

Archaeology and GIS: Prehistoric Habitat Reconstruction

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ABSTRACT

Archaeologically, site-catchment analysis can provide valuable information on ancient survival strategies and social organization. From a cultural resource management perspective, developing models of prehistoric site selection and settlement patterns can improve analysis methodology. Digital access to archaeological data allows the incorporation of cultural resource information into the overall planning process and GIS provides a means to integrate environmental and archaeological information into an effective tool. GIS technology can be used to create environmental archaeology maps to facilitate cultural resource management, planning, mitigation, preservation, excavation, and analyses. This GIS research project establishes site-catchment areas and identifies environmental variables associated with those areas. The sites are then statistically evaluated to determine if the distribution of artifacts is due to chance or related to specific environmental variables. The results are interpreted with ecological, anthropological and geographical theories to provide insight on prehistoric socio-economic behavior as reflected by the corresponding settlement patterns.

INTRODUCTION

Legislation protecting archaeological resources has produced massive data collection in the archaeological community. The rate at which growth and development is occurring is exceeding the capacity of the management systems that have already been established. Records housed in state and university laboratories are increasing in number, yet often site report content is not substantial enough to facilitate detailed regional studies. Coupled with the lack of communication between state and local agencies this situation has led to increased fragmentation in the archaeological record. One of the most significant components missing from Texas state archaeological site files is the specific environmental context where these sites and artifacts were discovered. Often sites are reported by individuals who have limited knowledge of the character of the landscape. Although many contract, academic and published reports reference zonal physiographic characteristics of the landscape there is a general disconnection between the sites, the data and the interpretive inter-relationships. This research seeks to bridge the gap by providing a series of maps with interpretive visual representations that provide a bird's eye view and facilitate pattern recognition to develop a more comprehensive understanding of site distribution within the environment. Glimpses into prehistory that have been provided by archaeological discoveries must be viewed cumulatively in order to understand the larger patterns that emerge regarding prehistoric behavior. As such, the archaeological community is in need of a consistent organizational mechanism that provides a means to access, integrate, analyze and interpret data from a variety of sources.

OBJECTIVES

Given the dynamic character of the cultural ecological relationships involved, reconstructing prehistoric habitats to formulate a regional model is a formidable task. Fortunately, Geographic Information Systems (GIS) technology provides organizational mechanisms to manage the wealth of data and create links between the various components of the ecosystem and archaeological sites. Site catchment analysis provides the methodological structure for the GIS to work within. As such, GIS and site catchment analysis methodology have tremendous utility for cultural resource managers. In order to illustrate the benefits related to this approach the objectives of this research are to:

1. Develop research methods and integrative techniques that enhance cultural resource management practices.
2. Reconstruct regional prehistoric habitat with environmental and interpretive digital data layers.
3. Transform environmental data layers into interpretive maps for statistical, spatial and site catchment analysis.
4. Define site catchments with GIS techniques to investigate the economic resource space around known archeological sites.
5. Construct models of regional prehistoric site selection and settlement patterns with results from the statistical and spatial analysis.
6. Create environmental archaeology maps to facilitate Cultural Resource Management planning, mitigation, preservation, excavation, and analysis.

To meet the objectives of this research, GIS software is utilized to place archaeological sites in their spatial context, establish economic territories, identify associated environmental variables, infuse the environment with interpretive meaning, correlate artifacts and evaluate a series of hypotheses with spatial and statistical techniques. These data are interpreted and results are synthesized in a regional model of prehistoric populations in North Central Texas.

RESEARCH METHODOLOGY

Site catchment analysis is conducted on a regional scale to reconstruct prehistoric habitat and analyze site location as it changes or stays the same through time. This technique defines the character of the economic resource space within 1 km site catchment areas around archaeological sites so that they may be collectively evaluated to formulate a regional model of prehistoric settlement patterns. While the results of such an analysis reconstruct prehistoric habitat to provide an interpretive regional

model it is important to note the multiple benefits of such a model incorporated into a GIS throughout the entire process of cultural resource management. The multifaceted character of the landscape requires preplanning to determine the most efficient strategy for survey, testing and excavation efforts. Throughout the excavation process databases that are compatible with GIS software provide a means to store multiple layers of information. When these attribute tables are joined to spatial locations the dynamic relationships that develop within the landscape can be observed and evaluated in a variety of ways. Ultimately this process leads to the final interpretation of the information, the deliverable publication and the ability to archive this information in a centralized location.

Site Catchment Analysis is performed with ArcView 8.3 to depict, extract, measure and evaluate environmental data in relation to archeological remains. Environmental variables are derived from modern habitat descriptions. Data are assembled on landforms and the potential of soil types to produce economically advantageous plant communities. Cultural variables based on ethnographic analogy are supported by the evidence of artifact assemblages related to the particular sites collected from Texas Archaeological Research Laboratory (TARL) files and a variety of reports. Criteria considered as viable explanatory mechanisms include:

1. soil settings (taxonomic, textural, topographic)
2. soil potential to provide suitable habitat for plants and animals
3. economic value (edibility, medicinal, supplemental) of soils
4. catchment diversity (based on soil series)
5. geological resources and foundation
6. geomorphology (terraces, uplands, bottomlands, floodplains)
7. physiographic resources (prairies, woods, ecotones, riverine settings)
8. cultural factors (archaeological composition, character and abundance)

These criteria are mapped by utilizing digital data layers derived from several sources. Some of the data layers did not exist prior to this research and had to be generated. Pre-existing environmental digital data layers consist of county boundaries (NCTCOG), geology (USGS), soils (SSURGO), streams (NCTCOG), rivers (TNRIS), lakes (NCTCOG), elevations (USGS) and physiographic regions (TNRIS). Generated data layers include archaeological sites, site catchment boundaries, economic values, topographic settings, riparian corridors and ecotones. Environmental modeling of these data results in the mapping of the distribution of topographic settings, physiographic settings, geological structure, hydrological resources, plant type (grains and seed crops, grasses and legumes, wild herbaceous) and wildlife (openland, rangeland, wetland) potentials and soil economic (edibility, medicinal, supplemental) values. Given the climatic character of the study area evidence indicates that modern soil types combined with their associated plant and animal communities are a viable source for reconstructing potential past environments. A conceptual diagram (figure 1) provides an overview of the pertinent data and general processes that are part of the site catchment analysis.

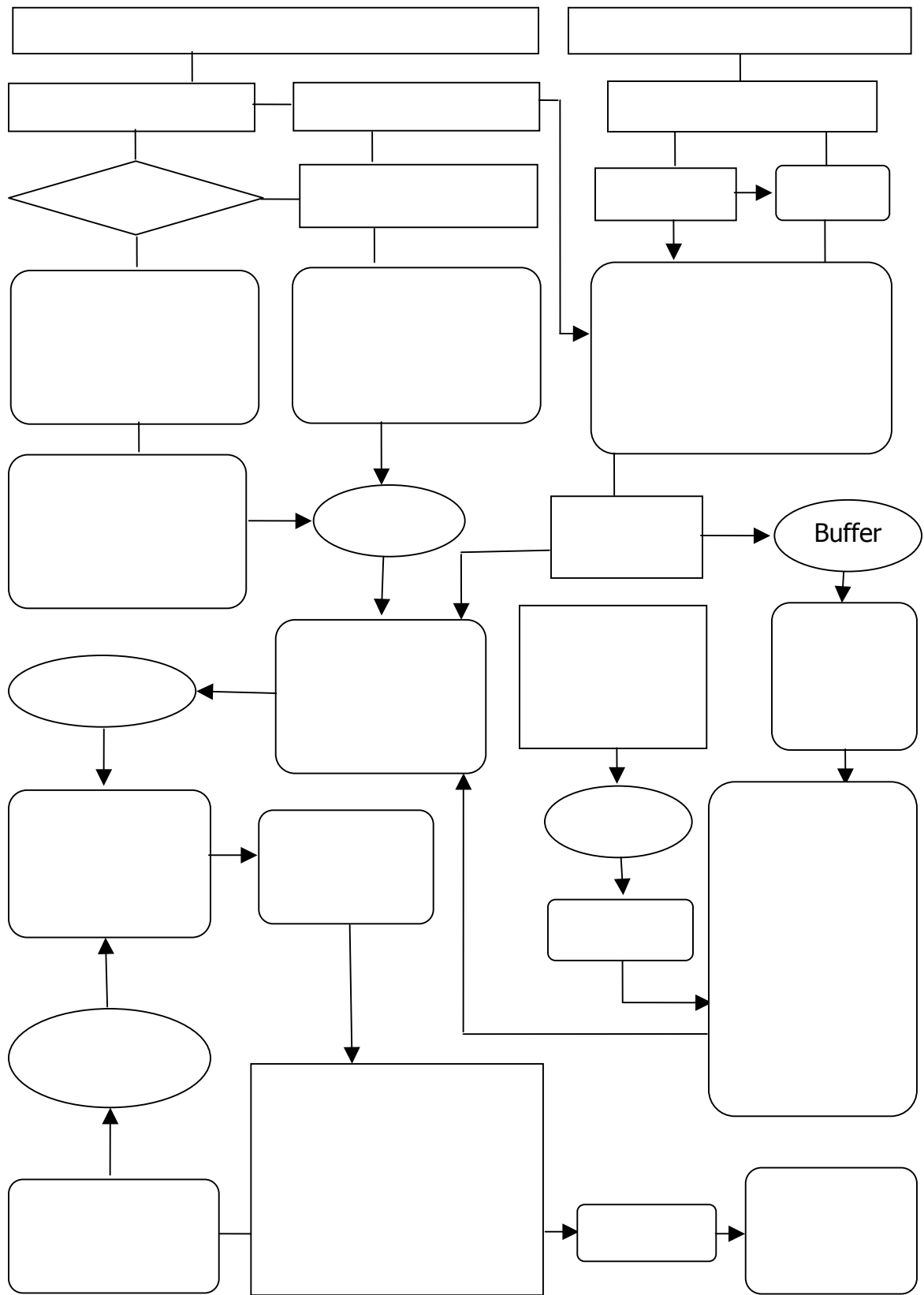


Figure 1. Digital Data and Data Generation Processes of Site Catchment Analysis

SITE CATCHMENT ANALYSIS: PROCEDURES

Geographic Information Systems (GIS) permits cultural resource managers to conduct sophisticated spatial analyses by providing an extremely useful methodological structure through which quantitative approaches to the spatial arrangement of environmental attributes and cultural remains can be addressed. GIS software plays a central role in the process of integrating the data collected and depicting spatial patterns to reconstruct relationships. Essentially the GIS component provides an organizational mechanism (figure 2) to manage large data sets from a variety of sources, generate new data sets and integrate these data to analyze the dynamic relationships that help explain prehistoric human behavior.

