns. With advances in mapping technology, this pilot study becomes a guideline for future research in the field of settlement archaeology and GIS. In conclusion, this type of animated mapping can be incorporated into any time series representation in other geospatial research in the natural and social sciences.

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Appendix A: **Geographic locations of Mayan sites plotted by latitude and longitude**

Site Name	Latitude/ Longitude	Source
Ceren	13.8275, -89.369167	UNESCO
Tulum	20.21495, -87.429521	Athena Pub
Nakbe	17.68232, -89.834626	Hanson
San Estevan	18.15508, -88.510582	Rosenswig
Cuello	18.06667, -88.6	Casado
Altun Ha	17.50337, -88.222361	A. K. Scherer
Rio Bec	18.46667, -89.366667	Holloway
Dos Pilas	15.78347, -90.230759	A. K. Scherer
Chalcuapa	13.98163, -89.681375	Sharer
Palenque	17.483056, -92.049722	UNESCO
Yaxchilan	16.89564, -90.966024	Tate
Sayil	20.17696, -89.652127	Smyth
Seibal	16.51167, -90.061111	A. K. Scherer
Mayapan	21.15081, -86.83693	Mayapan
Utatlan	15.02969, -91.144906	Babcock
La Milpa	18.08697, -88.571832	Hammond
Lubaantun	16.2811, -88.9650	IOC
Copan	14.93608, -88.864698	UNESCO
Uxmal	20.361667, -89.770278	UNESCO

Lamanai	17.25764, -88.765335	Casado
Chichen Itza	20.666667, -88.6	UNESCO
Calakmul	18.85766, -89.51846	UNESCO
Coba	20.49472, -87.736111	Coba
Tikal	17.216667, -89.616667	A. K. Scherer
Caracol	16.76308, -89.117811	Archaeology
Dzibilchaltun	21.09121, -89.5975	Maya World

Appendix B: **Postulated reasons of site decline/abandonment**

Site Name	Postulated Reason
Cuello	Unknown
Copan	The site was abandoned
Lamanai	The site was abandoned
San Estevan	Unknown
Chalcuapa	Was buried under ash deposits from Ilapango Volcano
Uxmal	The site was abandoned
Tikal	depopulation due to work and general artistic deterioration
Caracol	The site was abandoned
Dzibilchaltun	Took over by the Spanish
Calakmul	Struggle with Tikal
La Milpa	Unknown
Nakbe	Collapsed due to the rise of El Mirador
Seibal	The site was abandoned after war
Altun Ha	Regional conflict
Palenque	Were invaded by coastal people of Gulf of Mexico
Chichen Itza	Took over by the Toltec
Ceren	Buried under after an eruption of the Laguna Caldera volcano
Coba	Spanish conquered
Rio Bec	The site was abandoned

Dos Pilas	War with Calakmul
Lubaantun	The site was abandoned
Yaxchilan	War with Palenque
Sayil	Depopulation
Mayapan	Conflicts, welfare, and abandonment
Tulum	Killed off by the Spanish diseases
Utatlan	Was burned to the ground after the war with the Spanish

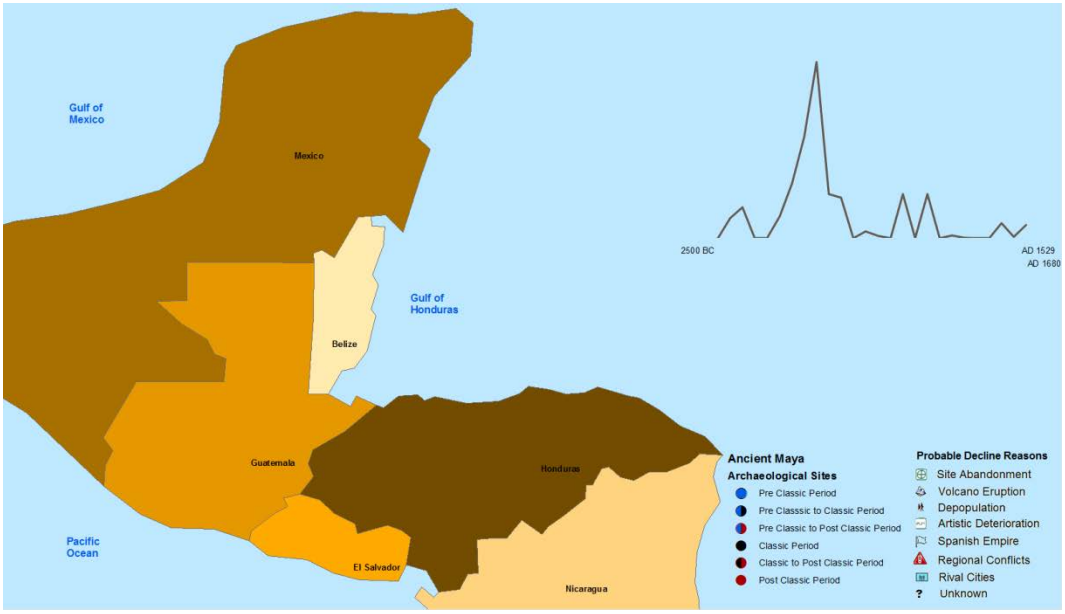
(Sources: Association for Belizean Archaeology (2015), UNESCO (2015a-2015h), Rosenswig (2008), Sharer (1969a), Chase & Spencer (2014), Maya World Expeditions (2014), Tourellot, Gonzales, Estrada (1999), Hanson (2002), World Monument Fund (2015), Institute of Archaeology (2015a), Scherer (2007), Hacienda Tres Rios (2011), Holloway (2014), Houston (1985), Institute of Archaeology (2015b), Tate (1992), Smith & Dore (1992), Hammond (1974a), Mayapan Archaeology (2015), Loco Gringo (2014), and Babcock (2012))

Appendix C: Summarized descriptions of UNESCO criteria

Number	Description
i	A masterpiece of human creative genius
ii	Interchange of human values
iii	Exceptional testimony to a culture which is living or is extinct
iv	Evidence illustrating significant stage(s) in human history
v	Example of a traditional human settlement
vi	Artistic and literary works of outstanding universal significance.
vii	to contain superlative natural and aesthetic importance
viii	Representing major stages of earth's history
ix	Representing significant on-going ecological and biological
x	Contain the most important and significant natural habitats

(Source: UNESCO, (2015g))

