Lake Pátzcuaro, Resource Wars and the Forming of the Tarascan State:

Applications of GIS in Archaeology

April 15, 2004

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Introduction

The main goal of this project is to demonstrate how GIS can be utilized within the field of archaeology in terms of prehistoric environmental reconstructions and the analysis of late prehistoric resource availability. This project was also, in large part, designed to verify the findings of Dr. Helen Pollard at Michigan State University, who first performed a similar analysis in 1982. This analysis will utilize the framework setup by Dr. Pollard, but will carry it out upon a much newer and more accurate set of elevation readings for the study area.

The study area chosen for this project is the Lake Pátzcuaro Basin located in the center of Michoacán, Mexico. Lake Pátzcuaro is considered to be an 'amplifier' lake, meaning that it is in a closed basin and is, therefore, especially sensitive to local changes in annual precipitation and evaporation. It is also a relatively shallow lake on the whole, with its deepest point at around 12 meters (Fisher 2000, O'Hara 1993). Furthermore, the lake is situated within the Central Lakes Region of the Trans Mexican Volcanic Belt above 2000 meters a.s.l. where the proper soils and slopes needed for productive agriculture are located within relatively close proximity to the lake itself (Fisher 2000, Pollard 1982, 1993). These conditions in concert with one another create a situation in which as rainfall levels have varied over time, large areas of agriculturally productive land have been repeatedly exposed and enveloped by receding and swelling water levels throughout the lake's past.

What makes this all particularly interesting is that Lake Pátzcuaro formed the heart of the Tarascan Empire, which came to control western Mexico from 1350 to 1522. The empire was at its greatest extent at the time of European conquest in the early sixteenth century, with an estimated population of 60,000 – 105,000 in the basin alone and 1.5 to 2.0 million within the empire, and had come to be recognized by the Aztecs, and their ruler Montezuma, as their only equal (Fisher 2000, Pollard 1982, 1993). While much is known of the Tarascan state, work is scant on the processes that helped shape it and the earlier polities out of which the empire formed.

Such fluctuations in available resources would have affected the population in the basin greatly and may be the key to what sparked the formation of the Tarascan state. This project will seek to analyze how changes in lake levels in the basin affected resource availability of irrigable and rainfall farmlands and how the stress created by these changes caused some polities to expand and control a larger area, subsuming weaker polities in the process.

Methodology

The water level of Lake Pátzcuaro has been steadily dropping over the past decade and is currently at its lowest known point in the last 2000 years. The base data chosen for this project, which will be discussed more in depth later on, is a 90 meter DEM from the Shuttle Radar Topography Mission (SRTM) that was flown in 2000. As the lake level at the time of the data collection was still lower than the lowest known prehistoric point, no bathymetric data was required to replicate the lake levels at the time of the formation of the Tarascan Empire. These levels were determined by ethnographic, historic and archaeological data, while the extents of land class types were determined utilizing elevation categories derived from ethnographic and ethnoecological studies in the Basin along with data from the field (Gorenstein & Pollard 1980, 1983, Pollard 1982, 1993). The areas under the control of central elites within each of these polities were created utilizing Thiessen polygons and were then used to calculate the area of different land types (before and after lake level changes) available to the individual polities. These measurements were then compared across the varying lake levels in order gauge the loss or gain in access to agricultural and lacustrine resources experienced by each polity over time and to then demonstrate a disparity in the levels of stress created within each polity due to such changes.[1]

As mentioned previously, Pollard has proposed that prior to the creation of the Tarascan State, several (ten) independent city-state or chiefly polities of varying size existed within the

[1] Refer to the flow diagram in Figure 1 for a detailed account of how this analysis was carried out

basin (Gorenstein & Pollard 1983, Pollard 1982, 1993).[2] Given that each polity was situated uniquely within the basin, each polity would have had differing degrees of access to lacustrine resources along with differing areas of various types of agriculturally productive lands. Due to the fluctuation in lake level over time, access to these resources is both a spatial and temporal concept. In order to analyze this unique situation, I have calculated the approximate areas of each resource within each polity over three differing lake levels. As mentioned above, the lake levels chosen for this analysis were determined from various ethnographic and archaeological sources (O'Hara 1993, Pollard 1982). The maximum prehistoric low for Lake Pátzcuaro currently documented is approximately 2032 meters a.s.l. and was modeled in Figure 2 (Fisher 2000, O'Hara 1993, Pollard 1982). Figure 3 is a model of the well-documented low for the majority of the 20th century that was first instrumentally measured in the 1940's at 2041 meters a.s.l (Fisher 2000, O'Hara 1993, Pollard 1982). This was used as a possible representative of what the Tarascan polities would have been experiencing during a more stable period of time prior to a more dramatic shift in lake level. Lastly, the high water mark that is estimated to have been present at the time of European contact, 2045.5 meters a.s.l., is modeled in Figure 4 (Pollard 1982).[3] [4]

The resources being assessed include 'Open Water', 'Wetlands' and 'Class 2 Land'. The 'Wetland', or marsh, category is held to be any water no deeper than two meters. This relates to the tule-reed, a native hydrophilous vegetation, whose roots typically do not exceed two meters and create large expanses of marsh within the basin. 'Open Water', therefore, is any portion of the lake deeper than two meters. The 'Class 2 Land' category incorporates both Class 2 land and Class 1 land. Class 1 lands are irrigable lands capable of yielding two to three annual crops and

[2] Only nine of these polities were utilized in this analysis. Pechataro lies beyond the limits of the DEM and, as it was unaffected by the lake level changes in terms of the land classes described above, was omitted.

[3] This analysis is utilizing a high water level estimated by Pollard (1982). O'Hara (1993) has come to a slightly lower level of 2043.5 meters a.s.l. utilizing ethnohistoric accounts in concert with an unpublished 1-meter contour level map released to her from SARH of the Mexican government. This map has not since been released and the therefore unverifiable results of O'Hara's work were chosen to be ignored in favor of Pollard's estimates.

[4] In performing the analysis on the high lake level, a measure of 2046 meters a.s.l. was selected due to the accuracy of the data. While readings were yielded in the output to several decimal places, it was believed that this would give a false sense of accuracy.

are typically located within close proximity to the lakeshore or springs. Class 2 lands are areas where the water source is rainfall and soil quality is such that a fallow period is necessary. The distribution of this type of soil, fortunately, matches closely to the 2100 meters a.s.l. contour and this fact was utilized in the creation of the category. For reasons to be discussed later, both Class 1 and Class 2 land classes were lumped together in the analysis. (Gorenstein & Pollard 1983, Pollard 1982, 1993)

Results

In looking at Figures 5 – 10, one gets a general impression that two polities in particular were affected to a significant degree by a rise in the lake level through time. Both Tzintzuntzan and Pátzcuaro lost considerable amounts of Class 2 land with the rise in lake level from the pre-historic low of 2032 meters a.s.l to the high of 2045.5 meters a.s.l. While Tzintzuntzan lost 12.72 sq. km., Pátzcuaro would have lost an astounding 15.14 sq. km. of productive land. Even in comparing the intermediate level of the lake at 2041 meters a.s.l. to the high lake level change, large areas were lost with 10.43 sq. km. for Tzintzuntzan and 8.25 sq. km. for Pátzcuaro. In looking at Figures 8 and 9, where these numbers are broken down into percentages of total area for the polities, this change seems even starker. Pátzcuaro lost 25% of its agricultural lands in the intermediate to high level shift, while Tzintzuntzan lost 35% in that same shift. Such a dramatic loss of agriculturally productive land would have placed a rather large stress on the populations of both Pátzcuaro and Tzintzuntzan. It is also noteworthy that these two polities are estimated to have been the most populous of the basin and, presumably, had the most military power at their disposal.

Discussion – Implications

The elites who headed the centers of Pátzcuaro and Tzintzuntzan would have wanted to maintain the same level of tribute that they had come to depend on in previous years. In order to exact the same amount of goods from a now stressed population, the elites could have chosen one of three paths: expansion, specialization, or leaving for ‘greener pastures’ so to speak.

There is, however, minimal evidence of further economic specialization for either Tzintzuntzan or Patzcuaro and it has been suggested that any of this was a secondary and not primary means of coping with newly added economic stress. There is also a dearth of evidence to support any sort of out migration from the basin showing that the elites of Patzcuaro and Tzintzuntzan avoided this option. There is, as noted by Pollard, ethnohistoric evidence that both polities chose to expand and went on to subsume other neighboring polities (Pollard 1982, 1993). It is known through the colonial Spanish text of the *Relación de Michoacán (1540)* that Tzintzuntzan brought Uayameo under its control. Tzintzuntzan priests made a move to Uayameo and those at Uayameo were said to have dispersed throughout the basin. We are not as fortunate in the case of Pátzcuaro, however, and must infer that Pareo was conquered by its neighbor to the east as hinted to by the complete lack of mention of Pareo in the *Relación* any text after this event (Pollard 1982, 1993).