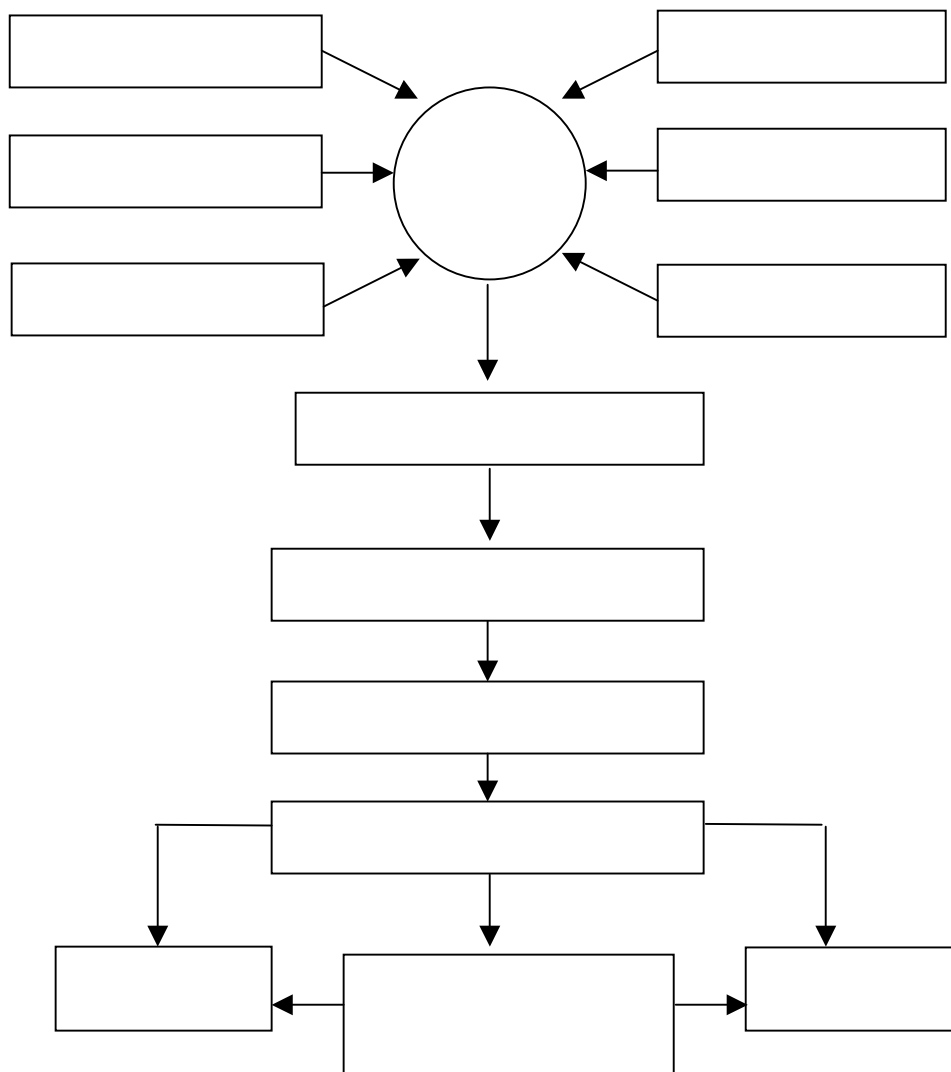


Figure 2. Conceptual Diagram of GIS in Relation to Components of the Research

In the past the process of performing site catchment analysis has involved extensive field survey with paper maps and arduous hand calculations. While fieldwork is essential to the integrity of the model the complexity of the procedures involved has historically created numerous limitations. One of the obvious limitations is related to the time element. GIS provides an ideal set of tools to facilitate the process of performing site catchment analysis efficiently. These tools provide a means to link the archaeological record with the environment on a regional scale and conduct multiple analyses. It is with these tools that site catchment analysis is performed and with ecological, anthropological and geographical theories that settlement patterns are interpreted. Procedures used to perform site catchment analysis include data collection, construction of databases, classification, scoring, data layer generation and a variety of geoprocessing techniques. ArcMap provides an interface to organize, manage, analyze, and extract data. These procedures are designed to conduct site catchment analysis and address research hypotheses that collectively serve to build a model of prehistoric settlement patterns. Site catchment analysis is performed with ESRI ArcView 8.3 and statistical tests are calculated with SPLUS 2000 statistical software. GIS techniques (figure 3) are an active component, throughout the entire process of site catchment analysis, from data collection to hypothesis evaluation.

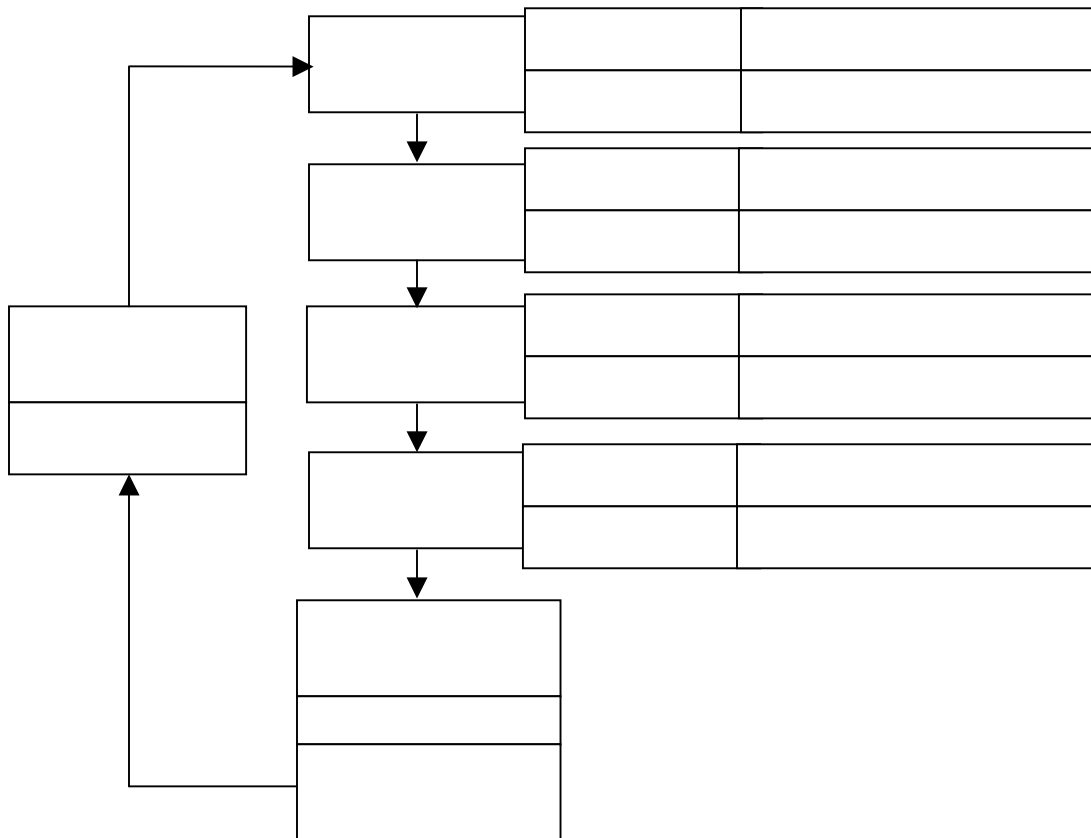


Figure 3. Schematic Diagram of GIS Data Processing Design in Site Catchment Analysis

In general, the current site catchment analysis includes the following procedures:

1. Soil Survey soil series level data are evaluated with respect to vegetation.
2. Vegetation, associated with specific soil types in the Soil Surveys are identified by Common Name, Family, Genus and Species.
3. Research is conducted to determine the relative values, per plant species, of edibility, medicinal value and supplemental value.
4. Values are attached to soil series level data in ArcMap GIS interface to the digital soils data layer.
5. Soil series are recoded with economic values, vegetation and wildlife potentials using ArcMap "joining" operations to relate to site distribution in light of chronology, site frequency and artifact density.
6. Archaeological Sites are projected with ArcCatalog and ArcToolbox and then imported into the ArcMap GIS interface where 1 km Catchment areas are constructed around the sites with ArcMap buffering techniques.
7. Soil types within catchments are proportionately extracted, recorded and interpreted into measures of diversity, plant and wildlife potential and economic worth with ArcMap selection and extraction techniques.
8. Overlay analysis is performed using ArcMap to provide a visual representation of the intersecting data layers that form the environment in association with sites and facilitate evaluation of spatial patterning.
9. Observable topographical, geological, hydrological, physiographic and ecotonal resources are related to sites chronologically, with respect to occupation frequency and assemblage composition, by selection and extraction ArcMap techniques to compile contingency tables for chi-square analyses.
10. Descriptive and multivariate statistical tests are performed with SPLUS 2000 software to objectively compare economic values, wildlife potentials, vegetation potentials, topographic settings, great groups, geological and physiographic settings within site catchment areas. These tests facilitate pattern recognition with respect to site occupation, composition and change through time.

Results generated from the site catchment analysis are, in part, presented in a series of maps. A series of thematic databases, charts, histograms, and graphs summarize the proportional distribution of soil types, geological settings, topographic settings, physiographic settings, economic potentials and catchment soil diversity. Site

catchments are summarized with descriptive and multivariate statistical techniques to describe, quantify and compare the resource potentials of site territories. Based on the results that emerge from spatial and statistical analyses a series of hypotheses are evaluated and a model of prehistoric settlement patterns is formulated to synthesize past and present research.

SOILS: A DIAGNOSTIC TOOL

Site Catchment Analysis in relation to prehistoric populations involves reconstructing the natural environment and potential wildlife habitat in past tense. The most complex part of environmental reconstruction is associated with vegetation. In this particular study, soil is selected as a primary diagnostic attribute because it provides the foundation for the potential of vegetation. Climatic patterns in combination with topographic settings explain the spatial distribution and abundance of vegetation that exist in response to the other environmental factors. Soil surveys contain an abundance of environmental information. Although many descriptive attributes are attached to soil types the particular attributes that are used for this study are limited to soil series, great groups, plant type potentials, wildlife potentials, soil settings and topographic settings. Soil series are consolidated or recoded to represent each of these variables. Pre-existing soils data layers, for each of the counties (the West Fork or Wise County, the Elm Fork or Denton County) in the regional study area, are utilized in the current research.

Soil Settings

Soil series data is connected to attributes that describe taxonomic, topographic and textural settings that are typically associated with certain soil series. These settings are depicted in ArcMap by adjusting the symbology of pre-existing soils data layers that are attached to descriptive databases derived from soil surveys. Topographic settings associated with soil types include alluvial terraces, bottomlands, floodplains, low hills and ridges, old terraces and valley fills, plains, Pleistocene terraces, ridges, stream divides, stream terraces, terraces, upland ridges and uplands. These settings are grouped into uplands, bottomlands, terraces and floodplains. They are incorporated into a chi-square statistical analysis to evaluate site location with respect to occupation frequency and change through time. Soil textural settings, as defined by the county soil surveys, include Blackland, Clay Loam, Clayey Bottomland, Claypan Prairie, Deep Redland, Deep Sand, Eroded Blackland, Loamy Bottomland, Loamy Prairie, Loamy Sand, Low Stony Hill, Redland, Rocky Hill, Sandstone, Sandy Loam, Sandy, Shallow Clay, Steep Adobe and Tight Sandy Loam. These groups are primarily utilized in the economic study to provide a linking mechanism between the vegetation and the soil series.

Soil series are consolidated into great groups based on links established by the Soil Survey. In order to attach economic value to these settings a "dissolve" operation is performed rather than adjusting symbology. This allows the economic values to be summed during consolidation of soil series into soils settings or great groups.

Archaeological data and soil settings are evaluated to facilitate Chi-Square analysis. In order to create contingency tables ArcMap tools are used to select the particular settings by "attributes" and archaeological sites (grouped into occupation frequency and according to chronology) by "location" in relation to the particular selected settings.

Site Catchment Soils Diversity

Soil series associated with sites provide the best resolution in terms of variation within a catchment area. Each catchment area contains a square kilometer of various soil series. Each great group contains proportional distributions of soil series relative to the location of the site. In order to estimate the diversity within site catchments each catchment is evaluated with regard to the proportional representation of each soil series category within each site catchment to calculate diversity. The Shannon-Weiner Diversity Index (Colinaux, 1993:316),

$$H_1 = -\sum p_i \log_2 p_i,$$

where p_i = relative abundance of soil type to total soil, is employed to evaluate the relative diversity of each catchment. This equation takes into account the "species richness" based on the proportion of the soil series represented in the catchment. Catchment diversity is calculated in this manner for all of the time diagnostic sites to correlate with occupation frequency and change through time. Diversity values in relation to these factors are analyzed with an ANOVA statistical test.

Soil Potential for Plants and Wildlife

Plant types and wildlife potentials are associated with soil series based on soil survey estimates. These attributes are recoded (figure 4) from soil survey ratings that are "high", "medium" and "low" categories. Soils considered to have "high" suitability were given a value of 0.64. Soil types with "medium" potential were given a value of 0.29 and soils with "low" potential were given a value of 0.07. These weighting techniques are derived from "Ranking Procedures" in GIS and Multicriteria Decision Analysis (Malczewski, 1999:180).