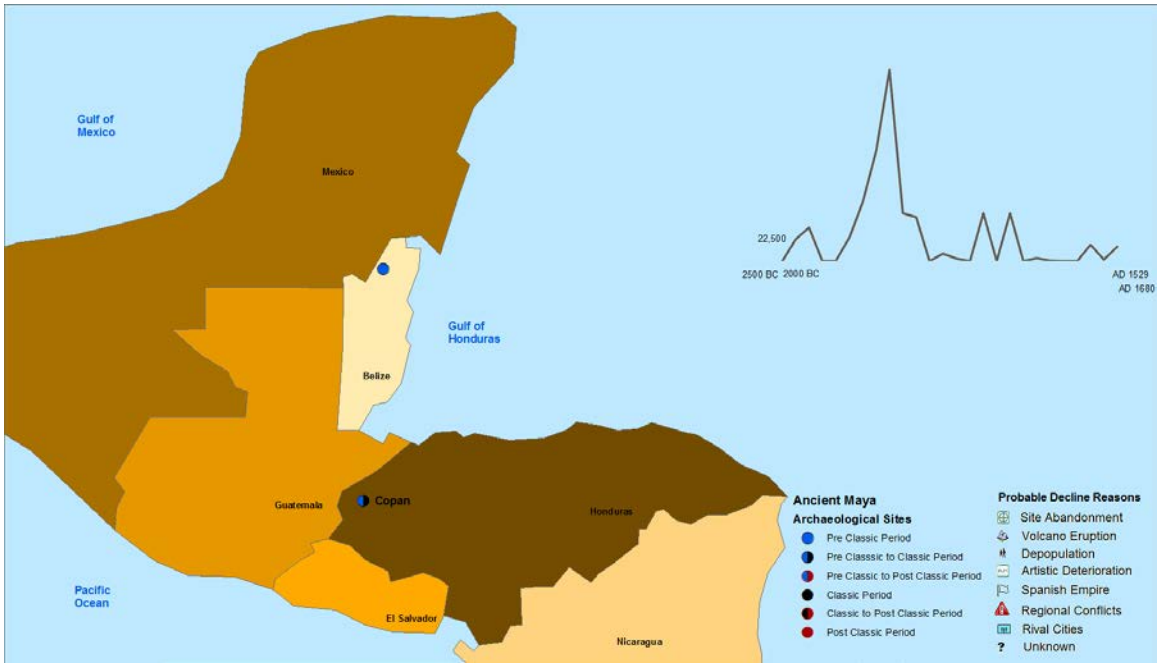
Appendix D: The 37 static maps, with data derived from Appendix A and Tables 2-4



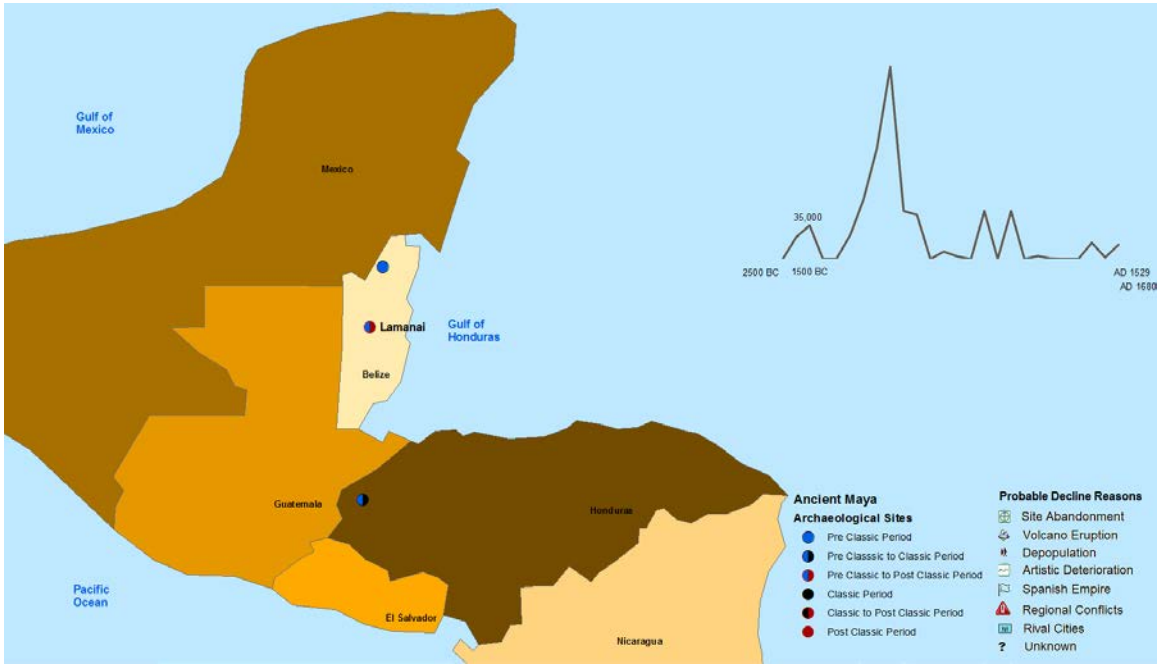
Map 1: Map of present-day countries
(Source: ArcMap 10.2.2 country base layer)

Map 2: Map of Pre-Classic Mayan site: Cuello

(Source: ArcGIS 10.2.2 countries base layer)

