Using Advanced Spatial Analysis to Create and Analyze the Prehistoric Environment of Pueblo III Tower Gallina Sites in Rio Arriba County, New Mexico USA

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Keywords: Archaeology, Spatial Analyst, Pueblo III, Gallina, Raster, Viewshed, Weighted Cost Surface

Abstract

The prehistory of New Mexico, USA is often represented by three specific phases in cultural development: Pueblo I (700 – 900 AD), Pueblo II (900 – 1100 AD), and Pueblo III (1100 – 1300 AD). During the Pueblo III occupation a specific cultural group known as the "Gallina" began to define both the archaeological and cultural record with construction of towers, an architectural feature unique to this sub-set of people. Coupled with the enigmatic tower feature, the focus of this study is to explore the spatial component of archaeology using a relatively small population of fifteen Pueblo III Gallina tower sites in Rio Arriba County, New Mexico. Spatial analysis and geodatabase design/creation were used to demonstrate the capabilities of GIS as a comprehensive tool to aid in the analysis of archaeological data. As a result, a topographic model was created through the use of elevation, slope, and aspect rasters. The sites evaluated showcase the versatility of GIS in the study of archaeology, one that should be regarded as a powerful tool in all stages of archaeological evaluation and understanding.

Introduction

New Mexico USA is located in a region that is defined by its arid climate, high elevations, and limited moisture. These environmental constraints seem to have manipulated settlement patterns among prehistoric populations. Those who took up residence in this area were often met with inconsistent growing seasons and poor soil development. Such restrictions limited the areas that were most suitable for agricultural development. Land forms such as mesas, cuestas (tilted plateau segments), canyons, and basins dot the landscape while simultaneously creating natural barriers. Water sources were limited and restricted the presence of game animals and vegetation. The most important tributaries associated with the Colorado River system that feed the area were the San Juan and Little Colorado Rivers (Cordell, 2009). The ability for a society to thrive and expand under these conditions was dependent upon their ability to develop behaviors to cope with their natural environment and to manipulate resources (Cordell, 2009). A hallmark of such an achievement was often met with population growth and is echoed throughout the archaeological record and within each different occupational phase of the Southwest.

Caputa, Kristin. 2012. Using Advanced Spatial Analysis to Create and Analyze the Prehistoric Environment of Pueblo III Tower Gallina Sites in Rio Arriba County, New Mexico USA. Volume 14, Papers in Resource Analysis. 9 pp. Saint Mary's University of Minnesota University Central Services Press. Winona, MN. Retrieved (date) http://www.gis.smumn.edu

Pecos Classification

The Pecos Classification is a system of organization that is used to define cultural phases through their diagnostic traits. This framework of nomenclature was first defined by Alfred Kidder and his colleagues in 1927 (Cordell, 2009) and included phases such as Basketmaker I through III and phases Pueblo I through V.

Pueblo III (1100 – 1300 AD) is often considered the florescence of the Ancestral Puebloan culture and is affectionately known as the "Great Pueblo" period. This specific phase in cultural development witnessed greater craft specialization, artistic elaboration and the appearance of substantially larger communities (Cordell, 2009). Enduring exhibitions of these communities are often found beneath an earthen mound, rubble mound or standing feature. These monuments to prehistoric architecture can be seen as a reflection of the environment; that it is a manifestation of ideas, beliefs and needs (Kenzle, 1997), the construction of which was at its height during the Great Peublo period.

The Gallina

The Gallina, a specific and curious cultural sub-set of the Ancestral Puebloan people, also flourished during the Pueblo III Occupation. While they followed the footprint of Ancestral Puebloan practices in respect to the evolution of ceramics and general methods of architectural expansion, they did stand alone in one significant method of construction; towers. Among other slight deviations from the "architectural norm" of the Ancestral Puebloans, the tower feature was unique to the Gallina people of Northwest/North Central New Mexico.

Gallina towers typically encountered in the field were described as peaked, circular mounds that lacked a central depression (Mackey and Green, 1979). Towers that have been excavated were documented as has having a double wall construction and exhibited extremely fine masonry. These towers have also been observed situated in defensive locations, with mounds of rubble beneath to add height (Mackey and Green, 1979).

The value of this study lies in its demonstration of GIS and its ability to spatially and visually compile and relay archaeological information. This analysis demonstrates the practical applications that GIS by focusing on specific sites that have recorded tower features while simultaneously exploring the spatial distribution among the sites and their respective relationships with both the environment and other sites.