The findings of this analysis are rather similar to those presented by Pollard in 1982. As one can observe in Figure 13, the primary difference in the two models is that Pollard under estimated the overall amount of Class 1 and Class 2 lands that were present in Tzintzuntzan and Pátzcuaro. This being said, the relative amount of change in resource availability she predicted to have occurred matches closely to that discussed in this analysis. If nothing else, the larger area of agriculturally productive land predicted in this analysis would have created a larger resource base and this would have, in turn, supported an even larger population in both of the polities. Therefore, the stress placed on Tzintzuntzan and Patzcuaro once lake levels had risen from the intermediate to high water level would have been of even greater magnitude. This not only supports findings by Pollard, but places even greater emphasis on the effects of environmental change in the Pátzcuaro Basin than had been predicted initially.

Discussion – Data Processing & Quality Concerns

The Shuttle Radar Topography Mission was flown in February of 2000 and sought to map nearly the entire globe in high-resolution. As the mission’s title might suggest, the topographic values that were collected were found utilizing radar (two antennas 60 meters apart) as the space shuttle Endeavor orbited Earth. The data has been released gradually as its processing has been completed; with 30-meter resolution data being released for the entire United States initially and 90-meter resolution data for other regions of the world made available later on. It is the author's understanding that data for the Pátzcuaro Basin only became available in late 2003. It should be noted that the amount of high quality topographic data now provided for areas outside the U.S. by the SRTM is unparalleled and is truly a boon for those archaeologists working in remote areas such as the Pátzcuaro Basin.

The data for this analysis had quite a few problems with it and several weeks were spent attempting to rectify them to no avail. The first issue encountered with this data is the very apparent problem that some areas of open water are being recorded as land by the DEM. While the majority of the lake and its boundaries appear identical to topographic maps for the area, there is a particular trouble area located at the lower section of the inner bend of the "C"-shaped lake (See Figures 2 – 4). Where there should be a chain of four small islands (the northern-most being where the polity of Pacandan was located), there sits a large area of land enveloping the two southern-most islands. While this problem is minimized in the intermediate and high lake level plots, there is definitely a soft spot within the data.

This particular problem is most likely due to error during the collection of the SRTM data. While the radar used in the mission may be capable of taking accurate measurements in both day and night and penetrating cloud cover, it is quite possible that there is higher level of uncertainty when it comes to taking measurements of open water, shallow water and marshland. As noted above, areas of clearly open water were recorded as 'No Data' values in the DEM; this was either the result of the initial data value recordings from the radar or the result of data processing techniques carried out by NASA. The author has been informed that the 'trouble area' in question is one of rather steep relief in terms of bathymetry and as a result, the tule-reed is unable to grow as its roots cannot stretch deep enough. This being said, it is quite possible that the clarity of the water in this particular area had adverse affects on the radar.

An attempt was made to remedy this situation by incorporating bathymetric data for the lake that had been created in the early 1980's using contour maps (Figure 14). The thought behind this was that one could essentially 'burn in' the bathymetric data into the DEM, creating a 'bowl' where measurements of the lakes surface (all recorded as 'No Data' in the DEM) had previously existed. However, when this bathymetry was digitized (in 2002 by a graduate student who left the university) no coordinates were recorded and there was no way of relating the bathymetric map to the DEM for the basin. However, there is still hope for solving this data quality problem. While the original bathymetry is virtually impossible to incorporate into a digital analysis such as this, a new and more accurate bathymetric map has been created and put into ArcInfo. Unfortunately, this new dataset is still in Mexico with its creator Arturo Chacón of the Universidad Michoacana, Morelia, Mexico and a copy was not received in time for the conclusion of this project.

Another problem was encountered in creating the proper categories of resources. While Dr. Helen Pollard utilized both Class 1 and Class 2 land in her analysis, the two were combined together in the analysis presented here. Originally, air photos and field survey were used to place where Class 1 lands were present. This was carried out in the late 1970's however, and was never brought into a digital format. Since then, soil maps have been produced by the state government of Michoacán, but due to time constraints these were unable to be digitized. It is appropriate here to mention that Class 1 land would be the first land to be inundated by the lake as it rose. Being more productive than Class 2 land, this means that a rise like that discussed previously would have had an even greater impact on resource availability than indicated by this analysis. So, while this is an item that could be accounted for in future research, it only lessens the predicted effect that such lake level changes would have had on the Tarascan polities and in 'fixing' this problem. The explanatory power of such an analysis is not harmed by not taking Class 1 lands into account and the predicted stress would only be increased.

Another ‘soft spot’ in the data that should be accounted for in the future is the lack of accounting for springs in the basin. Springs are a source of irrigation and were used to create additional Class 1 land. The locations of springs within the Basin at the point of European contact can be estimated from the locations of known springs in the 1940’s and there is some evidence of prehistoric irrigation within proximity to some of those springs (See Figures 2 – 4). What is unknown is how productive these springs were prior to, during and after the formation of the Tarascan state. It stands that, generally as lake levels rise so does the relative height of the water table. The Basin, however, is located within an area of relatively frequent seismic activity and such activity is likely to have an affect, one way or another, on the sub-surface flow of water. Therefore, while it may be speculated that when the lake level was at its peak height, springs were also their peak output; this would be a dangerous assumption and could be said only with a minimal degree of certainty. If this highly unlikely scenario did indeed take place, Class 1 land would have been able to be created away from the lake in a time when other Class 1 land was submerged. However, even if this was to be the case, it is highly doubtful that the amount of spring irrigated land would be significant enough to alleviate the added stress on resources created by the high lake level.

Lastly, there is another issue with predicting the extent of wetlands that would have been present during and prior to the formation of the Tarascan state. There have been periods of large-scale soil erosion throughout the past few centuries within the basin, namely the initial period immediately following European conquest and during a period of heavy logging in the nineteenth century. These periods of erosion have resulted in large amounts of soil deposition along the lake’s edge and in some areas, especially the area of the lake to the south and west of Parea and Urichu, this deposition has amounted to several meters above the surface horizon of interest for this analysis. This is revealed in the field by evidence of wetland remains several meters below the modern day surface and by ethnohistoric texts that speak to certain areas being reachable via waterways that are currently above 2046 meters a.s.l. It follows then, that any lake level prediction carried out in an area of high soil deposition will be to a lesser horizontal extent than would have been the case for the prehistoric Lake Patzcuaro. It so happens, however, that the areas that would have been considered under the control of Patzcuaro and Tzintzuntzan do not appear to have fallen within areas of high deposition and this would have little affect on the observations discussed in this analysis.

Conclusion

Ideally, this project will be carried out once again, but with the problems discussed above accounted for. The digital bathymetry will be intersected with the DEM (of possibly even better quality in the future) in order to ensure the accuracy of the elevation values. Soil maps will be incorporated into the data along with areas of late prehistoric potential spring irrigation so as to achieve a more accurate assessment of the loss of both Class 1 and Class 2 lands. And, perhaps through the work of taking core samples throughout the basin, the protohistoric surface can be better assessed and accounted for within the DEM. This improved assessment will allow for more accurate estimations of the food production capability and other resource availability of each polity at varying lake levels. The lake levels being assessed may also become more concrete in the future with the addition of more data from the field.

In assessing the data presented in this analysis, one can definitely see that the level to which the polities in the basin were affected ranges a great deal. In observing this range, however, one is only observing a small piece of the puzzle. This image of disparity in resource availability over time must be looked at in light of information about the polities it is depicting. The great cultural change that occurred in the Pátzcuaro Basin in the late 1300's and early 1400's would not have taken place if the polities that were placed under this stress were the weaker of the Basin. If Tzintzuntzan and Pátzcuaro were already at a disadvantage to other polities prior to this environmental stress, then it is most likely that they would have been taken under the control of another neighbor and not vice versa. This was not the case, however, and at the beginning of this phase of relative resource scarcity these two polities were indeed the most populous and, as we can see from what took place, the more powerful in the Basin. This allowed them the choice of being aggressive. Had they not acted when they did, other polities may have gained the upper-hand and what would be observed within the record would not be a story of power concentration, but rather a story of a power shift.