Soil Suitability	Rank	Rank Sum		Rank Reciprocal		Rank Reciprocal	
		Weight	Normalized Weight	Reciprocal Weight	Normalized Weight	Weight	Normalized Weight
	R	(n-r _j +1)	Weight/ Total Weight	(1/r _j)		(n-r _j +1)p, where p=2	
HIGH	1	3	0.50	1.00	0.55	9	0.64
MEDIUM	2	2	0.33	0.50	0.27	4	0.29
LOW	3	1	0.17	0.33	0.18	1	0.07
Total		6	1.00	1.83	1.00	14	1

Figure 4. Weighting Procedure: Plant and Wildlife Estimates Projected by Soil Surveys

Essentially this procedure transforms discrete data into continuous variables so that they may be proportionately assigned a value and evaluated in relation to their relative representation within site catchment areas. These weights are attached to soil series digital vector data by utilizing ArcMap to perform an "attribute join" operation. Once the attribute data is joined to soil series location and proportional values calculated, with GIS tools, the spatial distribution of these factors can be included in multi-scalar analyses. Resulting data layers provide an overview of the spatial distribution of wildlife and vegetation potentials for the entire county surfaces. In relation to archaeological sites these data layers can be "clipped" based on the extent of site catchment areas with ArcMap geoprocessing tools. Associated values that remain within the site catchment territory can then be measured, described and statistically evaluated.

Interpretations: Potential Economic Value of Soils

Locally available botanical resources that could have been utilized by prehistoric populations are of primary importance to settlement pattern investigations. Although, ethnographic botanical information is sparse, a variety of publications have been written that provide extensive information on the edibility, medicinal, and toxic properties of plants that are native to Texas. These resources are utilized to aid in the interpretation of the botanical data retrieved from archaeological sites and their site catchment areas.

Economic potentials of soils are linked to digital data layers by soil survey correlations of soil setting to vegetation type. This provides an interpretable view of prehistoric habitats. In order to depict interpretive values, codes are assigned to a sample size of 242 vegetation species collected from associations made in the soil surveys, botanical resource books and archaeological literature. Based on the edibility, medicinal value, and supplemental potential of the plant, relative values are translated into economic values per category. The resulting scores are arbitrarily calculated by assigning a percentage to the applicable category. For example, if a plant has both edible and medicinal properties each category is given a value of 50 percent. If a plant is primarily edible with limited medicinal value edibility would be given a value of 90% and medicinal properties a value of 10 percent. Each percentage is determined by the discretion of the author based on information provided in the descriptive literature.

Plants are associated with the corresponding soil settings and economic value is then related to soil series. As a result, the 242 vegetation species in the sample are consolidated into 22 soil settings. Economic values of soil settings are linked to 126 soil series and proportionally evaluated within site catchment areas. Soil series are then consolidated into the 11 Great Groups that are represented in the site catchment areas so that they may be summarized. Consolidation of the appropriate soils series provides a relative economic value for the great groups within each catchment. These values are summed and assigned to the catchment area to provide an overall economic value. Each catchment area is also assigned three thematic economic values (medicinal, edibility, supplemental) by establishing the same data links. This is how the relative

economic values are derived for each site catchment area. The general procedure to assign economic meaning to the landscape is summarized by a diagram (figure 5). Economic values are represented in a series of analytical maps by recoding attributes associated with the pre-existing soils data layers. These values are associated with archaeological sites with respect to time period, occupation frequency and site contents. The analog data are statistically evaluated to test a series of hypotheses. The spatial distribution of the economic values reveals the trends across the landscape that can be viewed in relation to archaeological site locations. While the current research depends on soils to ascertain the economic value and potential for vegetation and wildlife other environmental variables are included to provide a more comprehensive view.

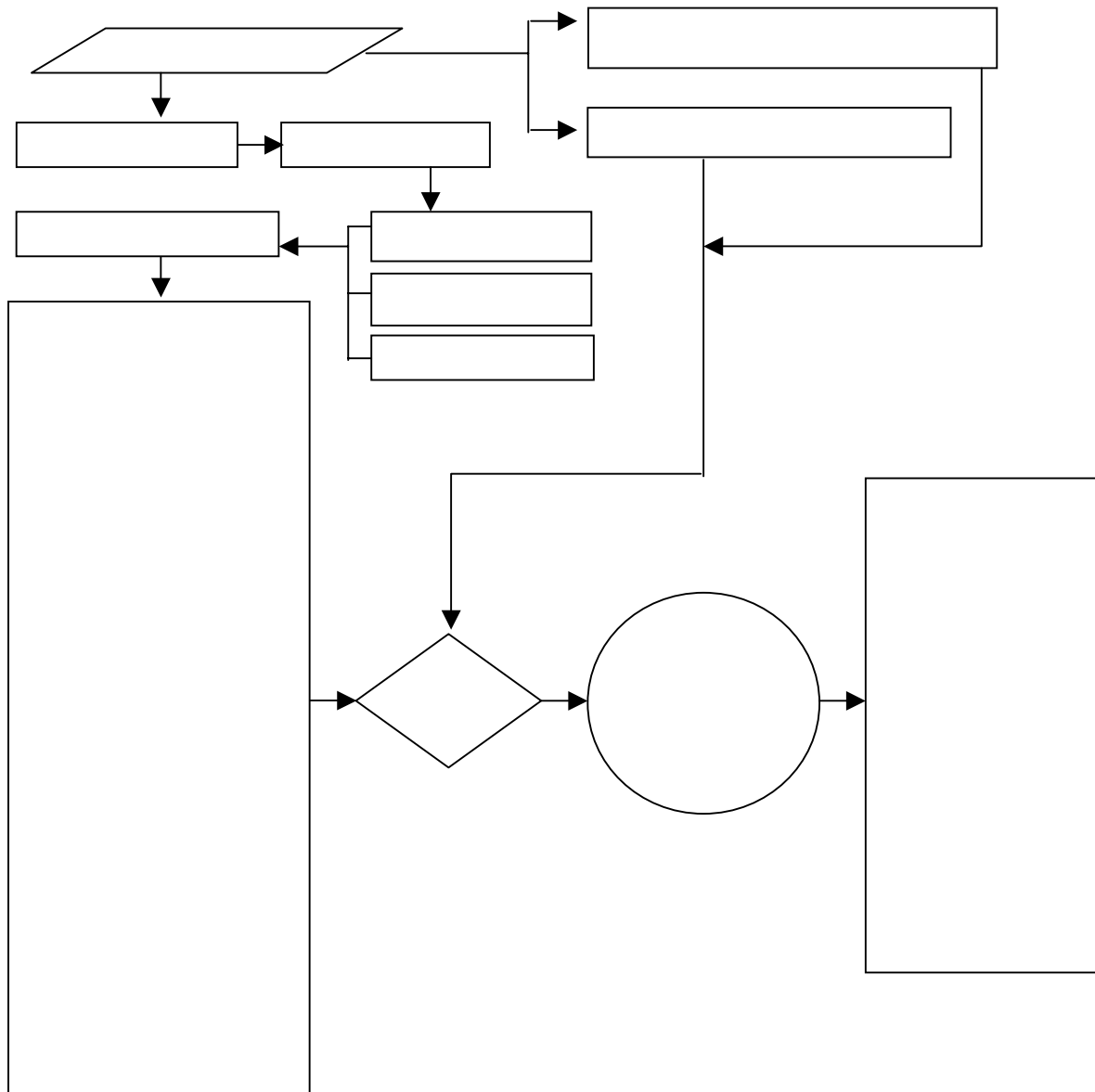


Figure 5. Conceptual Diagram of Procedure to Link Economic Value to Site Catchment

ENVIRONMENTAL FOUNDATIONS

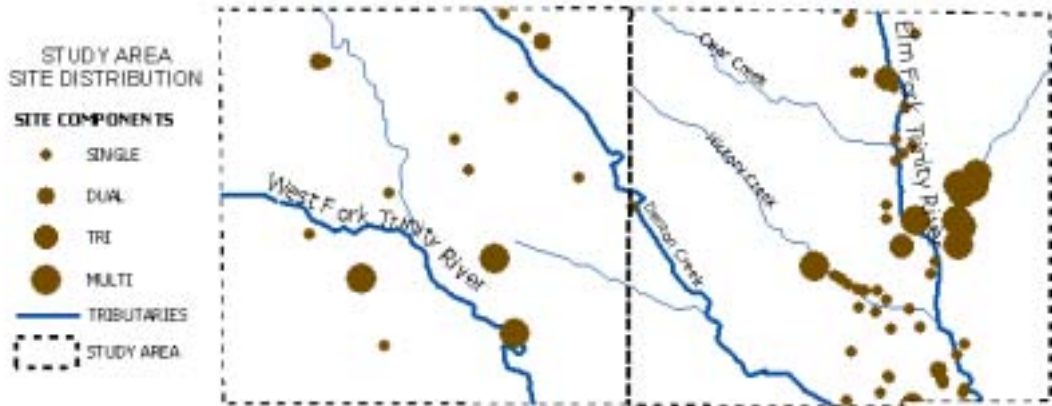
Geological formations provide the parent material and foundation for the range of soils that have the capacity to develop in a specific location. Given the minor differences, in the climatic regime of this region, the majority of landscape variation is dependent on the character of the bedrock lithology. The geological structures that are associated with archaeological site catchments in the region provide a means to view similarities and differences in more generalized site settings. This component influences the character of the physiographic setting and is evaluated with respect to change through time and occupation frequency in a discrete statistical analysis.

Physiographic variables that are evaluated in relation to archaeological sites include the Western Cross Timbers, Grand Prairie, Fort Worth Prairie, Eastern Cross Timbers, Blackland Prairie, Riparian corridors, Ephemeral Riverine settings and Ecotonal settings. The "Buffer Wizard" in ArcMap is utilized to generate transitional zones around water resources and physiographic boundaries. Ecotones are generated in ArcMap by creating 2 km buffers around physiographic boundaries. Riparian corridors are generated in ArcMap by creating 2 km buffers around major and minor tributaries in the streams data. Ephemeral streams are also included but relative to their influence on the landscape and intermittent character 1 km buffers are constructed around these areas. Hydrological resources are included in the physiographic category because these areas are considered to be unique microenvironments. Physiographic settings reflect the inter-relationships between the multiple components that have been sculpting the modern landscape for millennia. A wealth of information related to prehistoric socioeconomic behavior is reflected by the faunal and floral communities contained by these settings.

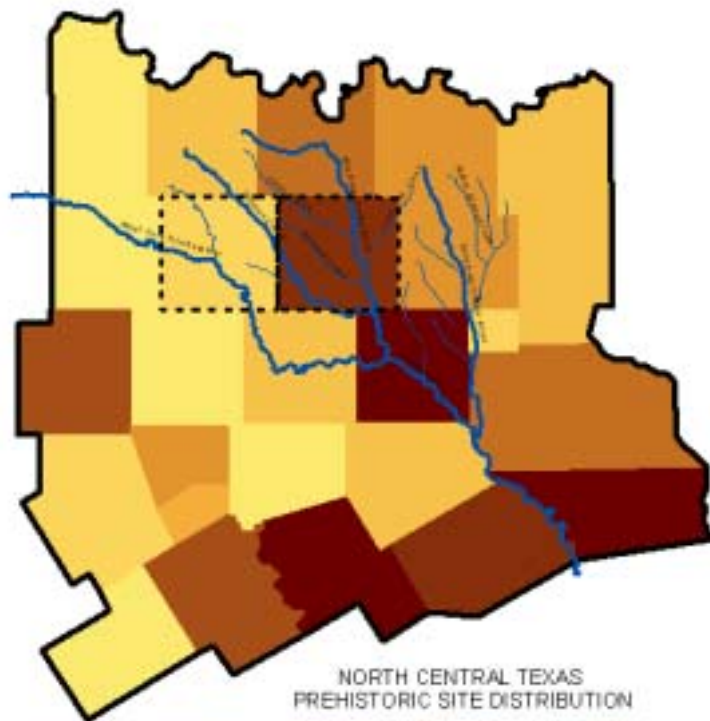
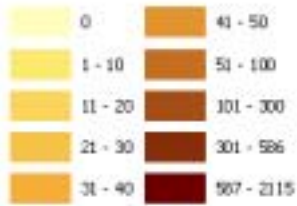
ARCHAEOLOGICAL FOOTPRINTS

Archaeological sites are plentiful in the Upper Trinity River Basin. Two counties have been selected for study (figure 6) in order to include sites along the West and Elm Forks of the Trinity River. Spatial coordinates were collected from Texas Archaeological Research Laboratory (TARL) records, converted to points in ArcCatalog and projected with ArcToolbox. Site catchment boundaries are established in ArcMap with the "Buffer Wizard". Although it is possible to construct time contours, with an equation, performed on the DEM, in the Spatial Analyst raster calculator, the character of the landscape in the study area did not provide a return on investment equal to the time it took to create the contours. Therefore, the site catchment area is established for the 100 sites with the buffering technique to construct an arbitrary 1-kilometer radius around each archaeological site. Diagnostic sites and surface sites that do not contain diagnostic material are included. The diagnostic sites are valuable in that they provide clues as to the specific time period and duration of occupation. The non-diagnostic sites provide evidence of prehistoric activities in relation to location. When these sites are associated with the specific characteristics of the site catchment areas they provide valuable comparative behavioral information for the time diagnostic sites.