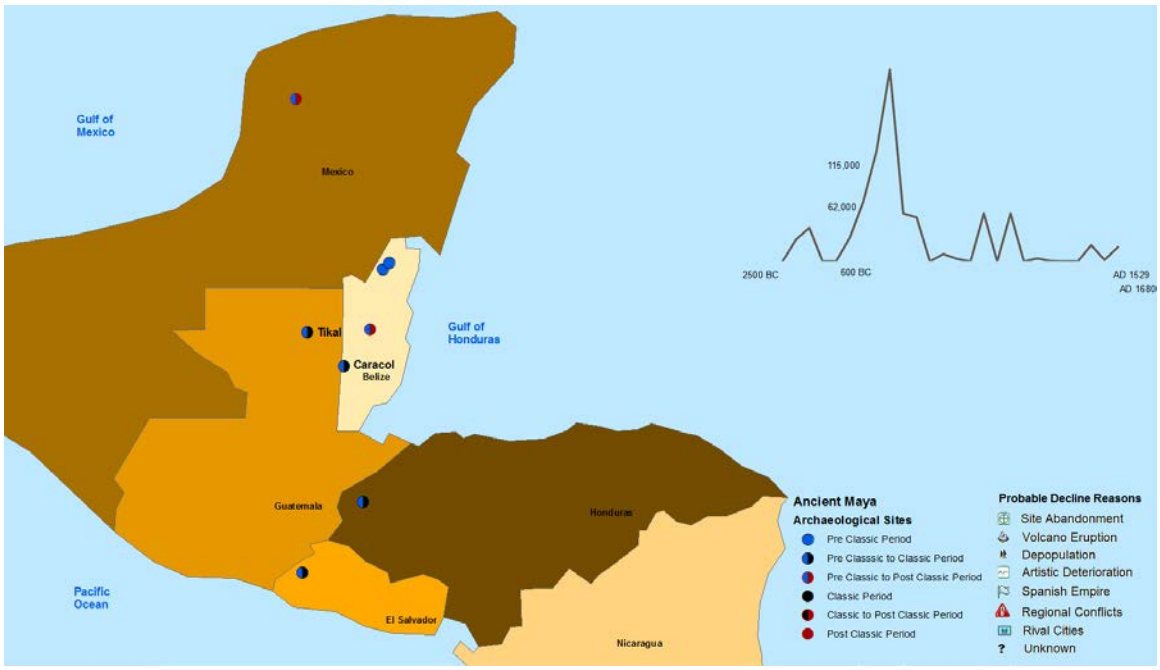


Map 3: Map of Pre-Classic to Classic Mayan site: Copan
(Source: ArcMap 10.2.2 country base layer)

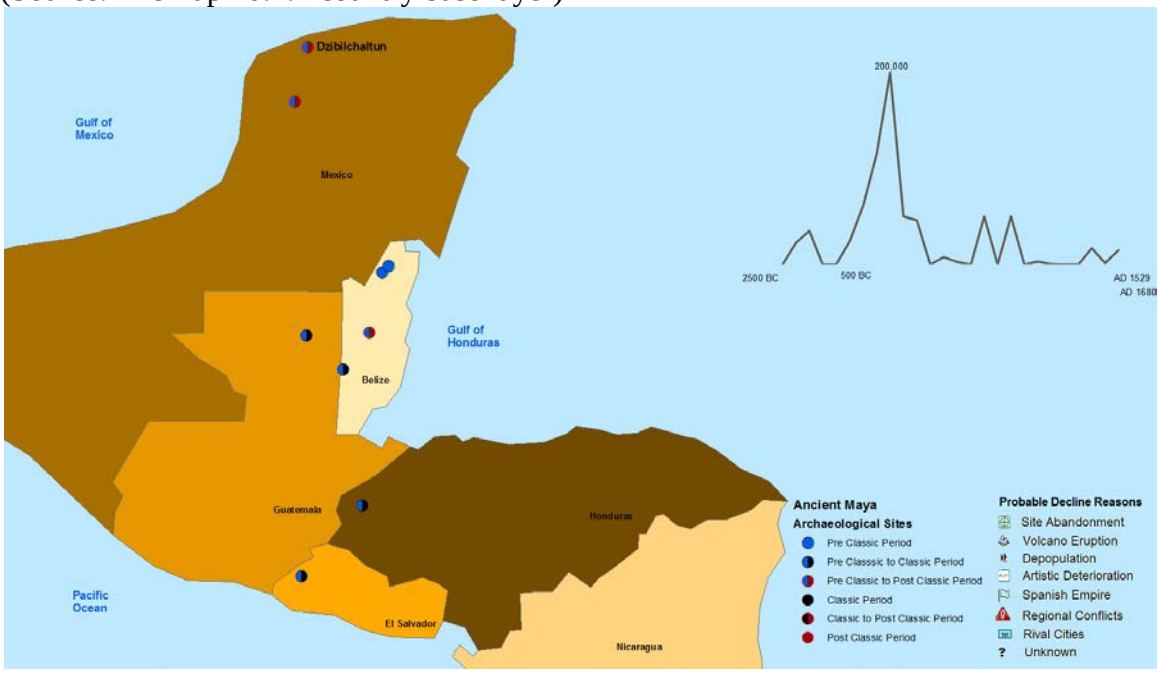


Map 4: Map of Pre Classic to Post Classic Mayan site: Lamanai
(Source: ArcMap 10.2.2 country base layer)

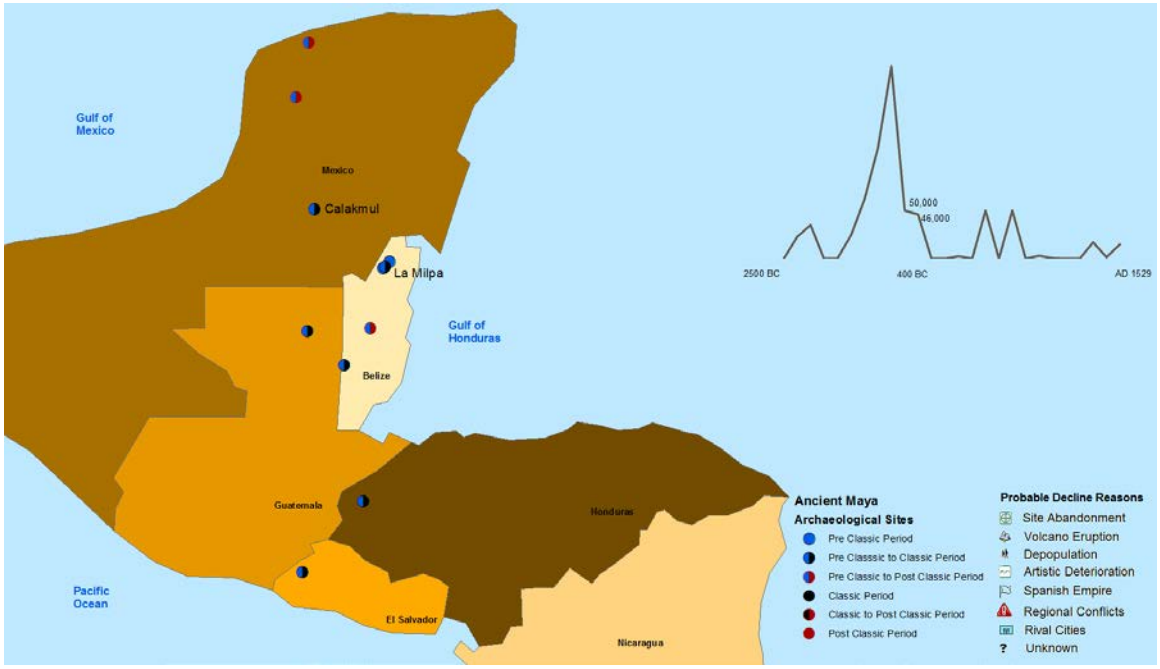
Map 5: Map of Pre-Classic Mayan sites: San Estevan, Chalcuapa, and Uxmal
(Source: ArcMap 10.2.2 country base layer)