Acknowledgements:

I owe a great deal to Professors Helen Pollard and Ashton Shortridge of Michigan State University for helping me throughout this project. Ashton Shortridge came to my aid with any and all questions regarding the technical aspects of this project and I want to thank him especially for walking me through a lot of the preprocessing issues I had with this data and putting up with my incessant attendance of his office hours. Helen Pollard came to my rescue when I was looking for a means of combining my GIS knowledge with my passion for archaeology and is responsible for peaking my interest in an area I knew very little of and look forward to learning much more about in the future.

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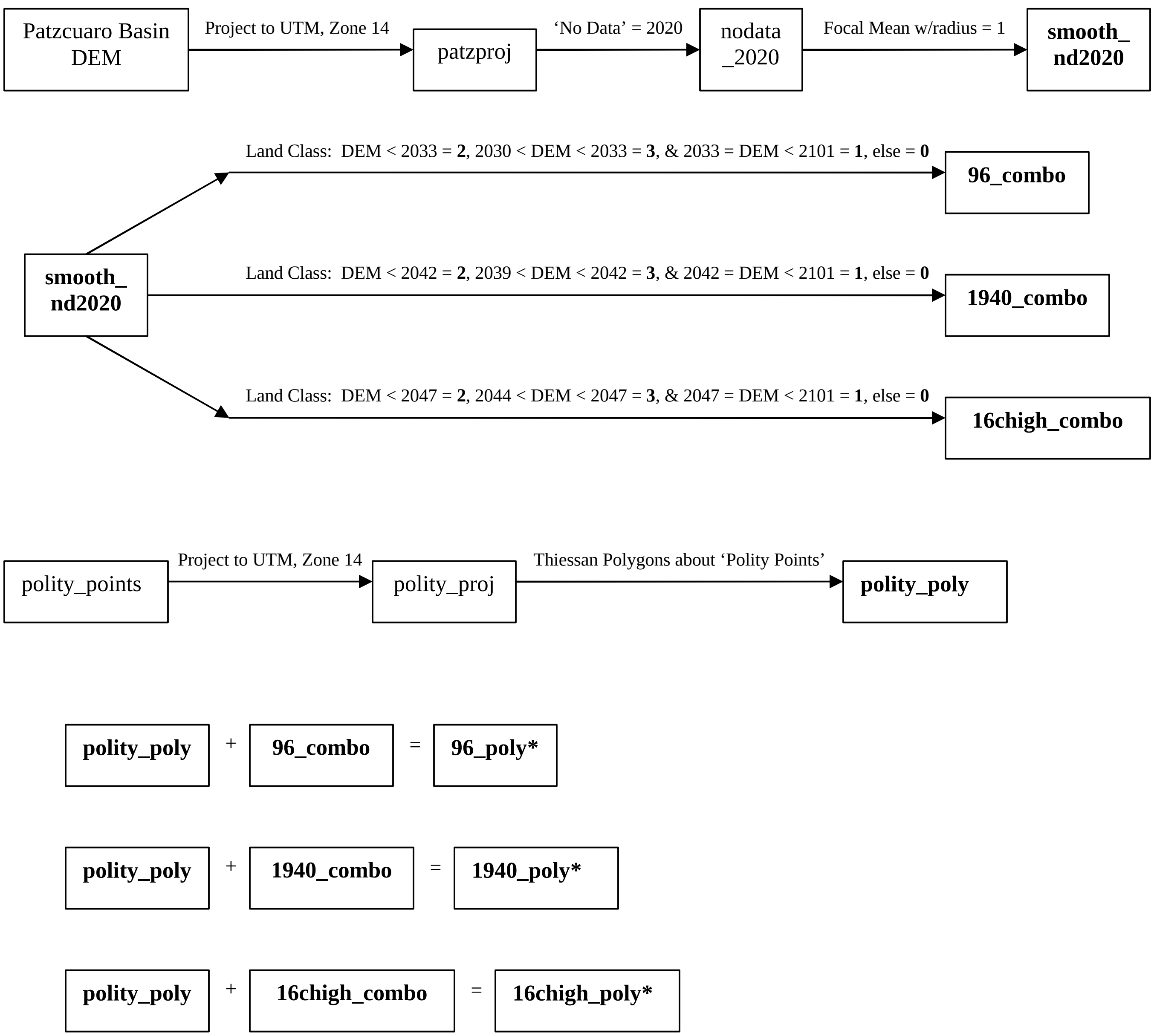
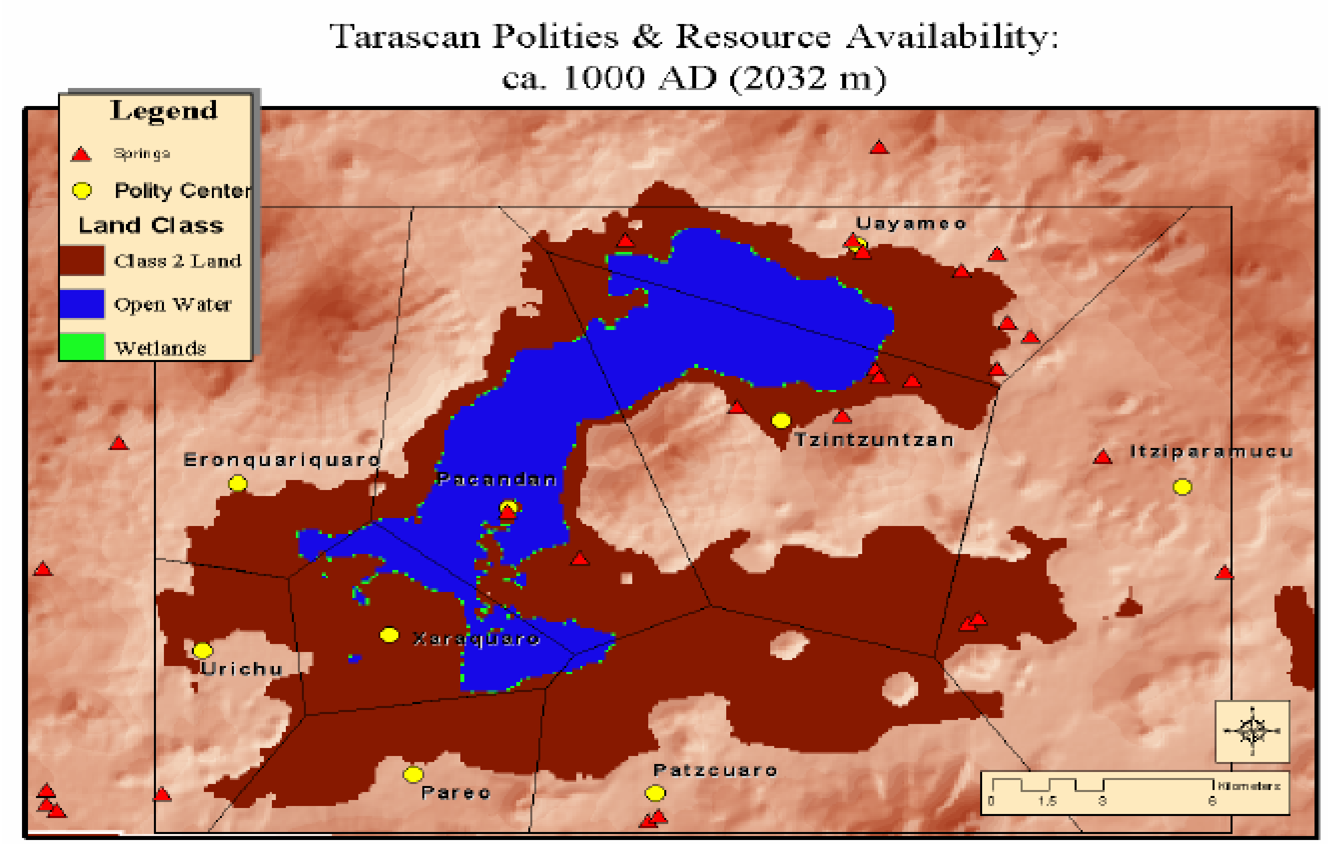
Figure 1: Flow Diagram



* The pat. file created by this intersection was exported into Excel using the INFODBASE command. This file was then manipulated within Excel in order to create the figures used in this presentation.