PREHISTORIC POPULATIONS IN TEXAS



TEXAS PREHISTORIC SITE DISTRIBUTION



NORTH CENTRAL TEXAS PREHISTORIC SITE DISTRIBUTION



Figure 6. Study Area: Prehistoric Site Distribution (Texas Historical Commission (1985) data for state and Texas Archaeological Research Laboratory (2003) for study area)

Archaeological site data is categorized into groups to test for statistical significance between site contents and catchments with respect to environmental variables, occupation frequency and change through time. Activity groups include: tool manufacture, food preparation, hunting and lithic scatter. Site files are evaluated to infer activities. Lithic manufacturing activities are inferred if the artifact assemblage at a site contains cores, hammerstones, preforms, bifaces, debitage or a variety therein. Evidence for food preparation includes tools, groundstone, ceramics, animal bones and fire cracked rock. Any variety of these items is sufficient for the site to be listed as including food preparatory activities. Hunting activities are inferred by the presence of diagnostic projectile points. A separate category of lithic scatter is created to account for sites where no functional diagnostic information is available. There are enough cases where various densities of isolated lithic scatter are reported to prompt inclusion of this category. An increase in the number of activities represented by tool types at a site indicates an increase in artifact diversity. Occupation density includes ephemeral, moderate and intensive categories. These categories are formulated on the basis of the number of artifacts reported at a site. Occupation frequency refers to how many times a site was occupied based on the number of time periods represented at the site as indicated by diagnostic tools or radiocarbon dates. The categories for occupation frequency include single, dual, tri and multi. Change through time is determined based on the time periods represented by diagnostic point types recovered from the site. The time periods that are evaluated during the course of this research include Early (8,500-6,000 BP), Middle (6,000-3,500 BP) and Late Archaic (3,500-1,250 BP), Late Prehistoric I (1,250-750) and Late Prehistoric II (750-350 BP). Sites are assigned to these time periods based on a variety of site files, contract reports and academic publications.

RESULTS

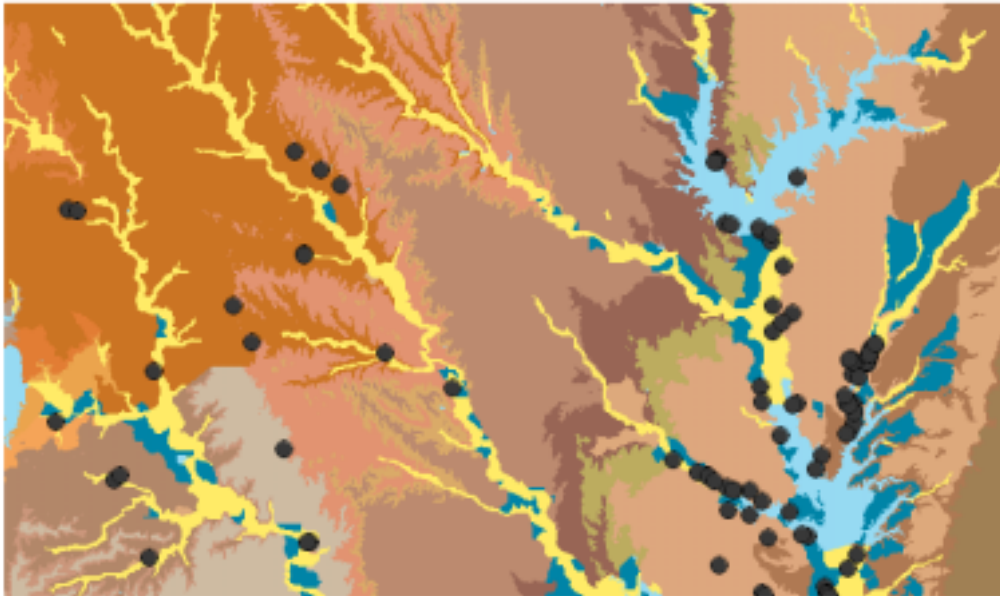
The most analytically informative data produced by conducting the site catchment analysis is contained by a series of maps, graphs and tabular data. For the sake of brevity, the bulk of the maps, graphs, detailed descriptions and tabular data are not included in this paper but are accessible in my Masters Thesis (Williams, 2004). Results yielded from the statistical analysis indicate that differences between site locations through time are predominantly due to chance. Similarly there is no indication of differential selection in relation to occupation frequency. Apparently prehistoric populations in North Central Texas returned to similar site settings that may vary in location but only slightly in economic content. Statistical results are notably biased due to the number of sites documented on the Elm Fork and the lack of sites reported along the West Fork of the Trinity River. Furthermore, repeated occupation at sites through time along the Elm Fork heavily weighted temporal considerations and occupation frequency. Raw data indicates differential selection and maps indicate variations that are supported by the economic values. Variation between site locations is primarily due to the diverse physiography. Although reporting bias affects the current study, valuable information is available from a spatial perspective that sheds light on the site distribution with respect to the explanation of site location as it changes through time.

Geological and Physiographic Settings

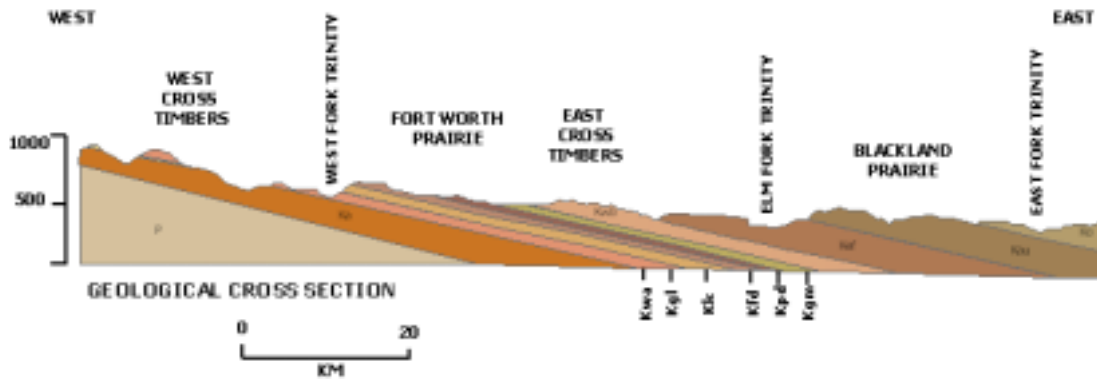
The geological setting of sites in the study area (figure 7) varies slightly but there is not a statistically significant difference in relation to change through time or occupation frequency. Archaic and Late Prehistoric sites located on the West Fork are predominantly situated in sandstone settings with a secondary presence in alluvial settings and a tertiary presence in limestone settings. Archaic and Late Prehistoric Elm Fork sites follow a similar pattern however shale settings replace the limestone settings that were more dominant in the West Fork study area.

Physiographic settings (figure 8) include woodlands, grasslands, riparian corridors, ecotones and ephemeral streams. From East to West, the Elm Fork of the Trinity River bridges the Blackland Prairie, Eastern Cross Timbers and Fort Worth Prairie nested within the Grand Prairie. These zones are specialized ecosystems rather than generalized ecosystems. Streams intersect these environments crosswise linking the separate ecosystems together.

The Elm Fork includes a wide band of the Eastern Cross Timbers that is flanked on the west by the Grand Prairie and on the east by the Blackland Prairie. The West Fork of the Trinity River shares the benefits of a transitional zone between the Western Cross Timbers, the Fort Worth Prairie and the Grand Prairie. Sites along the Elm Fork experience similar settings between the Eastern Cross Timbers and Blackland Prairie. Minor riparian corridors (41%) in both the West and the Elm Forks are utilized most often. Major river corridors (30%) and ephemeral stream settings (29%) are utilized fairly equally. There appears to be a stronger pattern related to the boundaries of major resources. Observations from previous investigations, that report a concentration of sites situated to equally utilize forest, riparian and prairie environments, are substantiated for the most part. Generally, the ecotonal settings along the Elm Fork, on the fringes of the eastern and western edges of the cross timbers, appear to be the most heavily utilized areas. However, along the West Fork sites tend to be located within the interior of the western cross timbers or prairies with a lower representation in ecotones. In addition, site distribution is widely dispersed in this area. When this pattern is viewed from an archaeological perspective these sites appear to be related to hunting activities. From a spatial and chronological perspective a westward shift during the Late Archaic is indicated. Given the spatial patterning and reoccupation of sites through time it is likely that the environment and climate was a more significant factor than socially defined boundaries. It is also possible, however, that environmental boundaries coincided with social boundaries. It appears that these populations strategically placed themselves so that they would have access to a wide variety of economically valuable resources. In general prehistoric cultures lived on the eco-tone between woodland and prairie environments allowing them to utilize a wide variety of natural resources. Site areas have a high degree of flexibility between the prairies and the woods increasing the success of various subsistence strategies.



PREHISTORIC SITE DISTRIBUTION AND BEDROCK GEOLOGY OF STUDY AREA



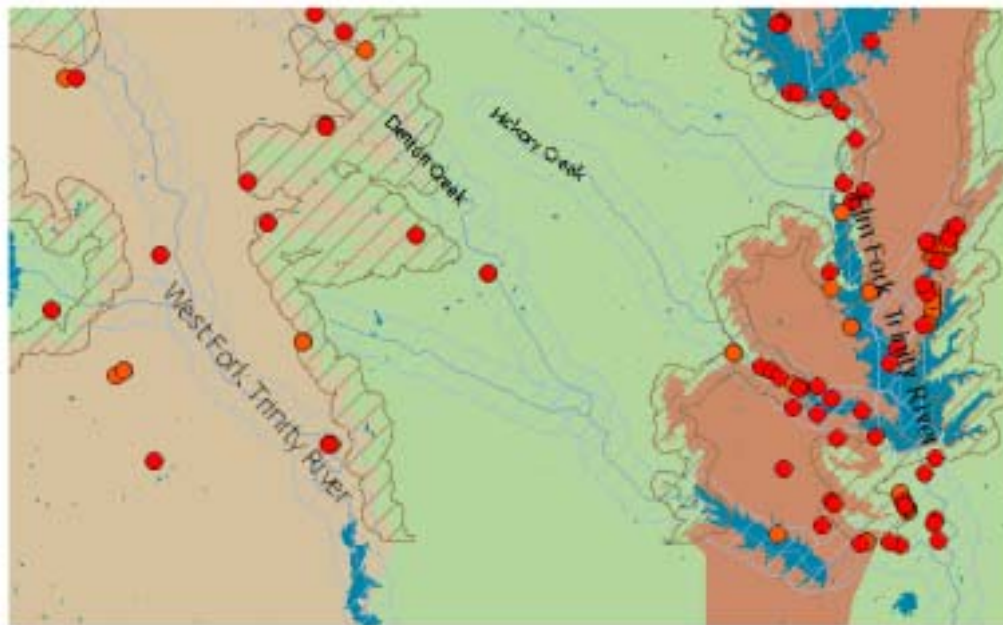
GEOLOGICAL CROSS SECTION AND BEDROCK GEOLOGY LEGEND