Archaeological Field Methods

An archaeological investigation conducted in the state of New Mexico relied on a methodology created by the New Mexico Cultural Resource Information System or NMCRIS. It is the largest cultural resource database in the United States and is managed by The Archaeological Records Management Section (ARMS). Those in the field of cultural resource management must be familiar with definitions and guidelines in order to submit an archaeological record.

To begin, NMCRIS (1993) defines an archaeological site as "…spatially finite areas containing physical remains of past human activity that are of interest to archaeologists." When encountered in the field, the archaeologist is responsible for locating, bounding, and documenting the site, the definition of which is left to the archaeologists discretion (NMCRIS, 1993). Flexibility in site definition is important because of an overlap in both spatial and temporal occupations of sites. Often cultural occupations overlapped and are evident through the survival of diagnostic features such as ceramics, projectile points and structural features. When a site is inventoried, an LA Site Record is completed by the performing agency or the company hired to conduct the investigation.

The LA Site Record references the LA number, a unique series of numbers assigned by ARMS to a newly recorded site. This method of site designation began in 1931 by the Laboratory of Anthropology (LA) and has been maintained as such over the years (NMCRIS, 1993).

A key component to the validity of a site is/are the presence of archaeological features. Included within the definition of an archaeological feature are structures, cultural remains and facilities (NMCRIS, 1993). Features can describe uninterpreted remains as well as feature types; the latter of which requires a higher level of interpretation (NMCRIS, 1993). An extensive list of commonly occurring feature types is outlined and defined within the LA instructions. With this consideration, a tower is defined as "…structure constructed to provide elevation above the surrounding area. May or may not be attached to other structures. Includes Spanish Colonial *torrenes*…" (NMCRIS, 1993).

Once an investigation has been conducted, a project report is submitted to NMCRIS and if a site is confirmed, it is registered with ARMS.

Methods in Spatial Analysis

In order to gain the necessary project data, a representative of ARMS was contacted and a bundle of data were received which contained a generic Gallina boundary layer along with tables that housed important data including component type, phase as well as relevant site data. Once the data was obtained, ESRI's ArcGIS 10 Desktop Suite was used to refine the project scope and the extent of the Gallina area of interest (AOI); the attributes of which relied on temporal occupation and the tower feature.

A file geodatabase was created with three domains to assure continuity among the data and once done use to house finalized data. Within this geodatabase a feature class was built that stored relevant spatial data for the tower locations, but also elevation values as well as the coded values for aspect (Table 1), slope (Table 2), and weighted cost (Table 4).

Table 1. Coded domain values for aspect in degrees.

0	Flat (-1)
1	North (0 – 22.5)
2	Northeast (22.5 – 67.5)
3	East (67.5 – 112.5)
4	Southeast (112.5 – 157.5)
5	South (157.5 – 202.5)
6	Southwest (202.5 – 247.5)
7	West (247.5 – 292.5)
8	Northwest (292.5 – 337.5)
9	North (337.5 – 360)

To help describe the mathematical relationship between a tower site and its environment, basic statistical analyses were conducted to include the arithmetic mean (Zar, 2010):

$$\overline{X} = \frac{x_i}{n}$$

where n = 15, the number of tower locations examined in this study.

The arithmetic mean was used to calculate values for elevation, aspect, slope, and cost in an effort to give a baseline for an average location and orientation of tower sites located within the project area.

Table 2. Coded domain values for slope in percentages.

0	0 – 3.5
1	3.6 – 7.1
2	7.2 – 11.6
3	11.7 – 16.4
4	16.5 – 21.6
5	21.7 – 27.4
6	27.5 – 33.8
7	33.9 – 43.5
8	43.6 – 82.2

Table 3. Calculated mean and standard deviation for elevation, aspect, slope, and cost values.