Figure 2



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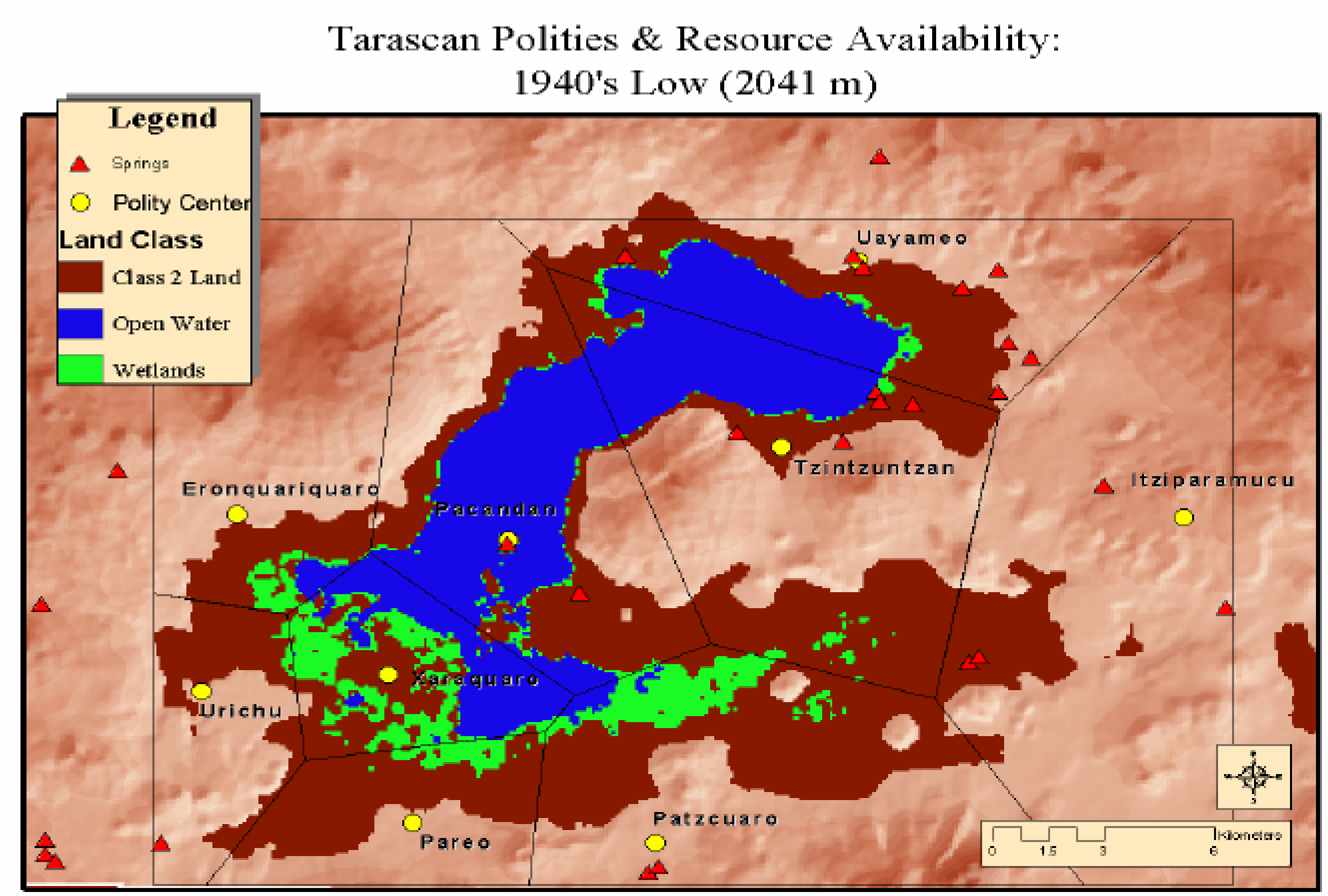
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1940's Low (2041 m)
Legend
Springs
Polity Center
Land Class
Class 2 Land
Open Water
Wetlands
Uayameo
Tzintzuntzan
Itziparamucu
Eronquariquaro
Pacandan
Xaraquaro
Urichu
Pareo
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0
1.5
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Figure 4

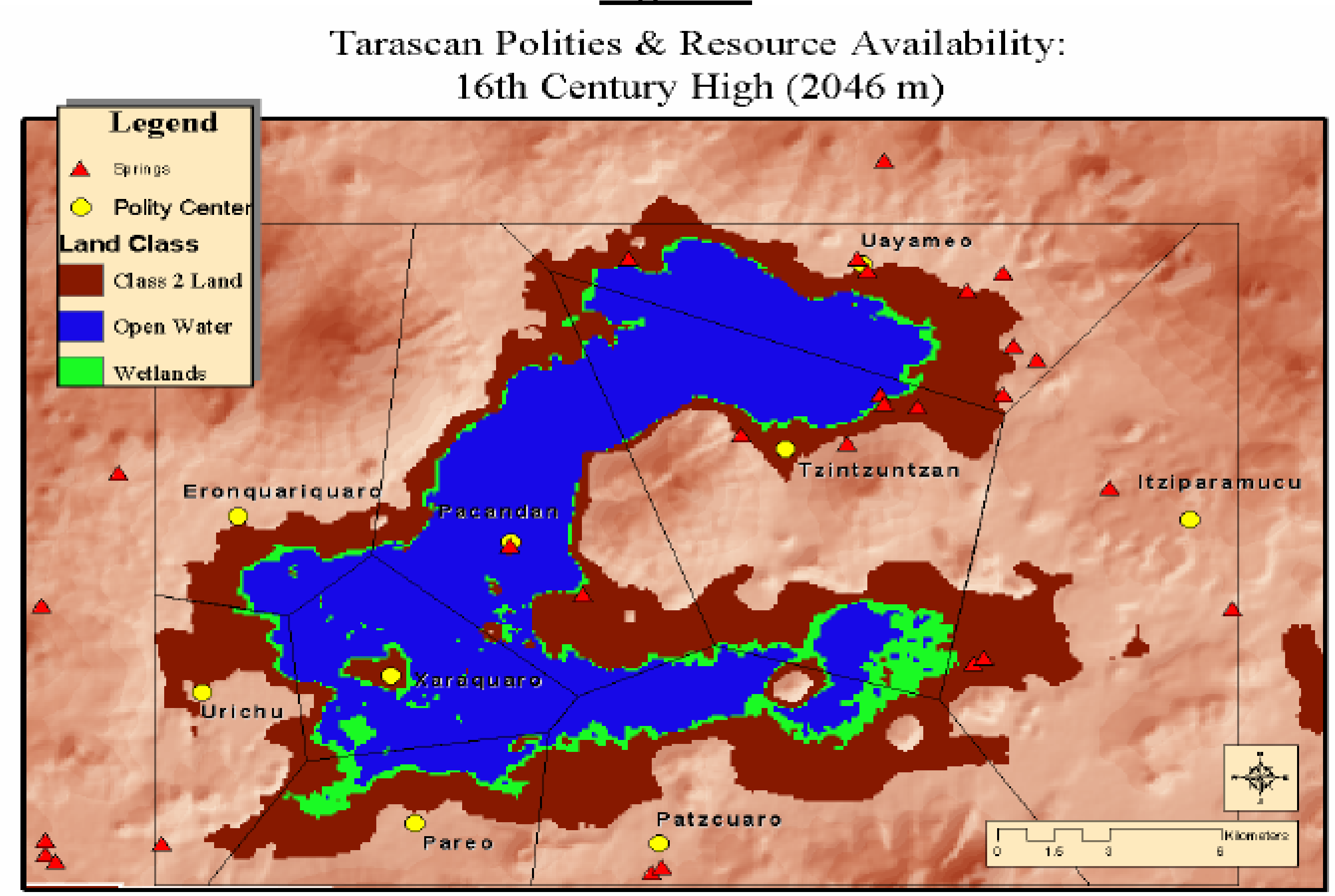
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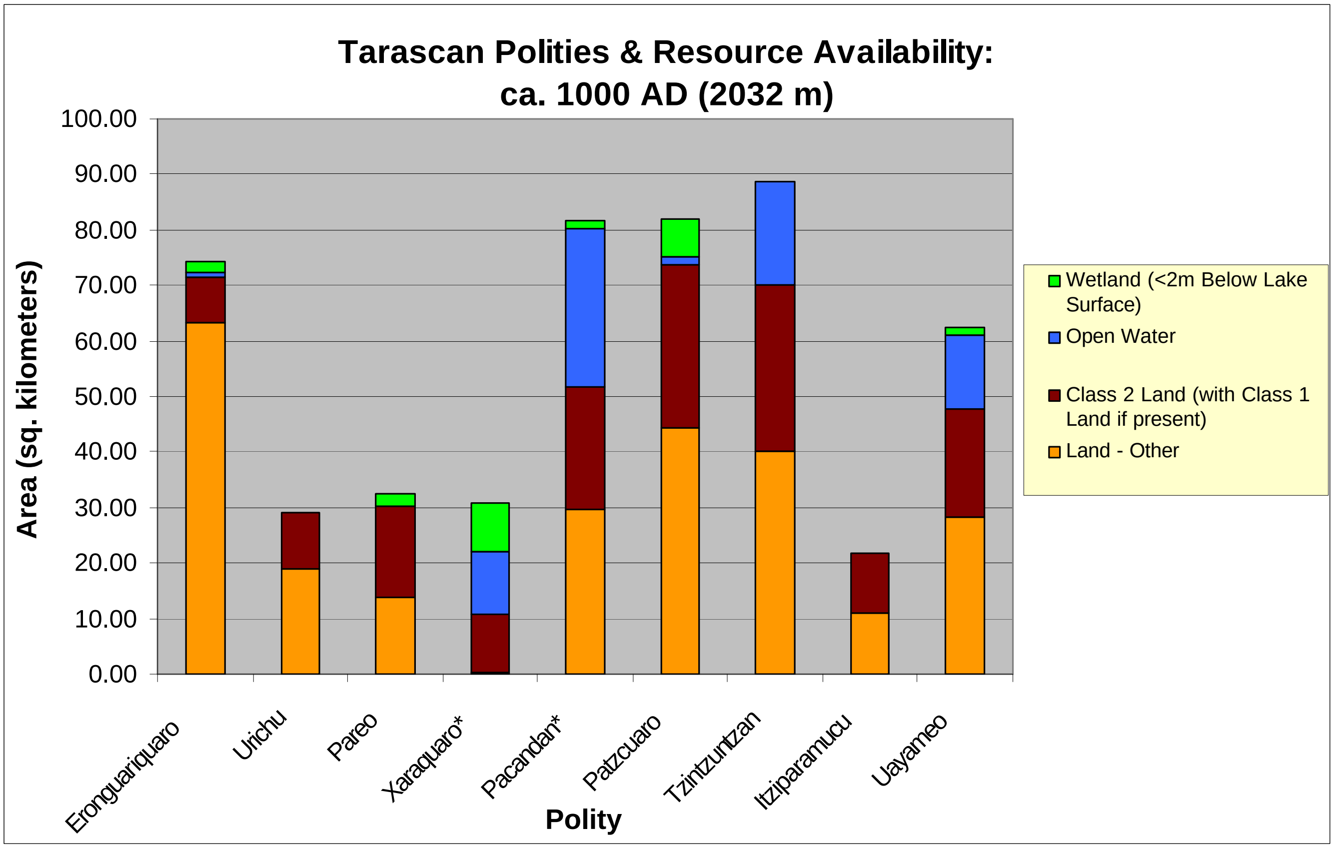
Figure 5