- | | | | |
|-----------------------|--------------------|--------------------|----------|
| ANTLERS SANDSTONE | GOODLAND FORMATION | PAWPAW-WENO-DENTON | FLUVIAL |
| AUSTIN CHALK | GRAYSON MARL | PENNSYLVANIAN | ALLUVIUM |
| EAGLE FORD SHALE | KIAMBCHI FORMATION | WALNUT FORMATION | WATER |
| FORT WORTH-DUCK CREEK | OZAN MARL | WOODBINE SANDSTONE | |

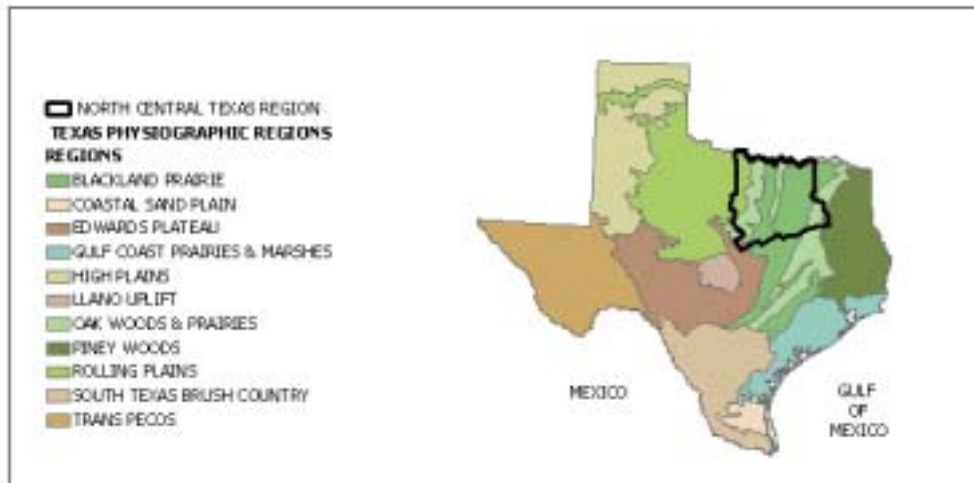


North

Figure 7. Geology of North Central Texas Study Area (profile based on Ferring, 1998)



STUDY AREA PREHISTORIC SITE DISTRIBUTION AND PHYSIOGRAPHIC SETTINGS



TEXAS PHYSIOGRAPHIC REGIONS

Figure 8. Physiographic Settings in Texas and Study Area.

Topographic Setting

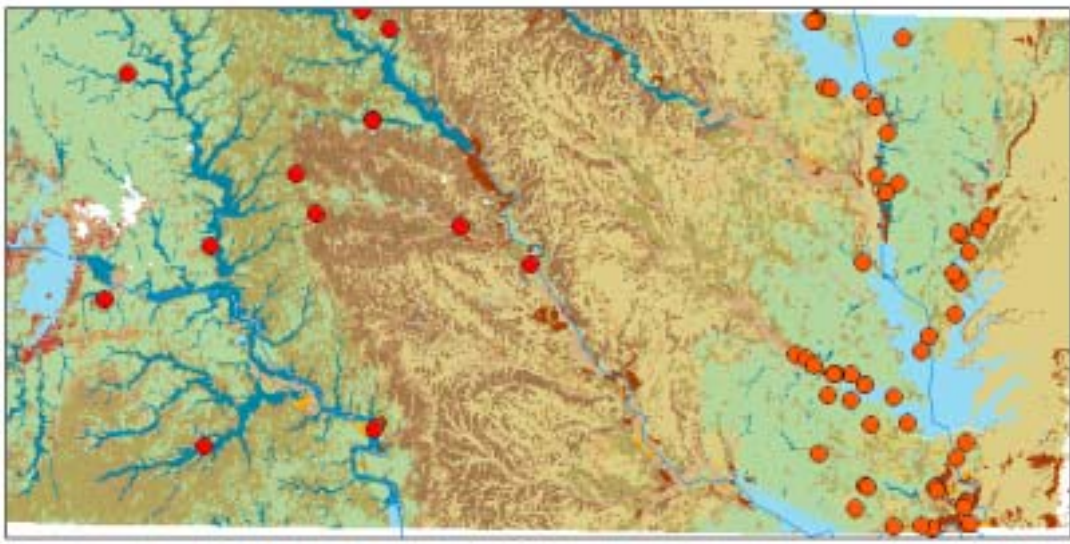
Topographic settings of sites in the study area vary according to site location on the landscape but there is not a statistically significant difference in relation to change through time or occupation frequency. Archaic and Late Prehistoric sites located on the West Fork are predominantly situated in terrace (47%) and upland (26%) settings near primary and secondary water sources. Drainage settings (21%) and floodplain (5%) settings in the West Fork study area are represented by 3 single and 2 multi-component sites. Elm Fork sites are predominantly located in upland (45%) and terrace (41%) settings. Only 12% are located in the floodplain and 1% in drainages. Results support the observations made during previous investigations that suggest that prehistoric populations primarily selected sites located in terraces and upland settings in ecotonal transitional zones between prairie and woodland settings. Terrace and upland settings along both the West and Elm Fork of the Trinity indicate reoccupation. Given the fairly equal distribution of sites in upland and terrace settings in both the West and the Elm Fork it is difficult to make any correlations with climatic intervals. Further complexity is introduced with the notable overlapping of time diagnostic sites. This is not the case in the vicinity of the West Fork due to the paucity of the sites that have been officially reported. In both the Elm Fork and the West Fork study areas diagnostic sites typically contain evidence of multiple occupations that tend to be concentrated in the same locations and therefore it is difficult to discern change through time.

Soils: Soil Settings

Soil Settings in the Elm and West Fork are fairly similar due to the level of detail provided by the soil surveys. The most dominant groups are the Clay-Rich and Loamy settings. Sandy soils for the most part have a high clay content which has created soils that are loamy in character. There appears to be an equal representation of each setting along the Elm and West Forks in relation to change through time and occupation frequency. The exception is related to the "other" category where sites are situated in unique hilly settings. Soil settings are the basis for vegetation correlations and are interpretable when relative economic value is observed.

Soils: Great Groups

Soil Taxonomy (figure 9) provides a means to interpret the potential of soils to produce vegetation and provide habitat for wildlife. Given the similar geological foundations of the East and West Fork the results indicate a fairly equal correlation with Alfisols, Mollisols and Vertisols. Paleustalfs, Haplusterts, Haplustolls, Haplustalfs, Hapluderts, and Calciustolls are listed by order of dominance. All of these Great Groups have a common denominator that indicates a fairly moist environment that experiences dry intervals probably related to seasonality. The primary difference is in the level of horizon development and soil order. The fairly uniform representation of soils orders indicates an equal presence of forest and prairie soils within the site catchment areas.



- ARENIS HAPLIDERTS HAPLUSTERTS PALEUSTALFS RHODUSTALFS
- ARGUSTOLLS HAPLUSTALFS HAPLUSTOLLS PALEUSTOLLS WATER
- CALCUSTOLLS HAPLUSTEPTS HAPLUSTULTS LISTRILENTS PREHISTORIC SITES

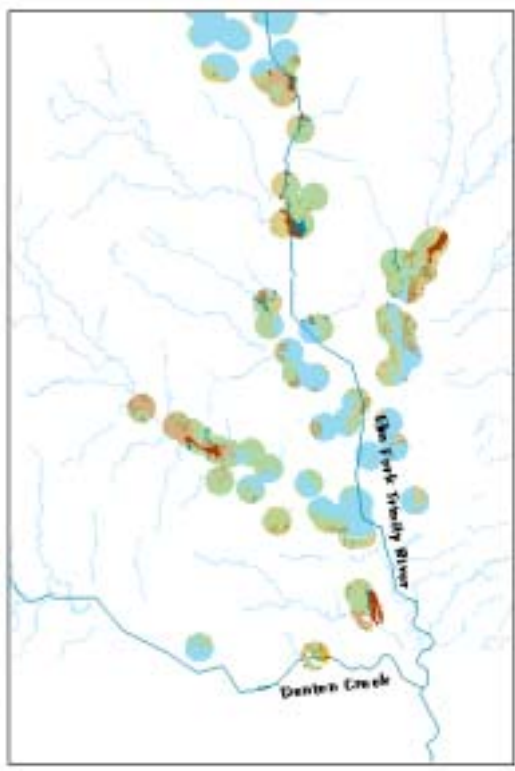
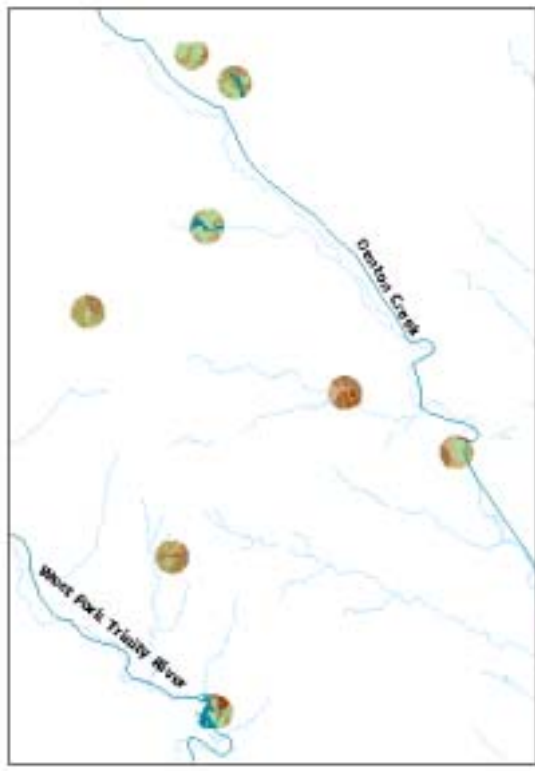


Figure 9. Taxonomic Soil Setting and Site Catchment Areas in Study Area

Soils: Economic Interpretations

Mapping the economic value of the entire landscape reveals the overall distribution of valuable resources as they relate to site location. This can help explain why certain areas were selected or provide a means to predict likely site locations. Economic interpretations for soils provide enlightening information in relation to site distribution. While there is not a statistically significant difference between sites there are similarities that indicate selection of locations on the landscape that provide important resources to sustain prehistoric populations. Mapping of the distributions of economic value with respect to edibility, medicinal value, supplemental value, wildlife and vegetation provide visual cues that shed light on prehistoric settlement patterns. Clear patterns emerge that reveal the variation of resources provided by the landscape. These patterns can be viewed in relation to change through time, occupation frequency, density, projectile point distribution and a variety of other facets. Maps provided in this section, for the sake of illustration, depict relationships between soil values and occupation frequency that reveal the relationships between site locations and varying degrees of economically valuable resources.

Soils data are recoded, based on botanical research, to illustrate (figure 10) the overall distribution of edible, medicinal and supplemental vegetation patterns on a larger scale in relation to the site locations. There is a fairly similar distribution of each group within the site catchment areas although the abundance varies. Sites that contain evidence of repeated occupation indicate a strong presence of edible vegetation followed by supplemental and medicinal along the West Fork and the Elm Fork. However, the Elm Fork values reveal a relatively higher edibility factor. With respect to change through time similar patterns occur. However, during the Middle Archaic and Late Prehistoric I medicinal values rise above supplemental values along the Elm Fork. Along the West Fork the situation is similar except during the Late Prehistoric I era when medicinal values notably jump above the supplemental values reaching almost the same level as the edibility values and then gradually decrease throughout the Late Prehistoric II. An interesting facet related to medicinal plants is their high toxicity. Given that medicinal plants are potentially lethal prehistoric populations would have had to experiment and learn the value of each plant in order to effectively utilize the plant and benefit from its medicinal properties. Therefore, an increase in the association between sites and environments that contain more medicinal plants is probably more of an indication of acculturation rather than health. In combination with other environmental variables these interpretive relationships help explain changes in site location. Site locations appear to have been concentrated in specific areas through time. It is likely that these locations provided seasonal resources that were complimented by a variety of edible and medicinal plants paired with woodland resources as reflected by supplemental values. The supplemental value category primarily reflects wood utilization and so for sites situated in Woodland settings this factor will be significantly weighted. The same situation is true for sites located along riparian corridors where this type of vegetation tends to aggregate.