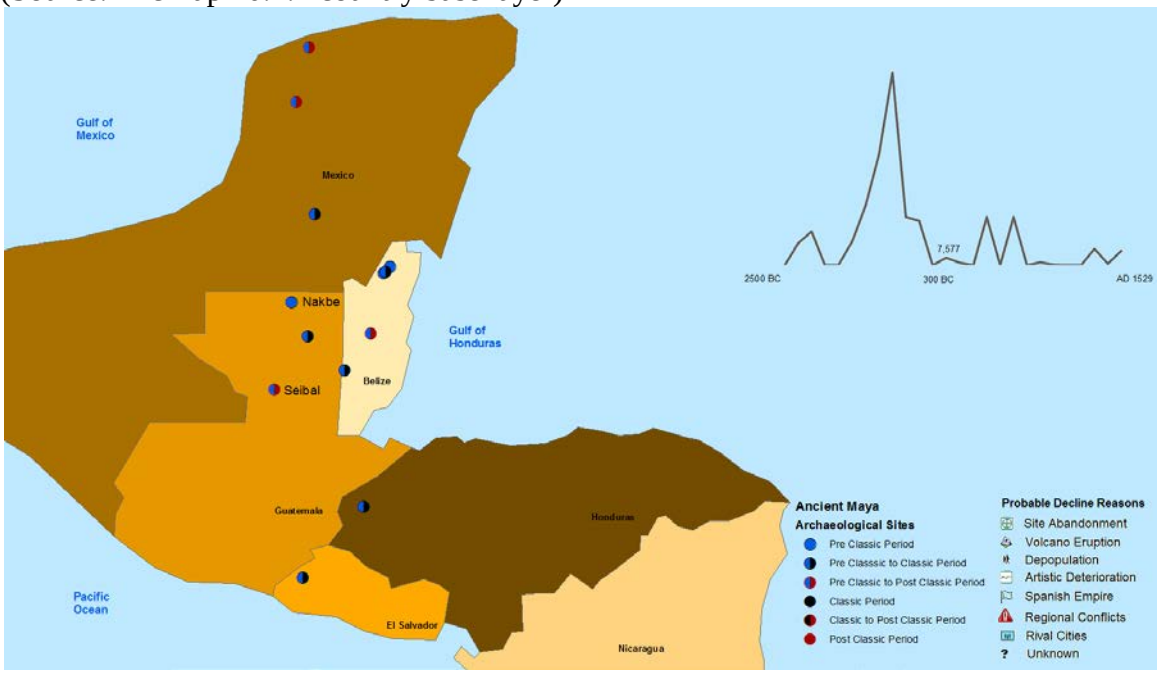
Map 6: Map of Pre-Classic to Classic Mayan sites: Tikal and Caracol
(Source: ArcMap 10.2.2 country base layer)



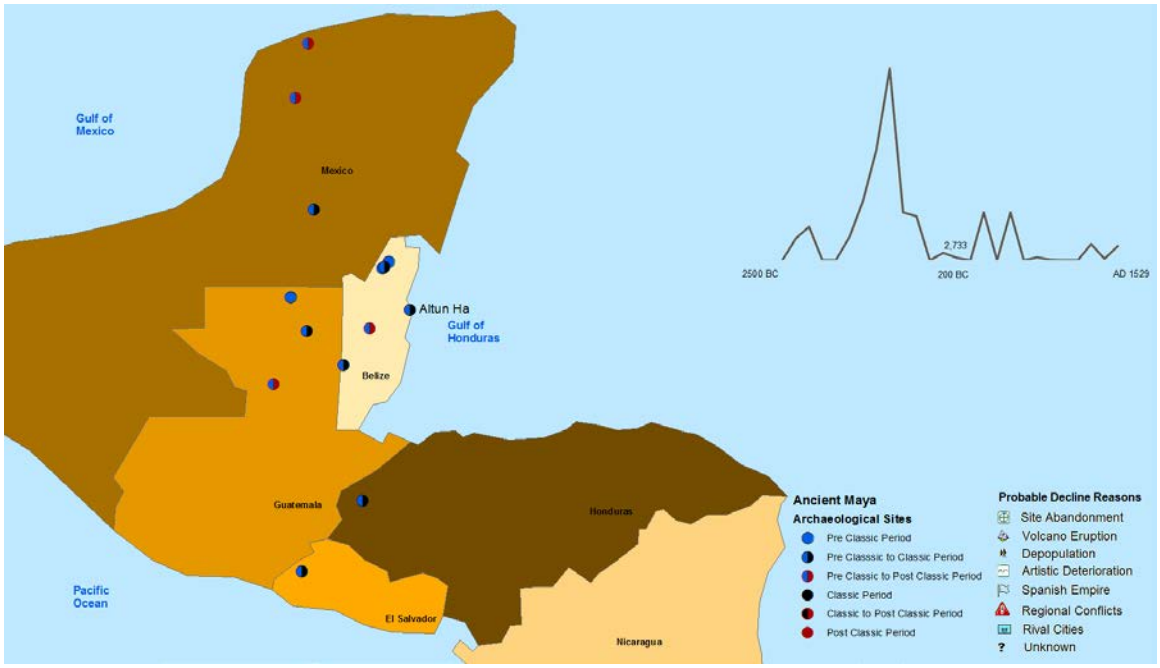
Map 7: Map of Pre-Classic to Post-Classic Mayan site: Dzibilchaltun
(Source: ArcMap 10.2.2 country base layer)