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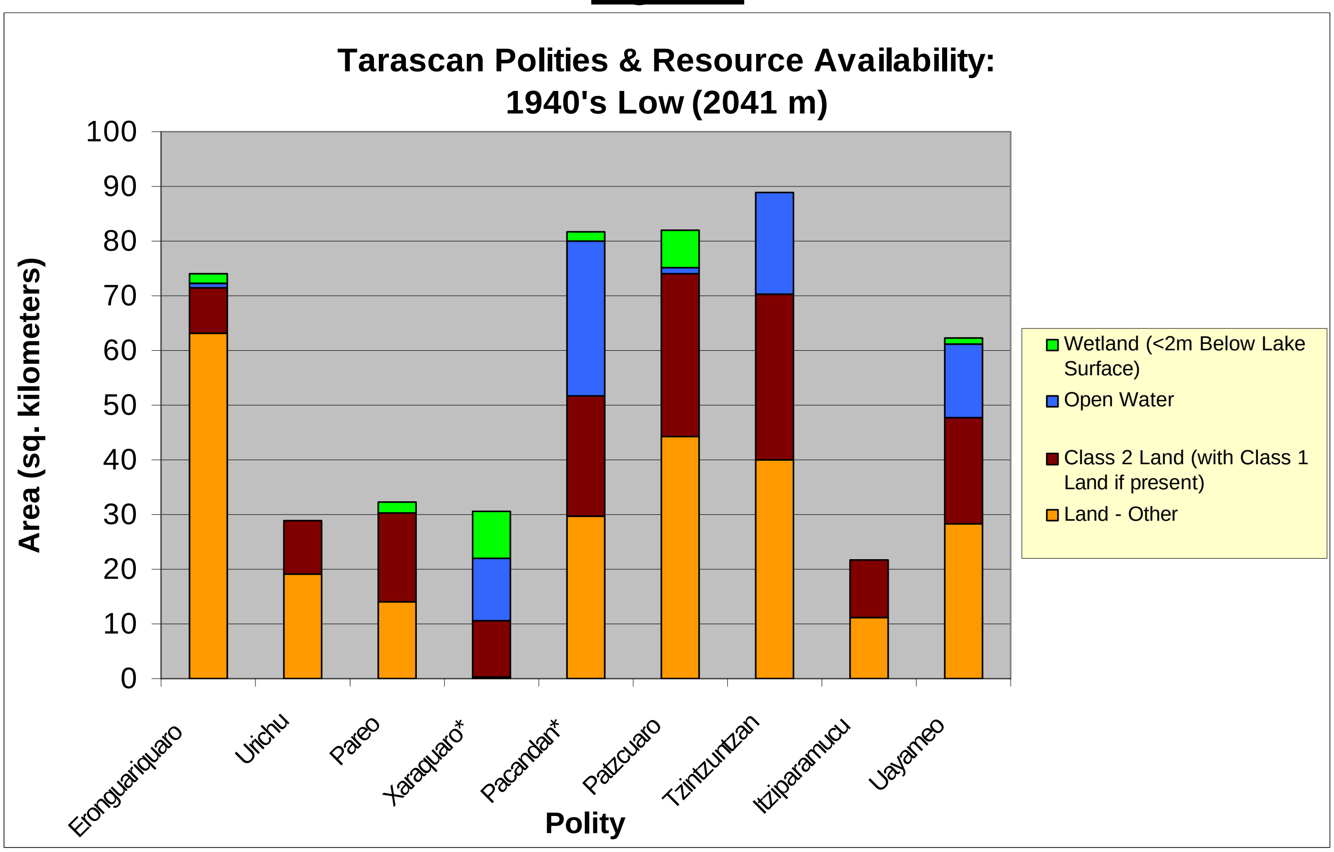

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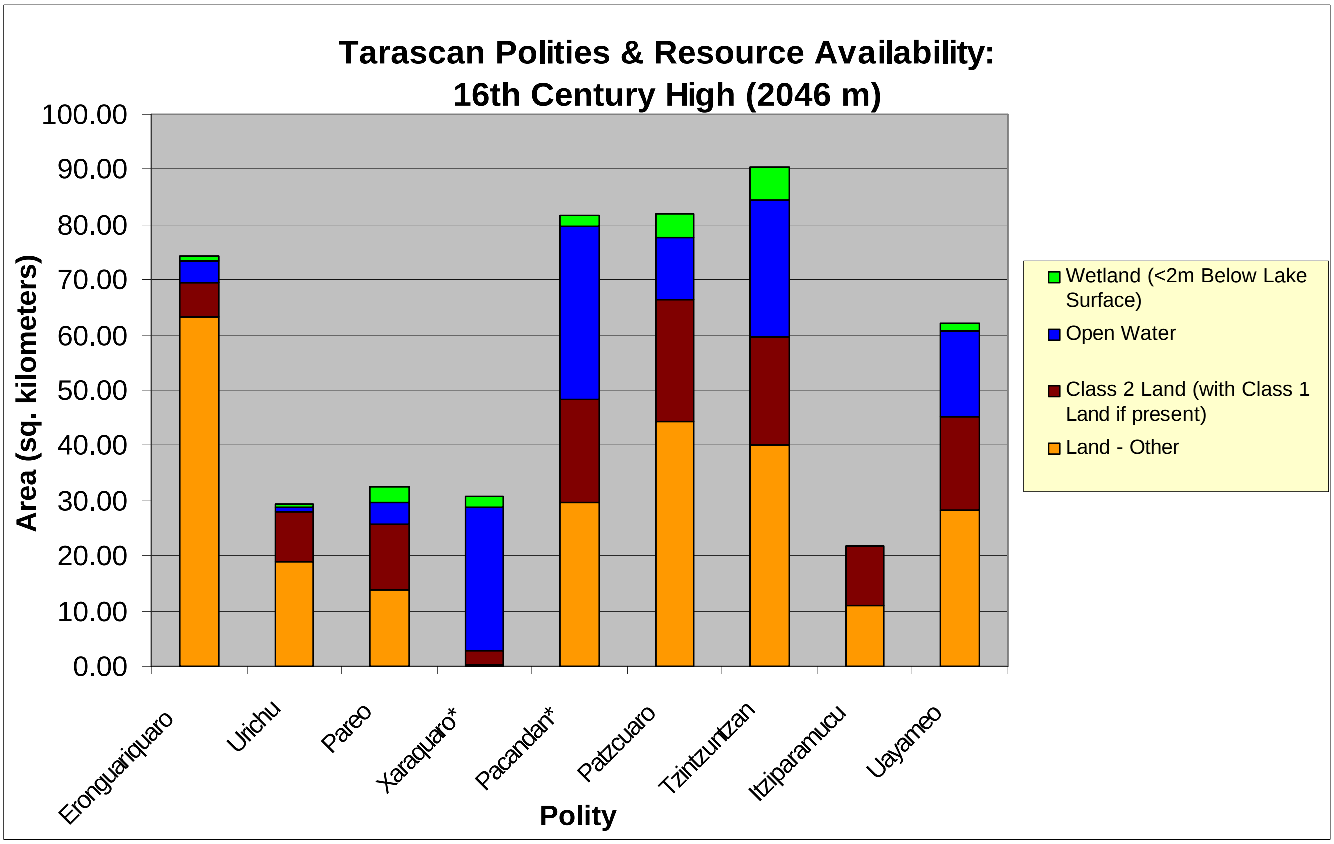