	Mean	**SD**
Elevation	2259.17	94.7
Aspect	4.4	2.2
Slope	1.6	1.1
Cost	4.7	2.9

The standard deviation was calculated to determine the variance from the calculated mean (Zar, 2010) as follows:

$$s = \sqrt{\frac{X_i^2 - \frac{X_i^{\;2}}{n}}{n-1}}$$

n = 15

Gallina Sample Population

A simple "select by attribute" query was used to define the Gallina sample population in different stages of refinement. The first step was to join a shapefile of site centers to a table that contained various information about this phase of Gallina occupation. Select by Attribute queries were conducted. Step one was to define the cultural type as "Anasazi," the second was to define the early and late periods between 1100 and 1300. Once the sites were selected that fell within the appropriate date of Pueblo III, an additional Select by Attribute query was initiated that extracted the "Gallina/Largo Gallina" sites associated with that temporal occupation. Approximately 1141 Gallina sites fell within the original Gallina polygon.

After defining the temporal and cultural framework for the data an additional join was created to select all sites with a designated tower feature. Fifteen Pueblo III Gallina sites were identified as having recorded tower features associated with them from the initial 1141 Pueblo III Gallina sites. Because this small sample of archaeological sites accounts for less than 1% of the extracted Pueblo III Gallina population and because all were within relatively close approximation to one another, a smaller and less expansive Gallina Area of Interest (AOI) was created (Figure 1).

Raster Surface Analysis

A small, twelve tile raster mosaic was built to create a custom elevation surface for the Gallina tower sites. All data were downloaded from the Data Depot GeoCommunity.com website. The GIS data downloaded were at a 10 m resolution. Following the initial download, each file was converted from an SDTS file format to a USGS DEM and then resampled to an ESRI GRID raster format.

A mosaic dataset was created and the 12 resampled DEMs were added to create a larger, seamless raster. This mosaic dataset was used as a base from which elevation, aspect (Figure 2), and slope (Figure 3) rasters were derived.

These values were then used in the basic statistical calculations of the mean and standard deviation among the tower sites.

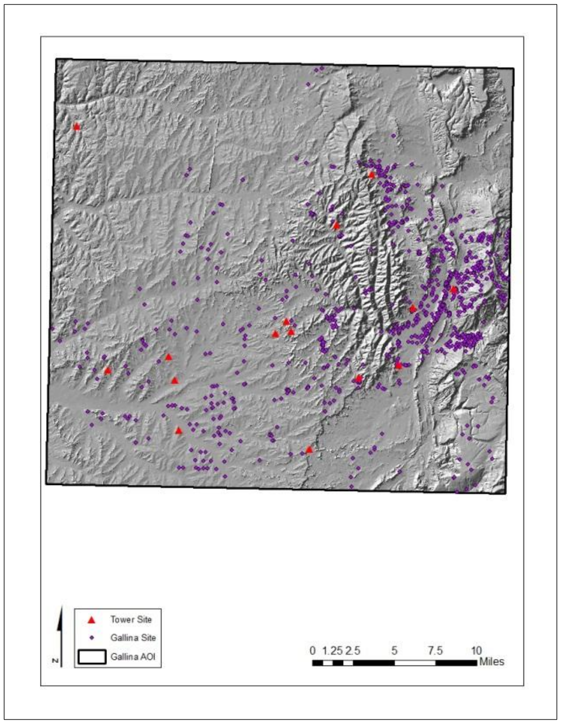

Figure 1. Gallina AOI with tower and Gallina Pueblo III locations.

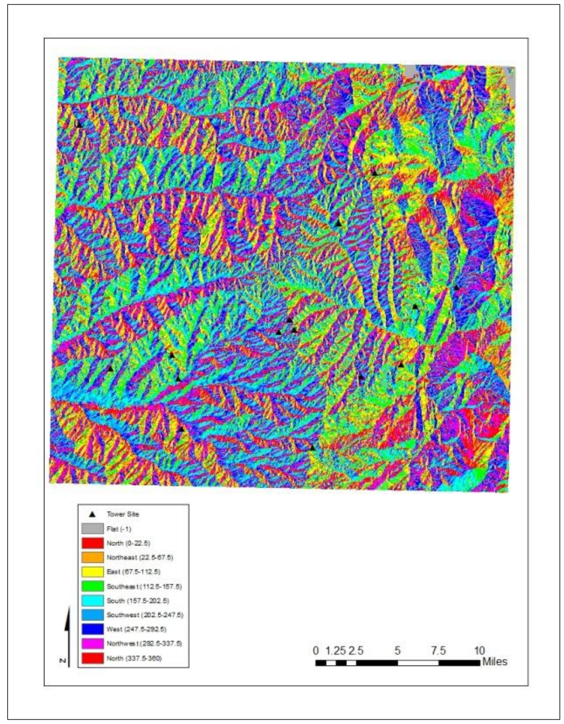

Figure 2. Aspect raster with tower locations.