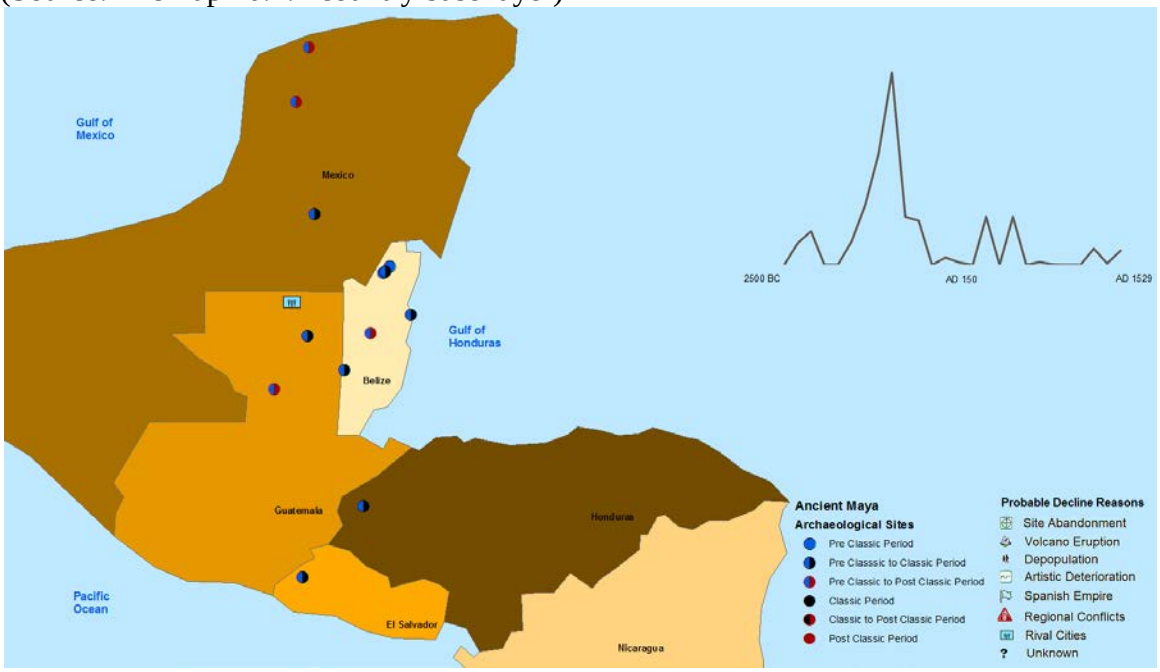
Map 8: Map of Pre-Classic to Post-Classic Mayan sites: Calakmul and La Milpa
(Source: ArcMap 10.2.2 country base layer)



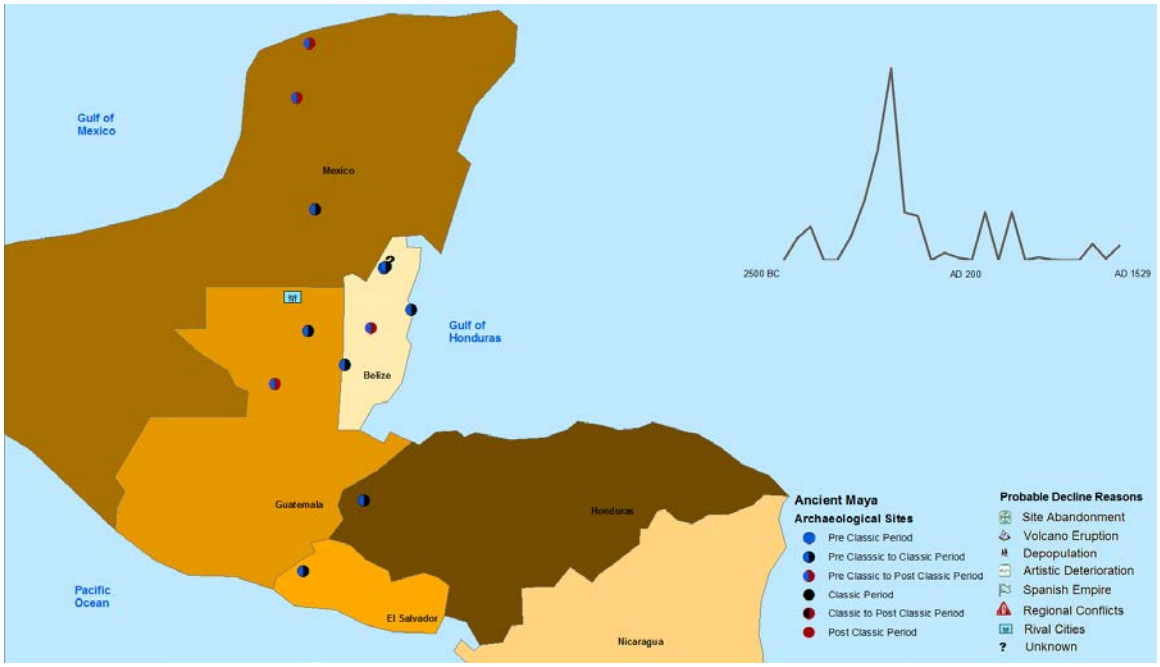
Map 9: Map of Pre-Classic Mayan sites: Nakbe and Seibal
(Source: ArcMap 10.2.2 country base layer)



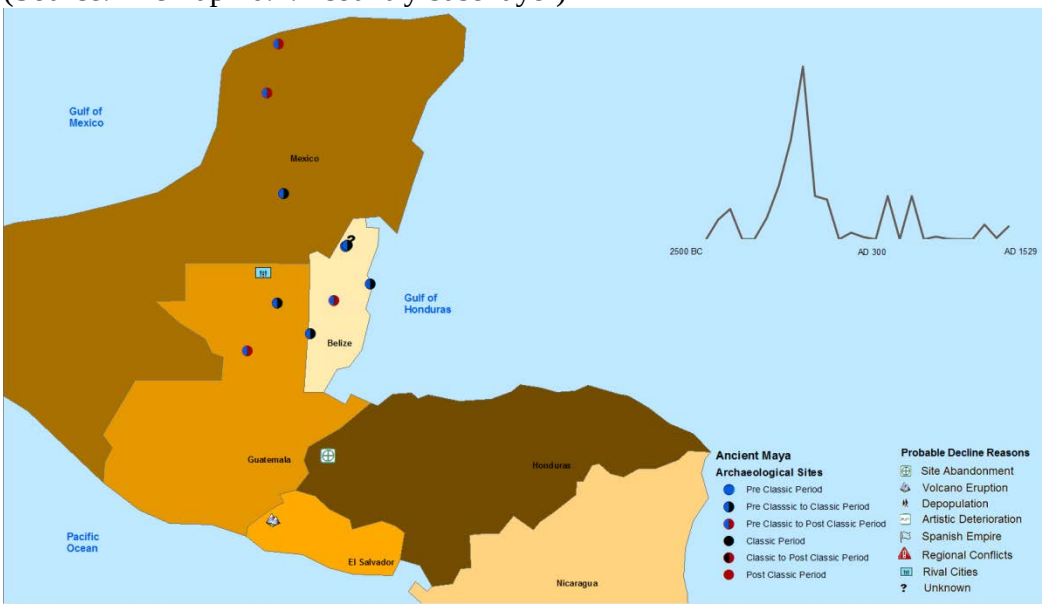
Map 10: Map of Pre-Classic to Classic Mayan site: Altun Ha
(Source: ArcMap 10.2.2 country base layer)



Map 11: Map of Pre-Classic Mayan site: Nakbe (collapses because of a rival city)
(Source: ArcMap 10.2.2 country base layer)