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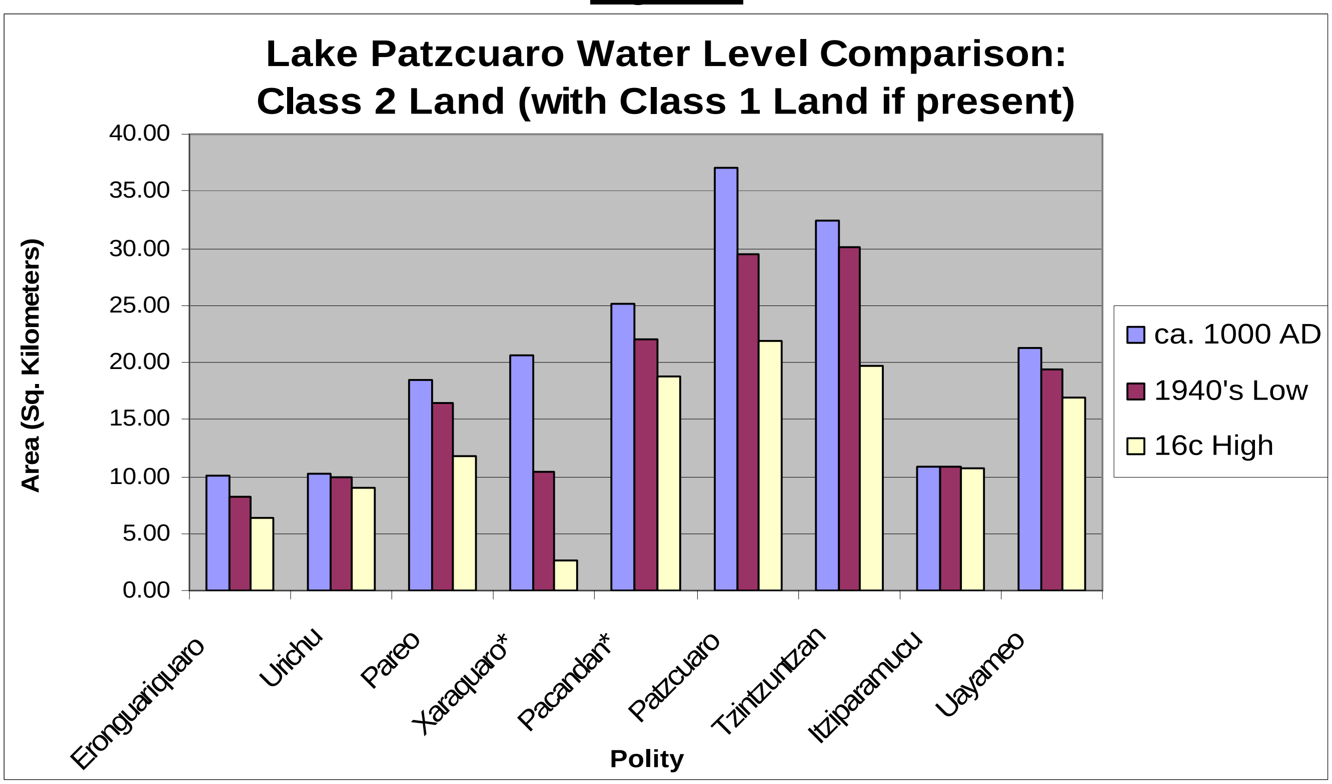

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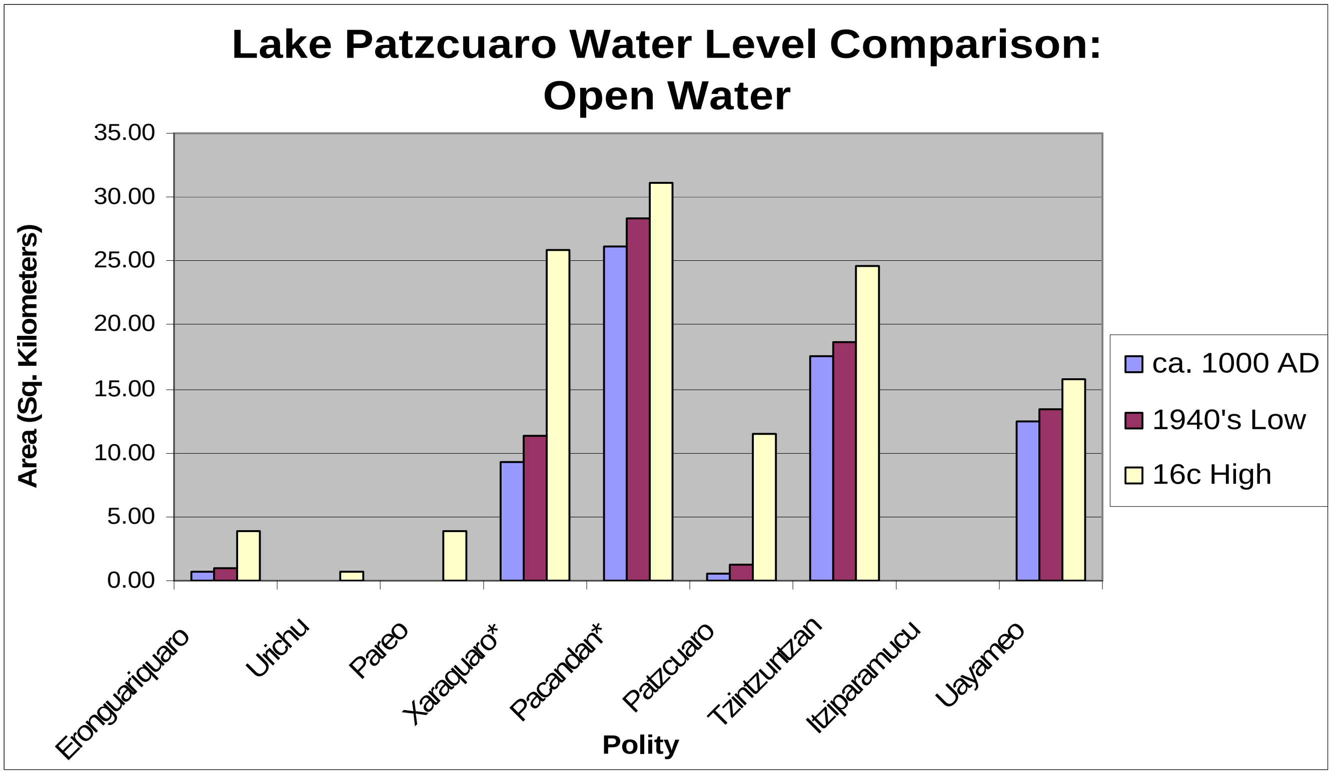