Mapped distributions of potential for vegetation types given certain soil combinations indicate relationships between site locations and concentrations of grains and seed crops, grasses and legumes, and wild herbaceous plants (figure 11). Recoded soil values are based on soil survey estimates. All of the sites along the Elm Fork in particular, appear to have a stronger relationship with wild herbaceous plants than any other vegetation group. These types of plants are primarily associated with forested settings supporting the tendency for prehistoric populations to aggregate in these characteristic locations. West Fork sites maintain a strong correlation with grasses and legumes correlating with the fact that the sites are primarily situated in prairie settings. This type of vegetation is proximal to Elm Fork sites although it is not concentrated in the site catchments. Relative relationships between the vegetation types are fairly similar with respect to change through time and occupation frequency.

Soil potential to provide habitat for certain types of wildlife (figure 12) estimated by soil survey data provides a view of another facet of potentiality. Mapped values reveal differential distribution indicating that certain types of wildlife are more likely to be concentrated in particular locations. Sites that contain evidence of variable occupation frequency follow similar trends. This is probably due to sample size combined with the fact that sites are often clustered along the Elm Fork and have overlapping site catchment areas that influence the outcome. Through time there are fairly consistent correlations between site location and openland, wetland and rangeland wildlife habitat. There is also a clear correlation between openland and rangeland wildlife concentrations, the westward expansion, hunting activities and site location in the West Fork area. Because there are fewer sites it is easier to see the subtle shifts occurring through time and detect the relationships that may have prompted such behavior.

Site Activities and Density

Prehistoric activities are inferred based on tool types recovered from site locations. When they are viewed in relation to the various characteristics of the site catchments the dynamic inter-relationships between prehistoric activities and the environment can be evaluated. Sites containing evidence of tool manufacturing, food preparation, hunting activities and lithic scatter are predominantly represented in fluvatile and alluvial deposits. The presence of all four activities indicates base camps. However, the degree of activity in a given area can be cross-checked with the degree of occupation intensity. Correlations indicate at least twelve site locations exhibit intensive occupation in upland and terrace settings associated with fluvatile and alluvial deposits. Ephemeral sites are primarily correlated with lithic scatter in terrace and upland settings situated on fluvatile, alluvial and sandstone deposits, along riparian corridors, in the cross timbers. Activities represented at West Fork sites indicate a higher frequency of hunting during the Archaic and equal distribution of tool manufacture, hunting and food preparation during the Late Prehistoric. Along the Elm Fork hunting and food preparation are predominant during the Archaic with a similar pattern to a lesser degree that includes a slight increase in food preparation activities during the Late Prehistoric.

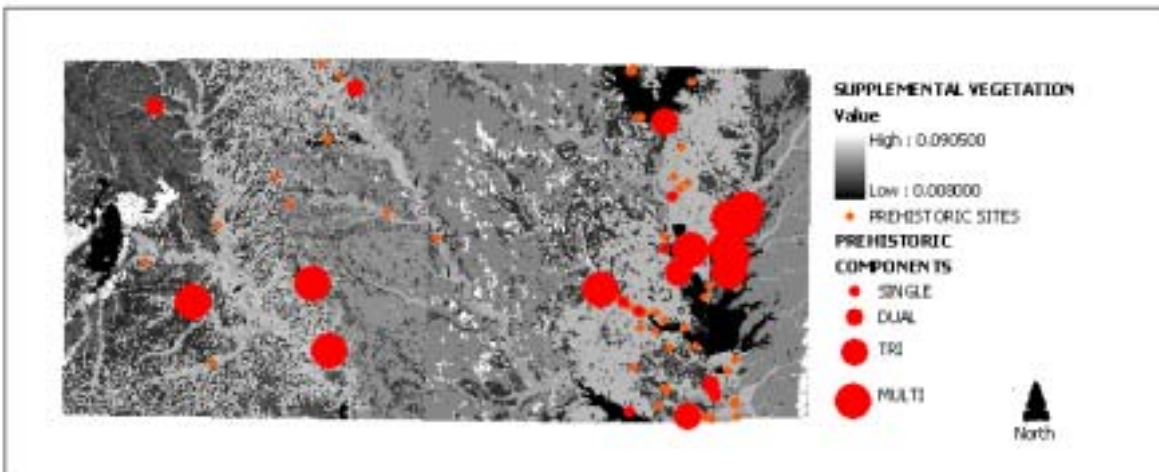
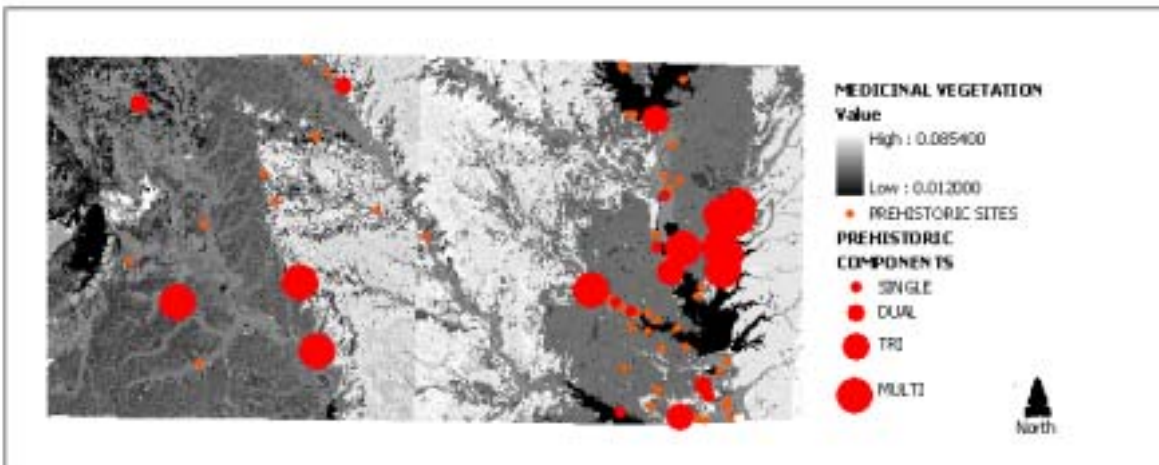
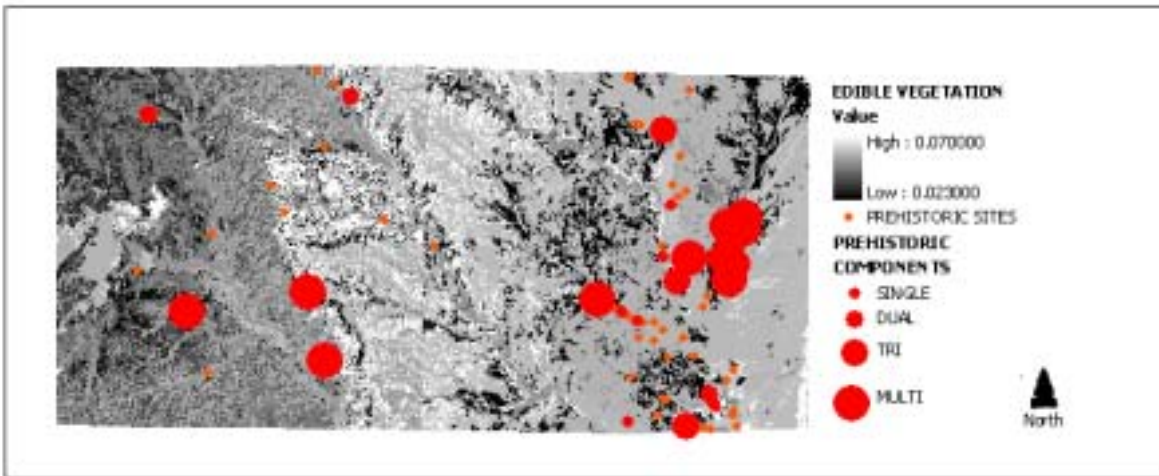


Figure 10. Site Occupation Frequency and Economic Value of Soils in Study Area

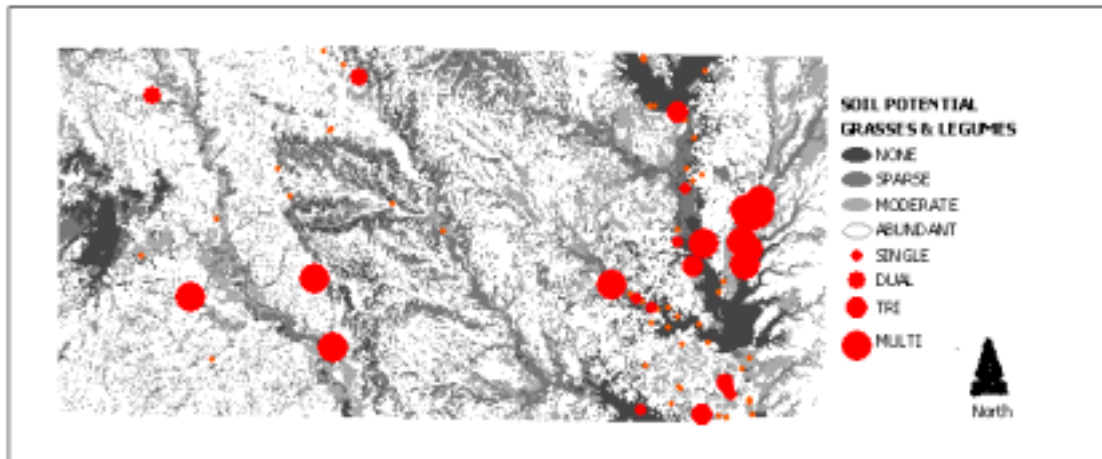
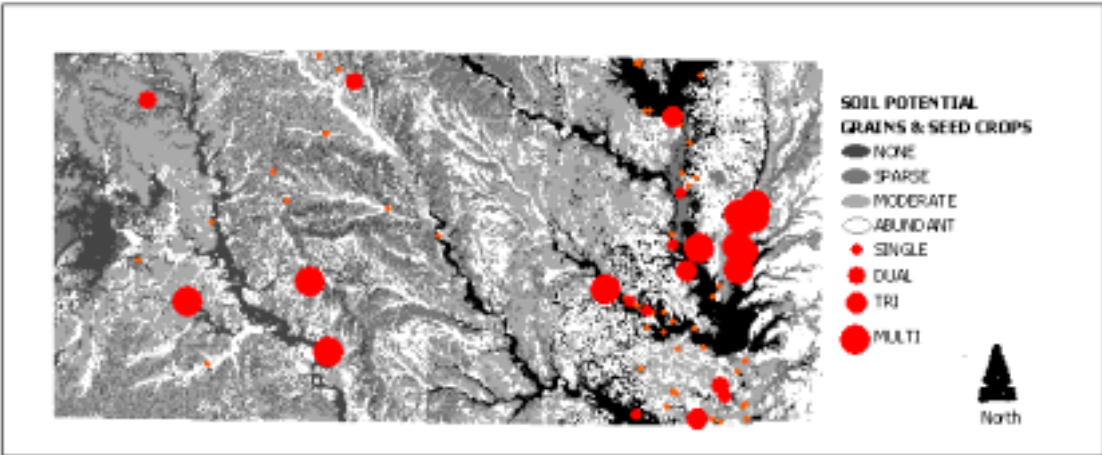
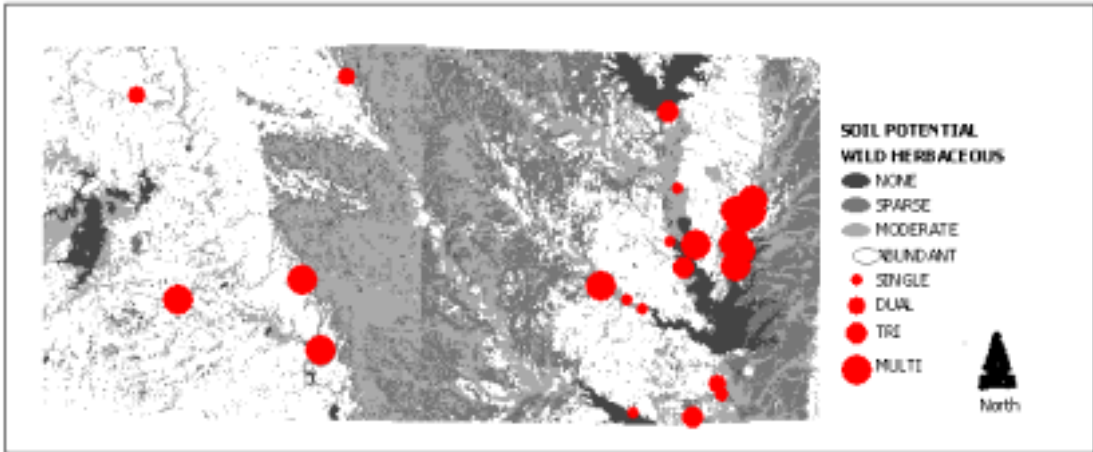