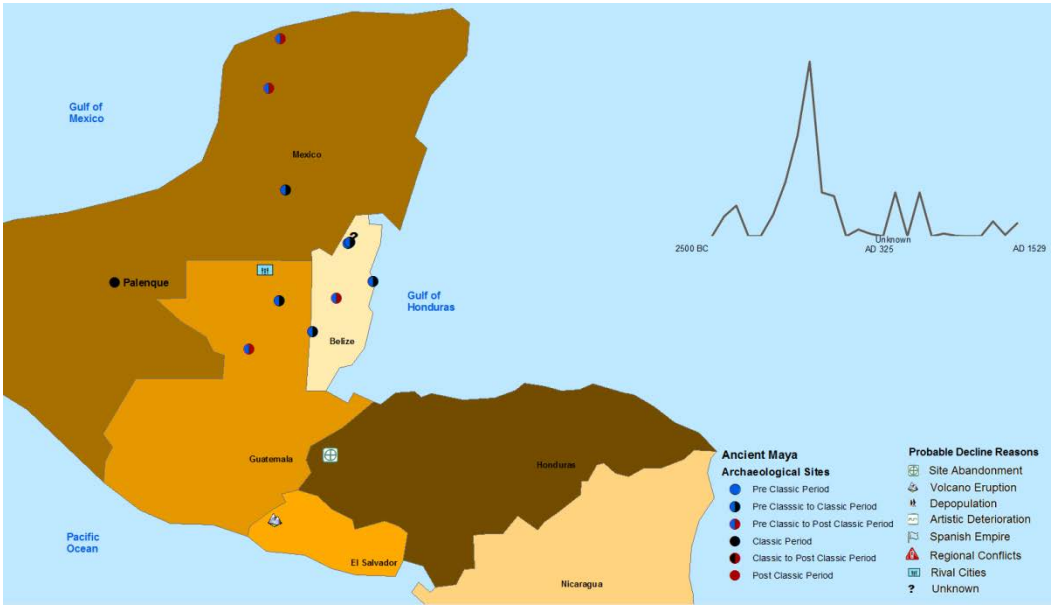


Map 12: Map of Pre-Classic Mayan site: San Estevan (collapses for unknown reasons)
(Source: ArcMap 10.2.2 country base layer)



Map 13: Map of Pre-Classic Mayan sites: Chalcuapa (collapsed due to a volcano eruption in Classic Period)

Copan (abandoned during the Classic Period)
(Source: ArcMap 10.2.2 country base layer)



Map 14: Map of Classic Mayan site: Palenque
(Source: ArcMap 10.2.2 country base layer)

Map 15: Map of Classic to Post-Classic Mayan site: Chichen Itza
(Source: ArcMap 10.2.2 country base layer)

Map 16: Map of Classic Mayan site: Ceren
(Source: ArcMap 10.2.2 country base layer)

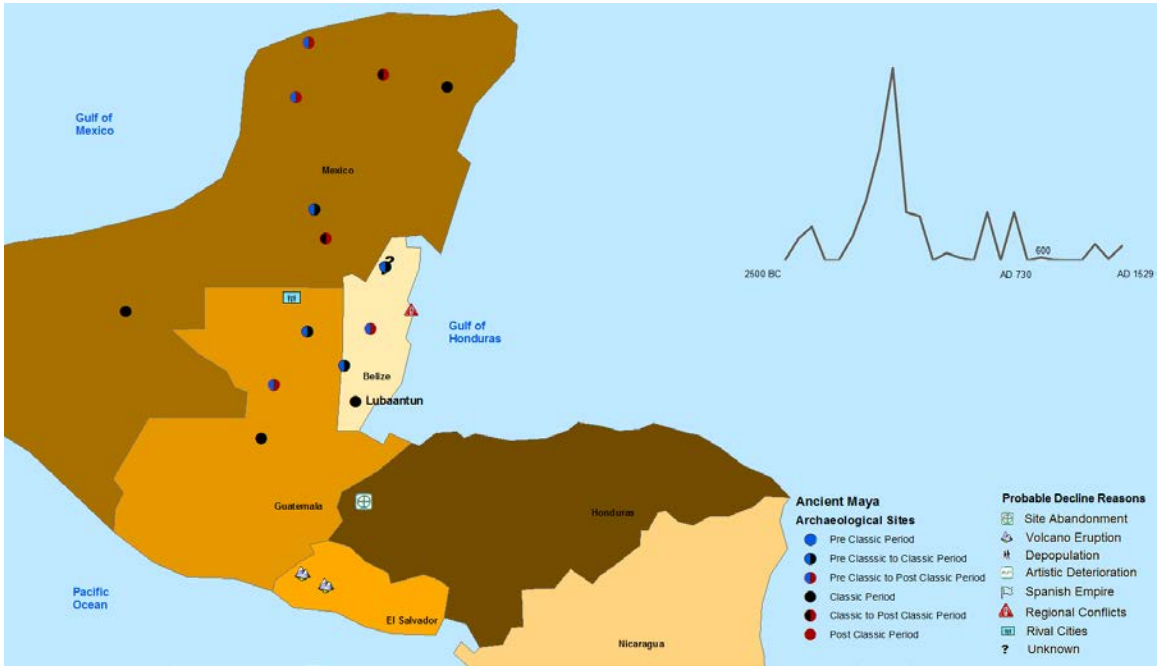
Map 17: Map of Classic Mayan sites: Coba
Cuello (collapsed for unknown reasons during the Classic Period)
(Source: ArcMap 10.2.2 country base layer)

Map 18: Map of Classic Mayan site: Altun Ha (collapsed due to a regional conflict)
(Source: ArcMap 10.2.2 country base layer)

Map 19: Map of Classic Mayan site: Ceren (buried under after an eruption of the Laguna Caldera volcano)
(Source: ArcMap 10.2.2 country base layer)