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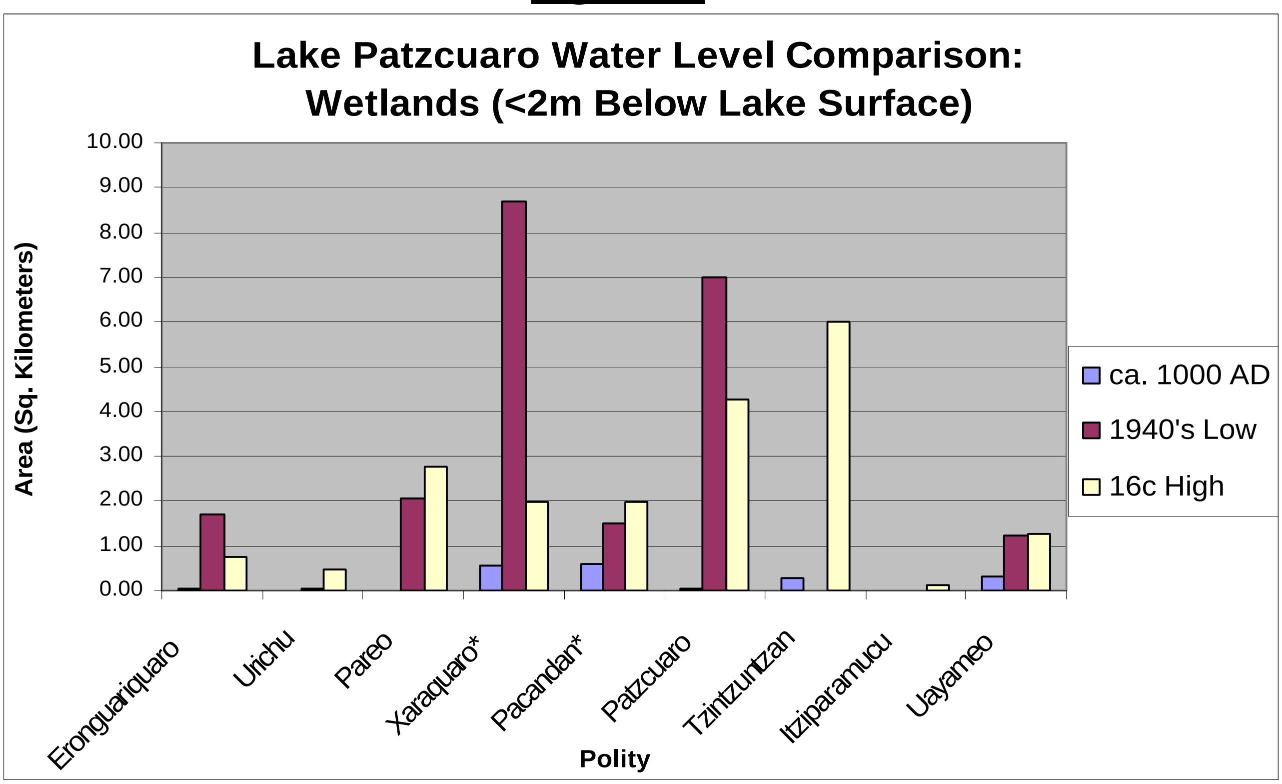

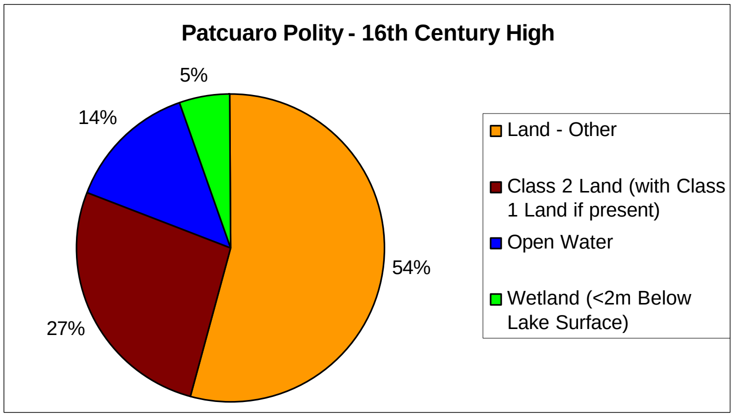

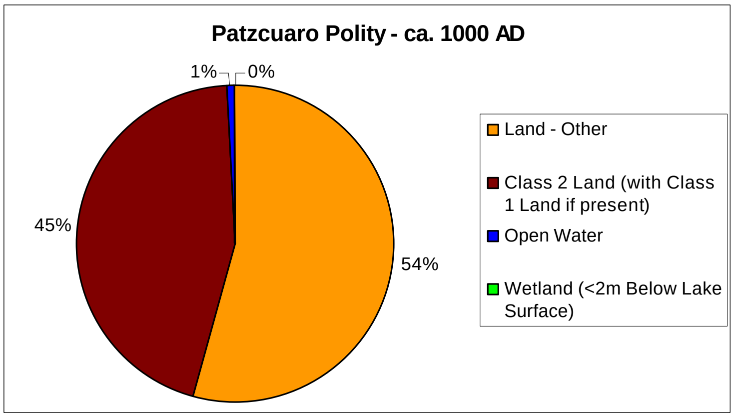

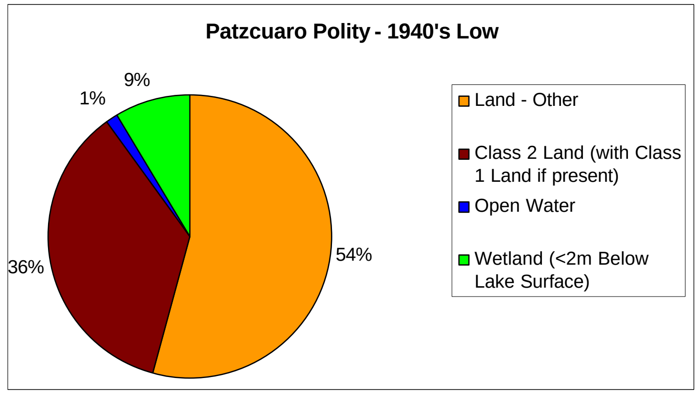

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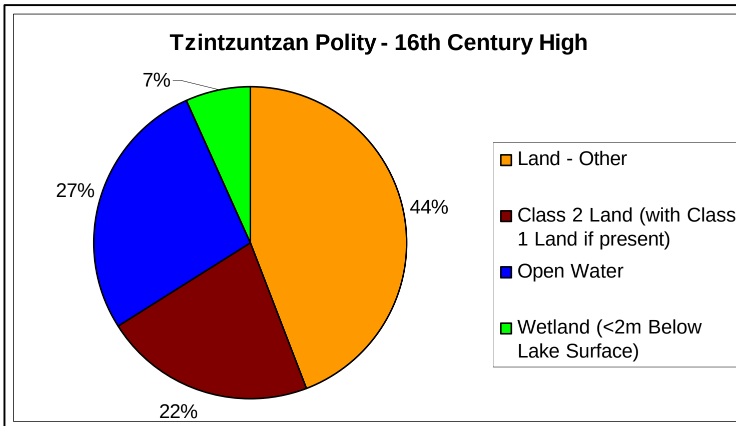
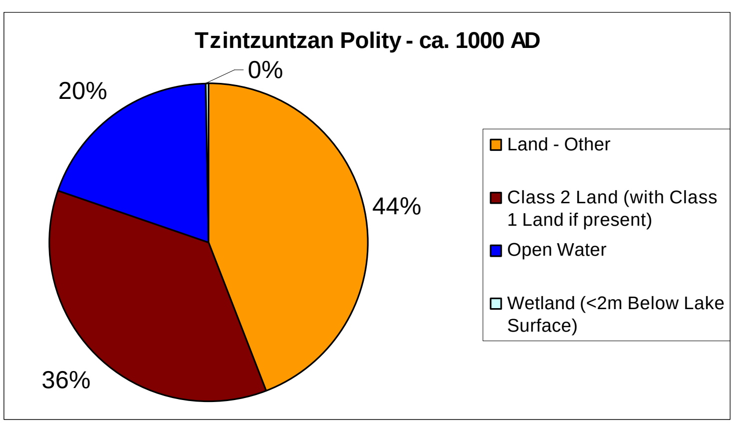