Figure 11. Site Occupation Frequency and Soil Potential for Vegetation in Study Area

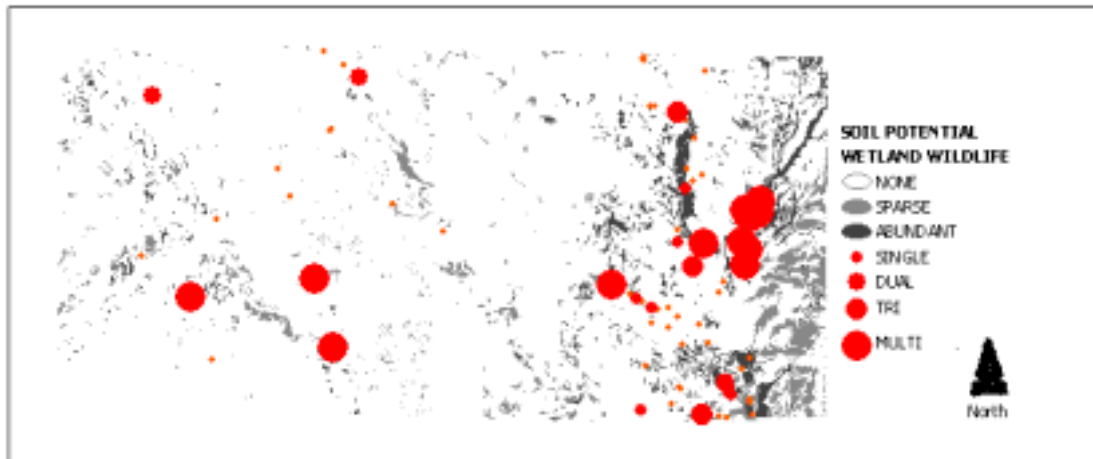
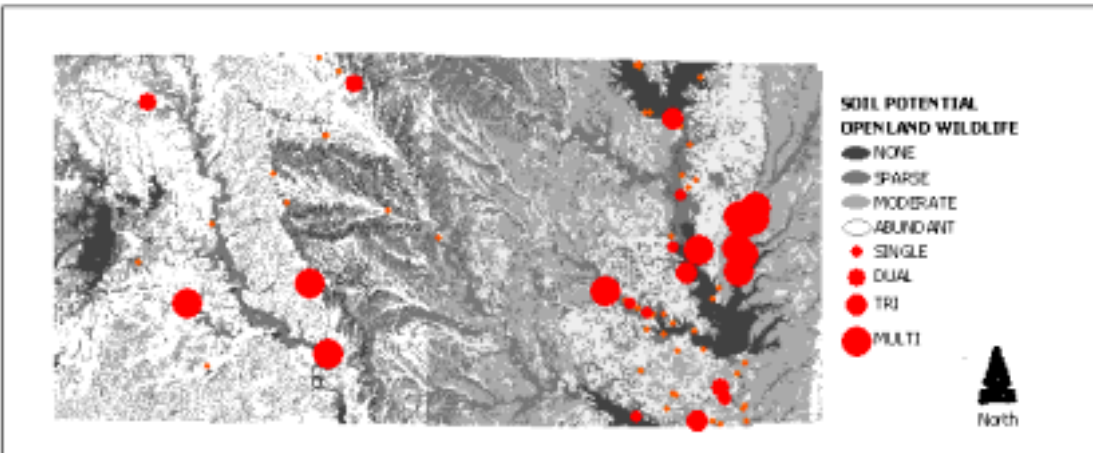
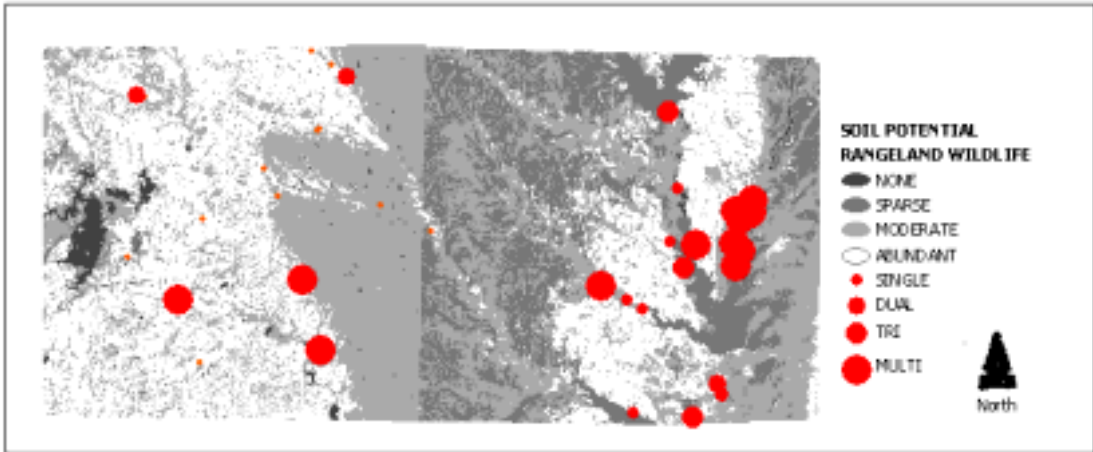


Figure 12. Site Occupation Frequency and Soil Potential for Wildlife in Study Area

ANOVA Statistical Results: Site Catchment Diversity

Sites Catchments are measured for relative degrees of diversity based on the proportional presence of soil series contained in the 1km area. Results indicate the largest amount of variability in sites that contain evidence of single occupation. Given the number of sites in this category this bias is anticipated. However, there are considerably less multi-component sites and this group also exhibits increased variability. With respect to change through time the most significant range of variation occurs with the Late Archaic. Results indicate that there are notable changes in relation to site catchment diversity. It is possible that during the Late Archaic populations diversified and enjoyed a greater range of motion. Previous studies have indicated that patterns of site location indicate an increase in territorial boundaries during the Late Prehistoric. If these populations were restricted to certain locations under variable climatic conditions there may be relatively less diversity. However, given the character of the region a fair amount of diversity is available within the woodlands, prairies, ecotones and riverine settings such that a certain degree is continuously present.

Chi-Square Statistic Results: Site Catchment Differentiation

Statistical results predominantly indicate that there is not a statistically significant difference between site catchments in relation to occupation frequency, density, activities or change through time. However, the few cases that indicate statistically significant differences are worthy of mention. Activities and site density indicate statistically significant differences in relation to change through time and occupation frequency. This simply means that site function and density varies through time but not necessarily in relation to site location. Occupation frequency exhibits statistically significant differences in relation to topography and soil setting. Given the character of the variables this suggests that a pattern is operating that can be correlated with site reoccupation. Of all the variables these two are probably the most informative in relation to extending interpretation beyond the physical landscape. Topographic location provides valuable information in relation to climatic fluctuations and micro-environmental variation. Soil settings are significant in that they represent the variation in economic values. Each soil setting is attached to a particular economic value. Overall, it can be generally inferred that prehistoric populations consistently selected site locations for intensive or ephemeral occupation that have similar characteristics. However, it is important to note that sample bias is affecting the statistical outcome. The multitudes of sites situated along the Elm Fork of the Trinity River are clearly skewing the results. One of the benefits of incorporating GIS into site catchment analysis is the ability to spatially analyze site locations with interactive overlay analysis. The GIS interface provides a means to visually evaluate the intersection of the multiple variables, interpret these patterns into dynamic relationships and observe change through time. The interpretive synthesis of this research, provided in a Masters Thesis (Williams, 2004), is based on comparative observation of prehistoric settlement patterns as they change through time by interactive overlay analysis in a GIS ArcMap interface.

CONCLUSIONS

Site Catchment Analysis has been conducted to extract environmental information from archaeological sites to evaluate previous research, develop innovative methods for future CRM research and enhance interpretations of prehistoric behavior. A variety of factors influence prehistoric decision making processes. Each of these factors has been evaluated, integrated and synthesized into a coherent whole to create a regional settlement model that is described in a master's thesis (Williams, 2004). The GIS interface (figure 13) is an important facet of the process. It serves as a means to examine sites individually or collectively whether it is during preplanning of a project, analysis, reporting or archiving archaeological and environmental data. Simply utilizing features, such as the identify tool, available in ArcMap, ArcReader, ArcExplorer or ArcIMS provides considerable benefit to the investigator. With the addition of statistical software (i.e. SPLUS 2000), geoprocessing tools provided in ArcMap, and extensions (e.g. Spatial Analyst, Geostatistical Analyst) the analytical capacity of GIS increases significantly. Geostatistical processing takes the data generated by this research a step further to create predictive maps (figures 14-17) that facilitate survey strategies.