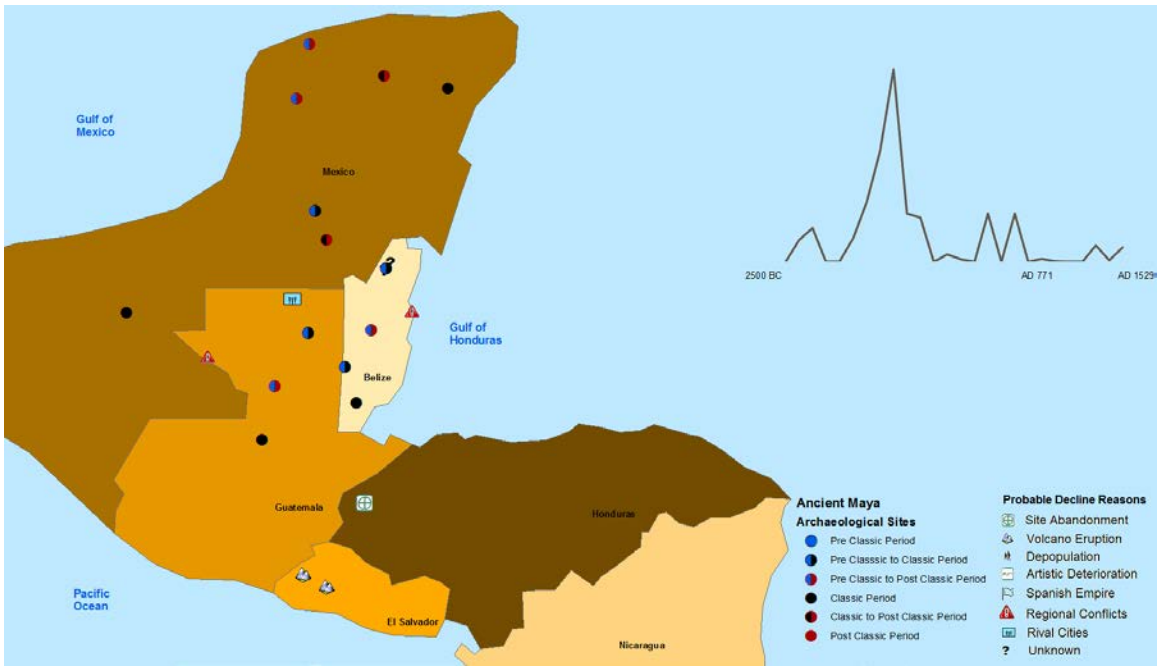
Map 20: Map of Classic to Post-Classic Mayan site: Rio Bec
(Source: ArcMap 10.2.2 country base layer)

Map 21: Map of Classic Mayan site: Dos Pilas
(Source: ArcMap 10.2.2 country base layer)

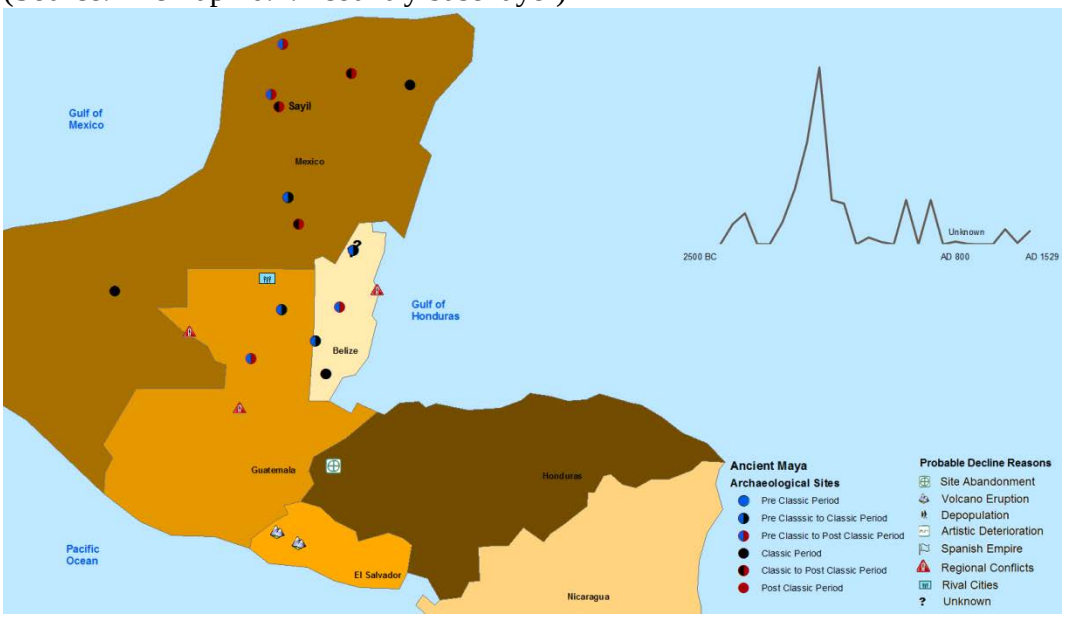


Map 22: Map of Classic Mayan site: Lubaantun
(Source: ArcMap 10.2.2 country base layer)

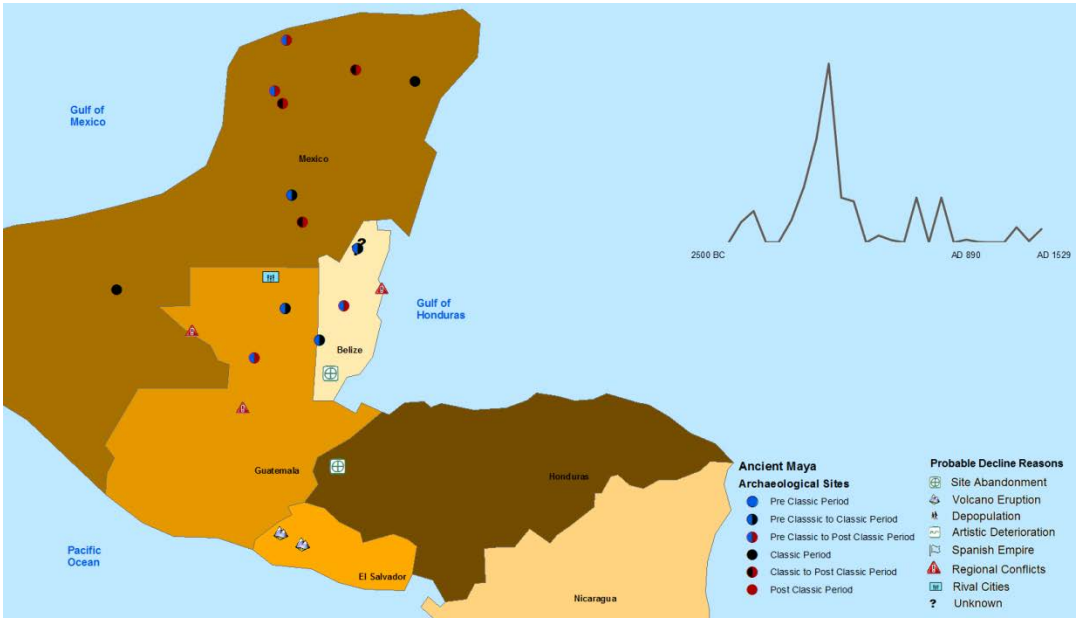
Map 23: Map of Classic Mayan site: Yaxchilan
(Source: ArcMap 10.2.2 country base layer)