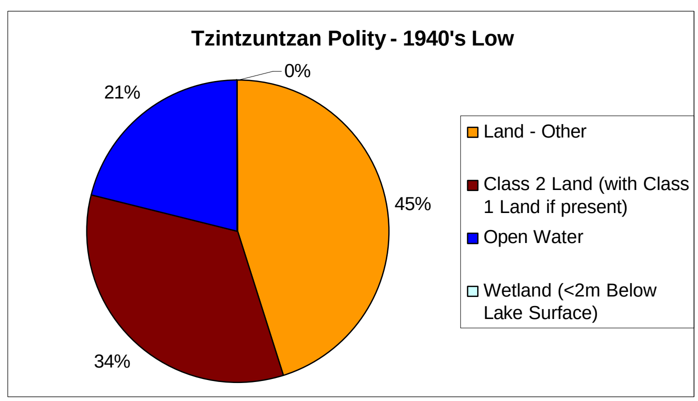
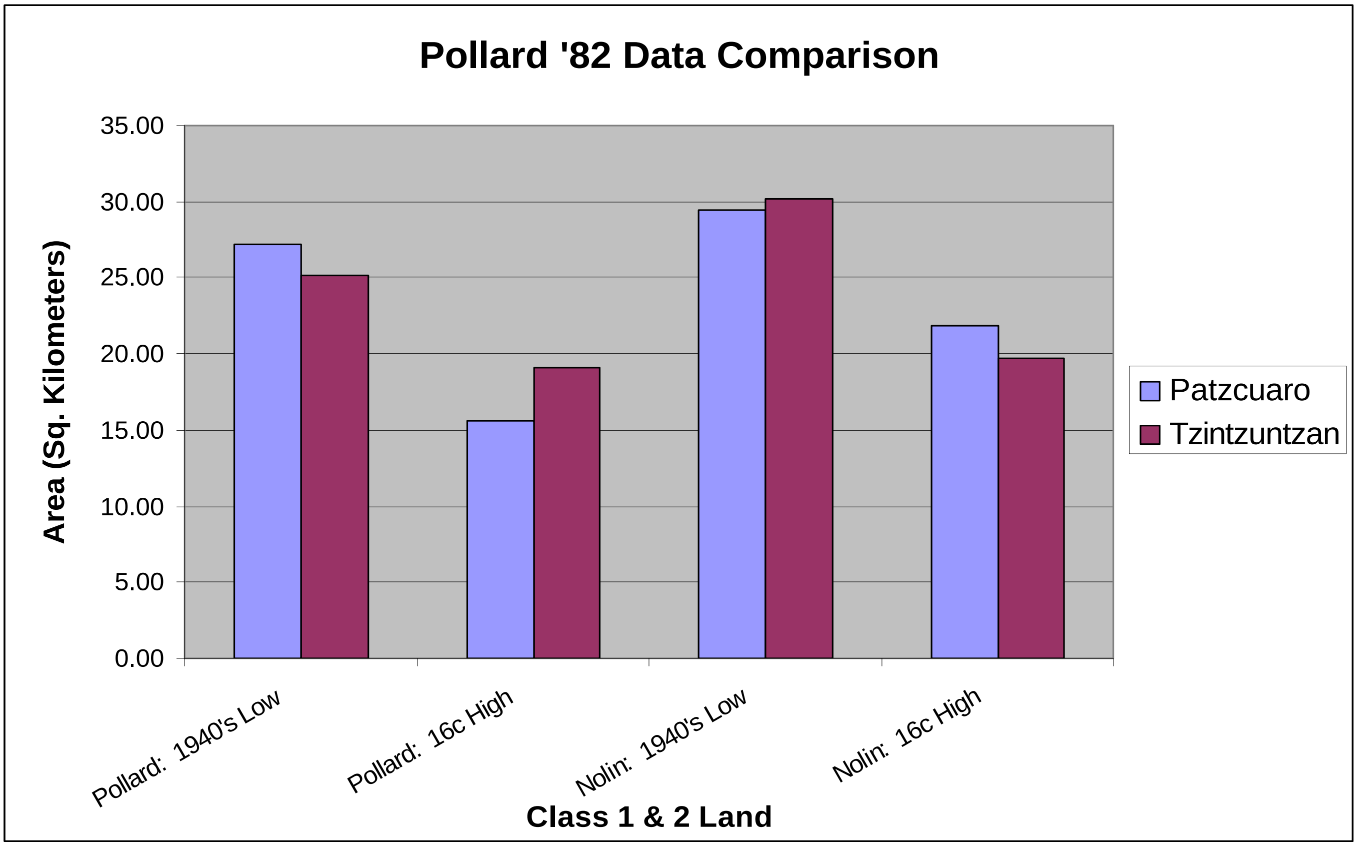


Figure 12

Figure 13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Area (Sq. Kilometers)
35.00
30.00
25.00
20.00
15.00
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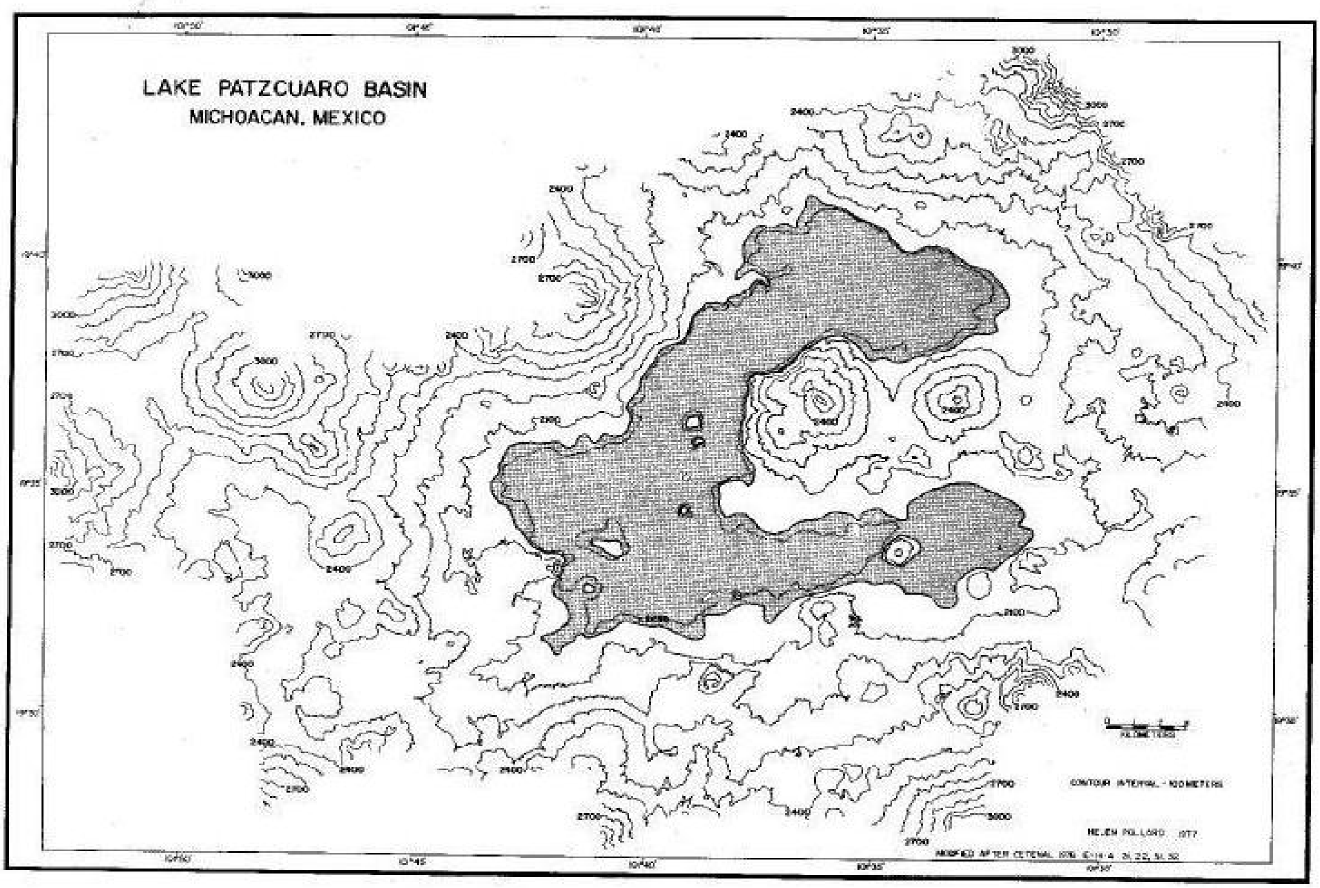
Pollard: 1940's Low
Pollard: 16c High
Nolin: 1940's Low
Nolin: 16c High
Class 1 & 2 Land
Patzcuaro
Tzintzuntzan

Figure 14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