The average elevation in meters was approximately 2259 (7411 feet). Because the values for both aspect and slope were coded, the interpretation for each value for the arithmetic mean and standard deviation were as follows: the average orientation for a tower was Southeast to South or 112.5 – 202.5 degrees while slope was between a 3.6 – 11.6 percent grade. Table 3 illustrates calculated statistics for elevation, aspect, and slope.

Weighted Cost Surface Analysis

Often in archaeology, settlement patterns are of interest and patterns in the cultural characteristics and physical environment are observed. However, often physical barriers and/or sacred locations may not be taken into account, elements that could greatly influence settlement behaviors (Wheatley and Gillings, 2002).

A weighted cost surface (Figure 4) was created to identify those tower locations that were erected in areas of greater cost (areas that would cost a greater expenditure of energy to reach). In this analysis, the slope and aspect datasets were used and each was reclassified on a scale from 1 to 10.

Each reclassified raster was then weighted according to its percent of influence. Slope, was considered a greater influence than aspect because of the harsh natural environment posed to prehistoric peoples and weighted at 60%, and as such was multiplied by .6. Aspect was then considered at 40% influence and multiplied by .4 with the use of simple map algebra in the raster calculator. Once both rasters were weighted, they were combined to create the final cost surface raster. The mean and standard deviation were also calculated for each tower location (Table 3).

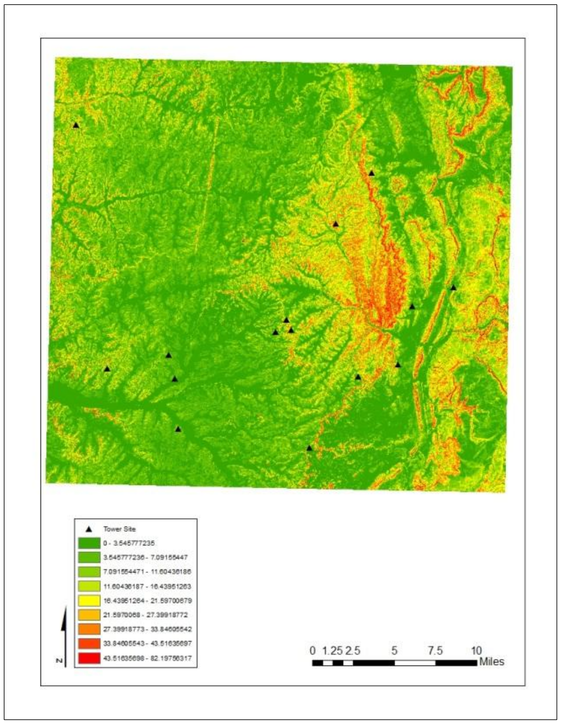

Figure 3. Slope raster with tower locations.

Table 4. Coded domain values for cost field.

0	1 - 1.7
1	1.8 - 2.8
2	2.9 - 3.5
3	3.6 - 4.3
4	4.4 - 5.2
5	5.3 - 5.8
6	5.9 - 6.5
7	6.6 - 7.3
8	7.4 - 8.3
9	8.4 - 10

Visibility Analysis

In archaeology and especially among sites that exhibit features located in defensible locations, it is important to determine an area that can be theoretically viewed from a single viewing area which determines the direct visibility between features (Wheatley and Gillings, 2002). Structural features in particular lend themselves to a variety of visibility analyses and two are considered in this research: viewshed and line of sight analysis.

A cumulative viewshed (Figure 5) was created using the tower feature class and the elevation raster. This produced a binary display of areas that were visible or not. Within the Gallina AOI there are 831 recorded sites and of these, approximately 36% or 300 locations fall within the viewshed of the tower locations.

A Line of Sight analysis was also undertaken using the tower feature class and elevation raster. Theoretically, a Line of Sight takes into account any land or object that rises above the line of sight and creates a trajectory, coded initially in red and green, of the view of the intended target (Chang, 2010). In the case of the towers, a Line of Site was generated to model visibility between towers.

Results

The topographic approach used in the analysis of the fifteen tower locations determined that given the relatively small sample population of fifteen towers, definite relationships among towers and their physical environment was not conclusive. However, there seems to be a high concentration of Pueblo III Gallina sites near the eastern border of the project AOI (Figure 1).