Map 24: Map of Classic Mayan site: Yaxchilan (collapsed after war with Palenque)
(Source: ArcMap 10.2.2 country base layer)

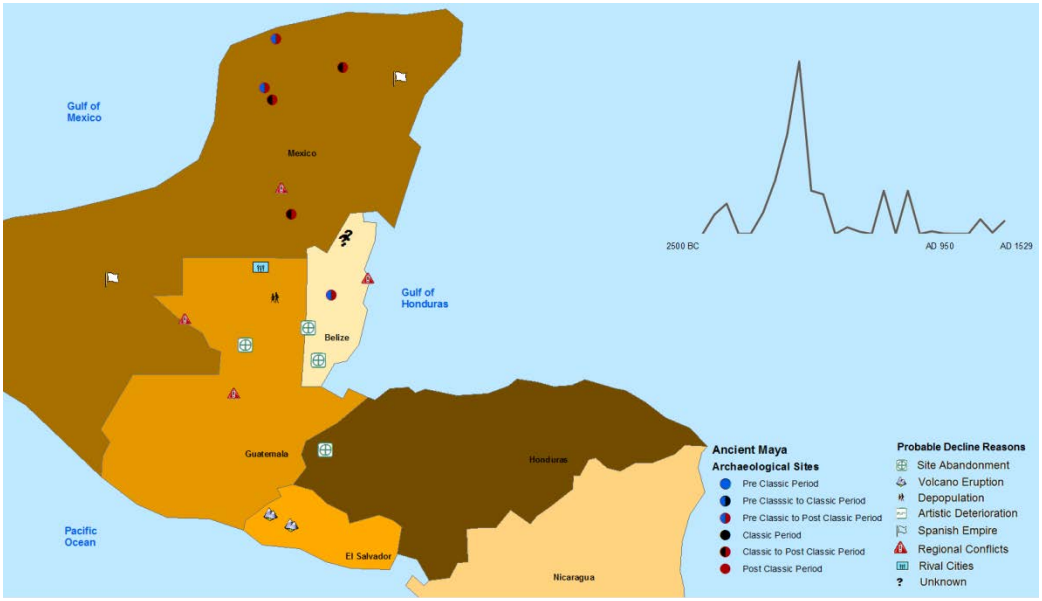


Map 25: Map of Classic Mayan sites: Sayil
Dos Pilas (collapsed due to war with Calakmul during the Classic Period)
(Source: ArcMap 10.2.2 country base layer)



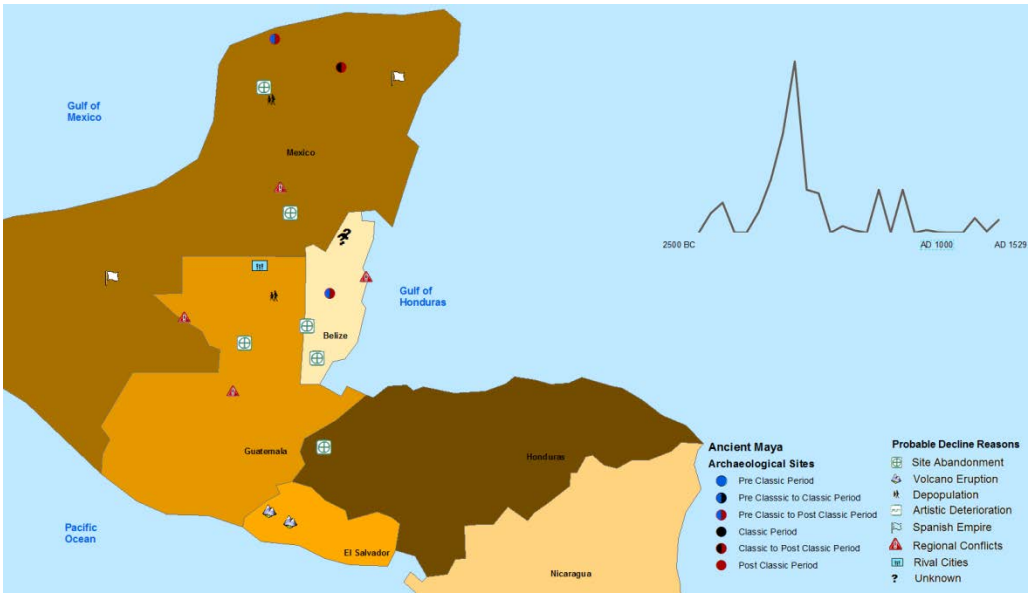
Map 26: Map of Classic Mayan site: Lubaantun (abandoned during the Classic Period)
(Source: ArcMap 10.2.2 country base layer)

Map 27: Map of Classic Mayan sites: Caracol (abandoned for unknown reasons)
Tikal (collapsed due to depopulation and artistic deterioration)
Calakmul (collapsed after a struggle with Tikal)
La Milpa (collapsed for unknown reasons)
Palenque and Coba (conquered by the Spanish Empire)
(Source: ArcMap 10.2.2 country base layer)



Map 28: Map of Classic Mayan site: Seibal (abandoned after war)

(Source: ArcMap 10.2.2 country base layer)



Map 29: Map of Classic Mayan sites: Uxmal and Rio Bec (abandoned)
Sayil (collapsed due to depopulation)
(Source: ArcMap 10.2.2 country base layer)

Map 30: Map of Post-Classic Mayan site: Mayapan
(Source: ArcMap 10.2.2 country base layer)

Map 31: Map of Post-Classic Mayan site: Tulum
(Source: ArcMap 10.2.2 country base layer)

Map 32: Map of Post-Classic Mayan site: Utatlan
(Source: ArcMap 10.2.2 country base layer)

Map 33: Map of Post-Classic Mayan site: Mayapan (abandoned after conflicts, welfare, and abandonment)
(Source: ArcMap 10.2.2 country base layer)

Map 34: Map of Pre-Classic to Post-Classic Mayan sites: Dzibilchaltun (conquered by the Spanish Empire) Chichen Itza (took over by a rival city run by Toltec city)
(Source: ArcMap 10.2.2 country base layer)

Map 35: Map of Post-Classic Mayan site: Tulum (citizens were killed off by Spanish diseases)
(Source: ArcMap 10.2.2 country base layer)

Map 36: Map of Post-Classic Mayan site: Utatlan (burned to the ground after the war with the Spanish Empire)
(Source: ArcMap 10.2.2 country base layer)

Map 37: Map of Pre-Classic Mayan site: Lamanai (abandoned)
(Source: ArcMap 10.2.2 country base layer)