Additionally, only a relatively small number (1:20) of tower sites to “civilian” Gallina locations fell within the viewshed analysis area. It was noted that tower locations were positioned on the periphery of steeper land formations and this may have minimized energy costs of movement (Figures 3 and 4). Aspect and elevation seemed to have little impact in the locations of tower sites.

Discussions

Given the relatively small sample size of fifteen towers among a population of 1141 Pueblo III Gallina, less than 1% of the population, it might be fair to reconsider the primary function of a tower structure. More in depth archaeological analysis might confirm or invalidate.

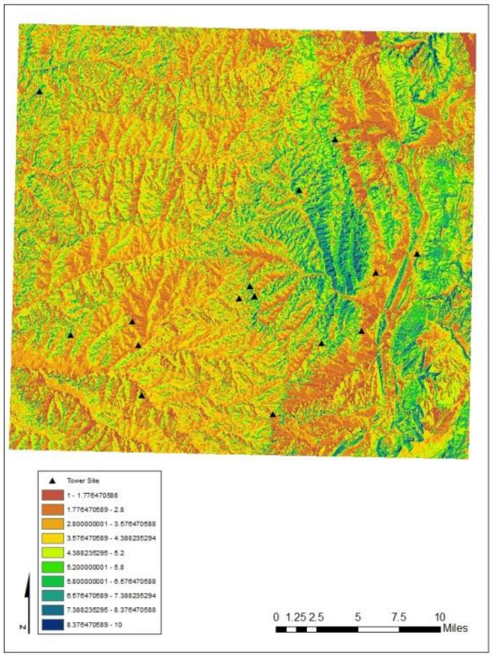

Figure 4. Weighted cost surface raster with tower locations.

While the viewshed analysis (Figure 5) gives an approximation of the viewing area, it is just that, an estimate. Because the height of towers vary and none of the tower sites considered boast excavated tower features (to determine relative height), no observer height was included in the analysis.

It is also important to consider the viewshed analysis is only as accurate as the elevation dataset used, and it is also subject to edge effects when the viewshed analysis is limited to the project area and does not consider those points outside of the area of interest (Wheatley and Gillings, 2002). This is true in the case of the Gallina project area and was known the AOI creation.

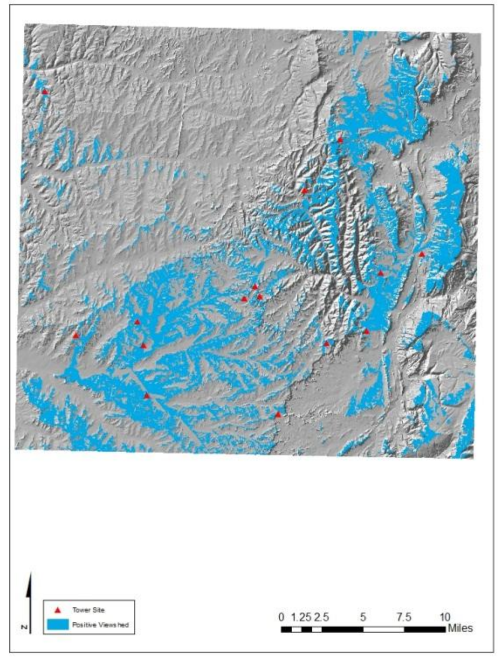

Figure 5. Positive cumulative viewshed map with tower locations.

More advanced statistical analysis could be undertaken to explore the mathematical relationships between slope, aspect and elevation and their relationship to the tower sites. Linear correlations among the fifteen tower sites and the variables of elevation, aspect, and slope could help to delineate relationship among the independent variables. Using the Poisson distribution to define random occurrences between tower locations and, elevation, aspect, and slope might also allow insight in to the “why?” of Gallina tower construction.

Other variables to consider with a more holistic and environmental approach to this analysis would be to include distance to water sources, which in of itself might be a task considering the perpetual ebb and flow of climactic change over the past seven hundred years. However, this is an important element that aids in the sustainability of a location and would contribute to a prehistoric cultural landscape.

Rattlesnake Point

More can be done at a site specific level where the area of focus is limited to a single site. By conducting an analysis in a region that is comprised of twelve raster tiles or an area that is roughly fifty miles in area, the versatility of certain tools offered by both the spatial analyst and the 3D analyst toolboxes are greatly limited. To give insight into what characteristics a site would need to present in order to best benefit from these toolboxes, a brief overview of an archaeological site known as “Rattlesnake Point” was undertaken.

Rattlesnake Point (Figure 6) is a Pueblo III Gallina site that was chosen for excavation in 1947 (Hibben, 1948). Two pit houses, a unit house, and a tower were identified via various surface indicators and structural remains but only the tower feature was excavated.

An additional inventory was taken of the four features but for this discussion, focus will be kept to the tower feature and the characteristics that best lend to a GIS analysis. Hibben (1948) describes the tower within the Rattlesnake Point site as being fifteen to twenty-six feet in horizontal dimension while measuring twenty-five to thirty feet in height. This approximation in height is based from wall-fall and its thickness. Surface indications were a mound of rubble four to six feet in height among depressions and ridges of contiguous rooms.

When encountered in the field, it is not uncommon for an archaeologist to draw a scaled sketch of a rubble mound, provenienced stone with dimensions, and/or a profile. The ability of spatial analysis to give meaning to this archaeological data is in its expression of spatial data. The estimated tower height and width can be delineated from the sketch through the creation of a polygon feature and can then be extruded via the 3D analyst toolbox in ArcScene. It also can show the depth of excavation. If contour lines are present on the sketch a custom surface can be built and a 360 degree site plan can be viewed. In essence, with the right spatial and locational data, an archaeological site can be “brought to life” with the aid of GIS.

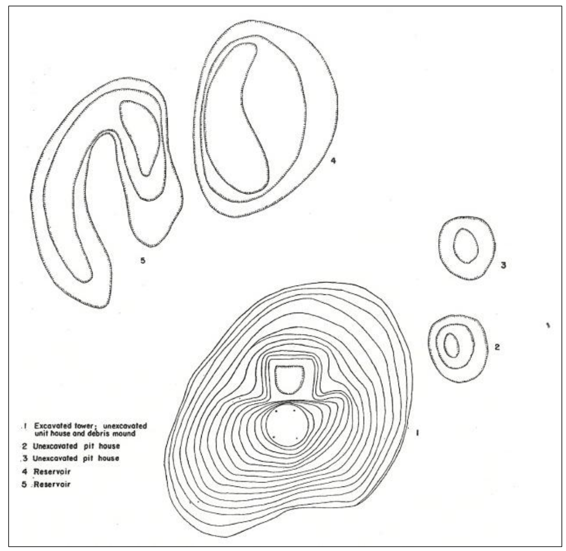

Figure 6. Sketch of Rattlesnake Point (Hibben, 1948).

Conclusions

GIS is a spatial tool that gives greater clarity to the temporal nature of archaeology. Instead of looking at an archaeological site on a two-dimensional plane, spatial analysis allows for a more holistic and three-dimensional approach giving the site or even culturally relevant location spatial relevance.

It can also enhance an archaeologist’s understanding and insight in to the “why” of a particular site by analyzing the “where.” By looking at the measures of central tendencies, even within the small sample population of fifteen tower locations, it was possible to see a small relationship among elevation, aspect, and slope.

This analysis was a demonstration on the versatility that GIS has to offer the world of archaeology by analyzing a small population of towers. Utilizing various methods in raster creation and manipulation, a prehistoric cultural landscape, and even site specific analyses do not need to be limited to topographic maps and field sketches. Through the use of these techniques, as well as encompassing GIS visibility analyses and the creation of a cost surface, features of a tower location can be visualized and the interpretation of the past can become more clearly understood.

Acknowledgements

At this time, although I feel I should have begun the report with this section at the forefront, I'd like to take a moment to thank Tonya Fallis at ARMS who took time out of her busy schedule to help identify and obtain the appropriate data needed for this analysis, sometimes with vague information to guide her. I'd also like to thank John Ebert, Greta Bernatz, and Dr. David McConville for their support throughout my graduate career. Never have I met not only such a supportive network of professors but a group of people genuinely concerned for the outcome of both my academic and professional careers. To my family and friends, the people most important in helping me stay focused and whose unwavering support during this past year has helped me believe in myself again.

Most importantly however, I'd like to remember my late husband Santo Caputa, whose continual support to pursue graduate school and his consistent belief in me as a person has left a remarkable imprint not only on my academic career, but also my life.

Here's to you.

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