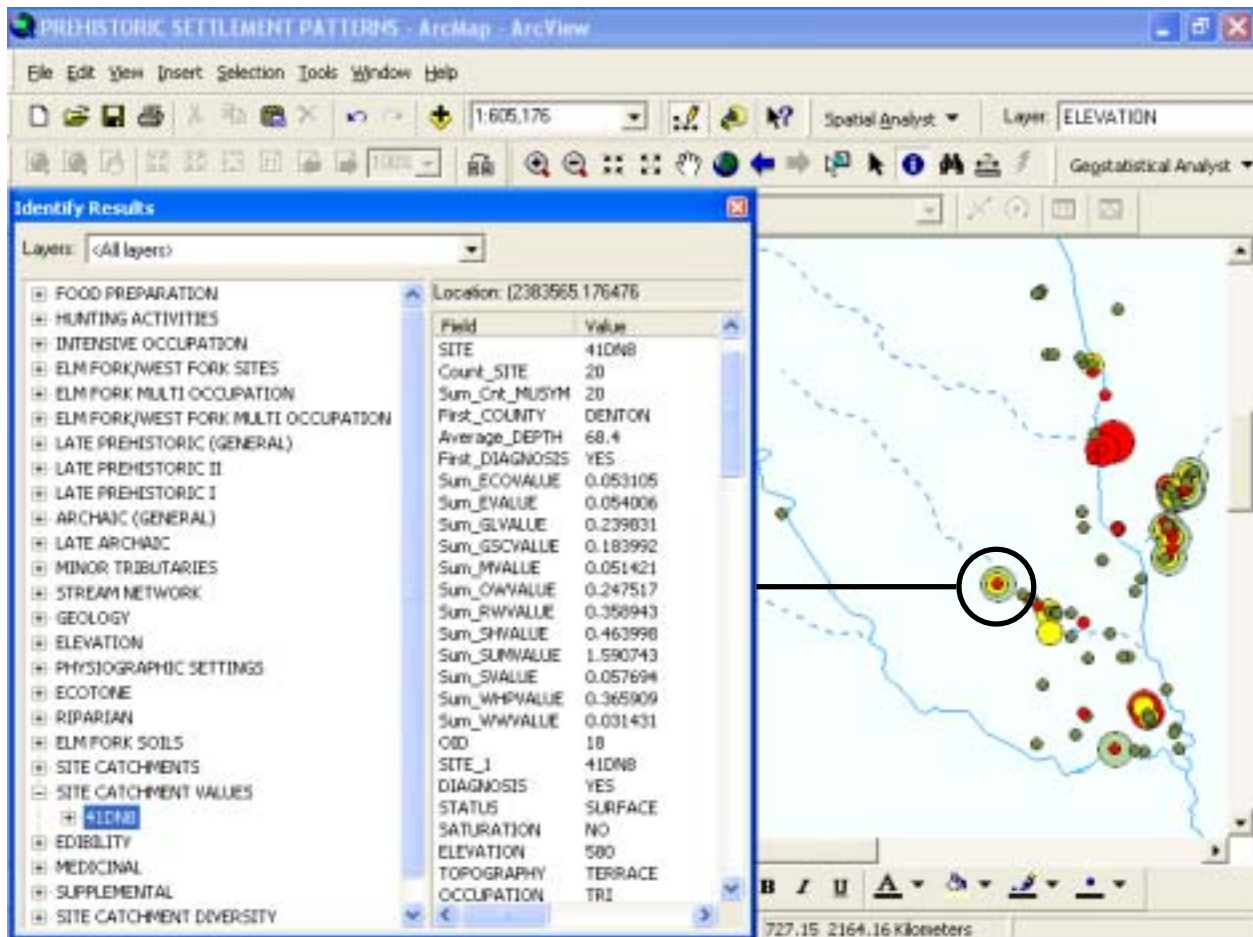


Figure 13. GIS Interface with Site Catchment Identify Results for Sample Location

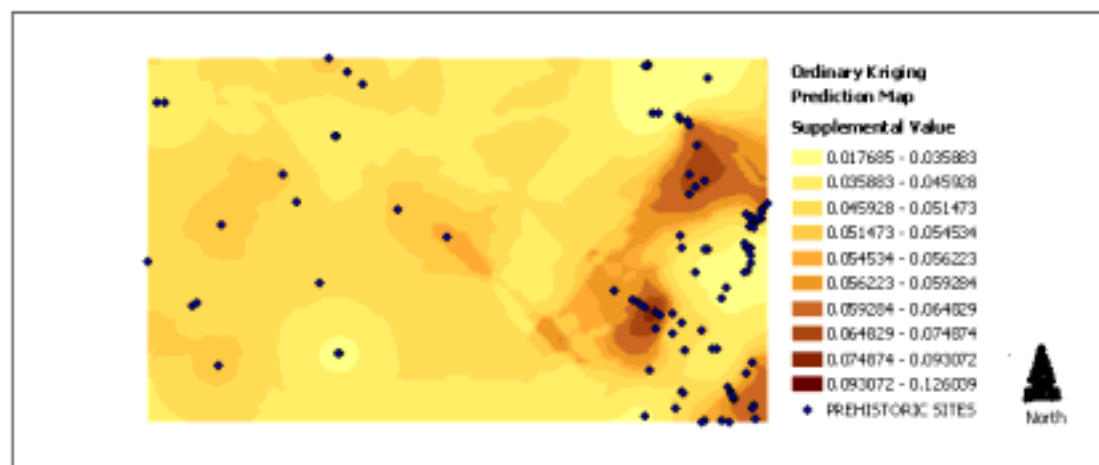
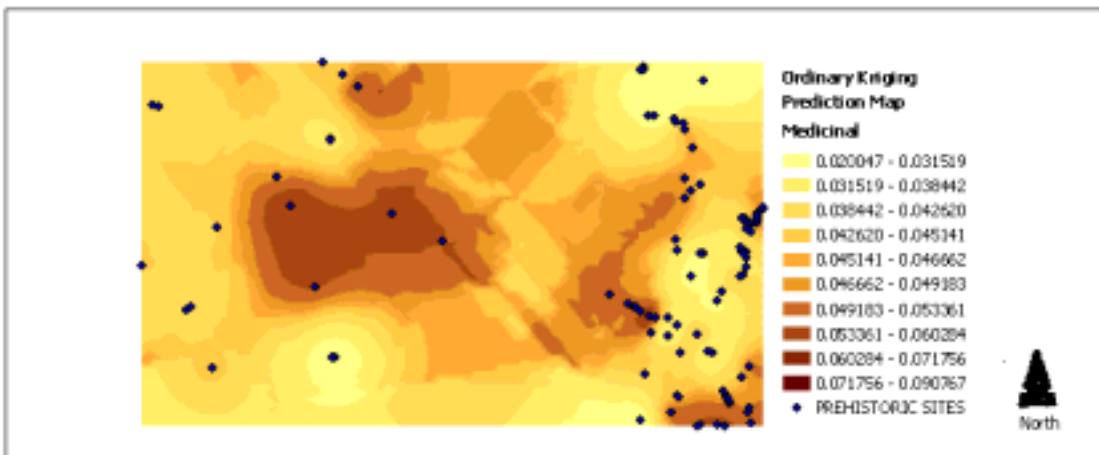
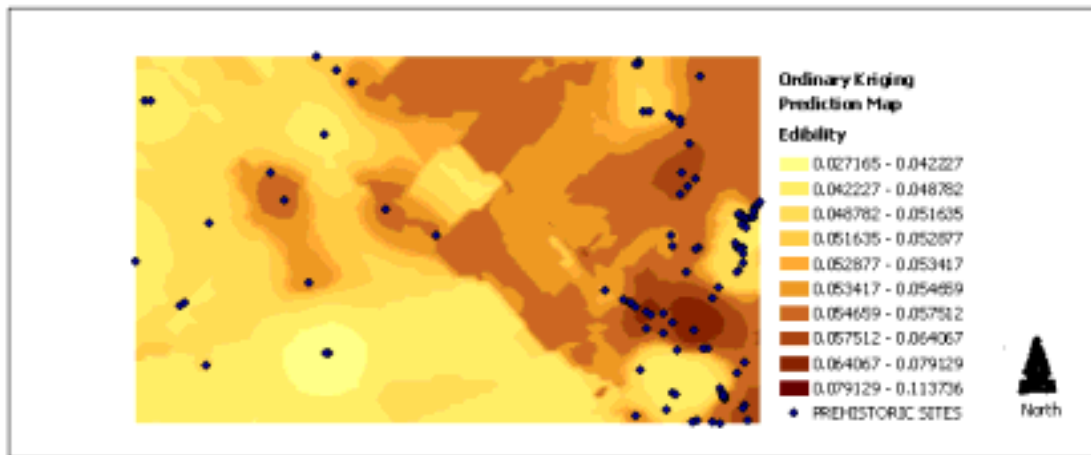


Figure 14. Site Distribution and Sample Predictive Map for Economic Values

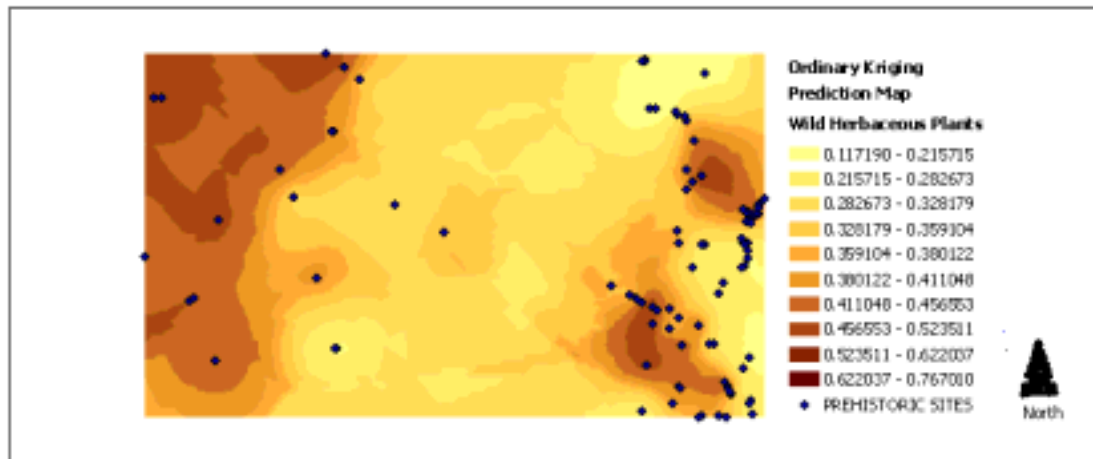
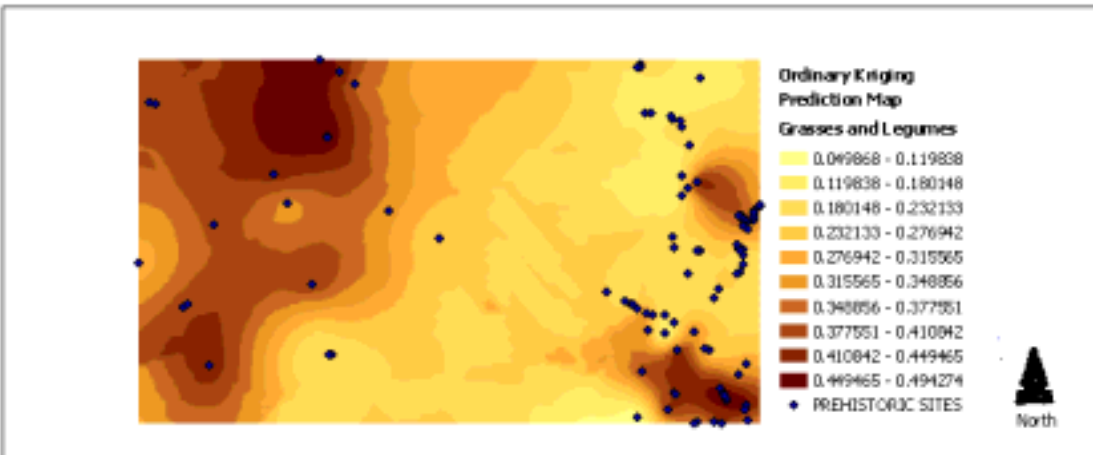
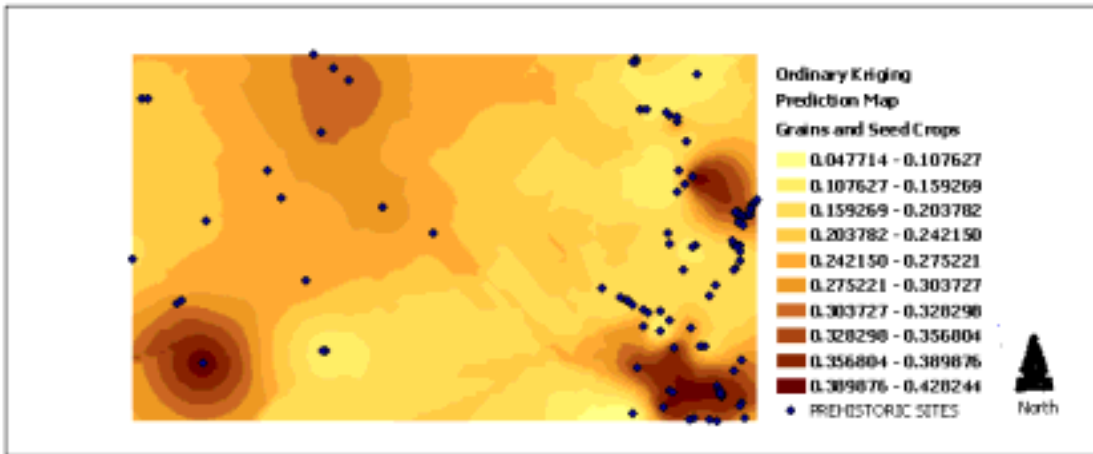


Figure 15. Site Distribution and Sample Predictive Map for Vegetation Potential

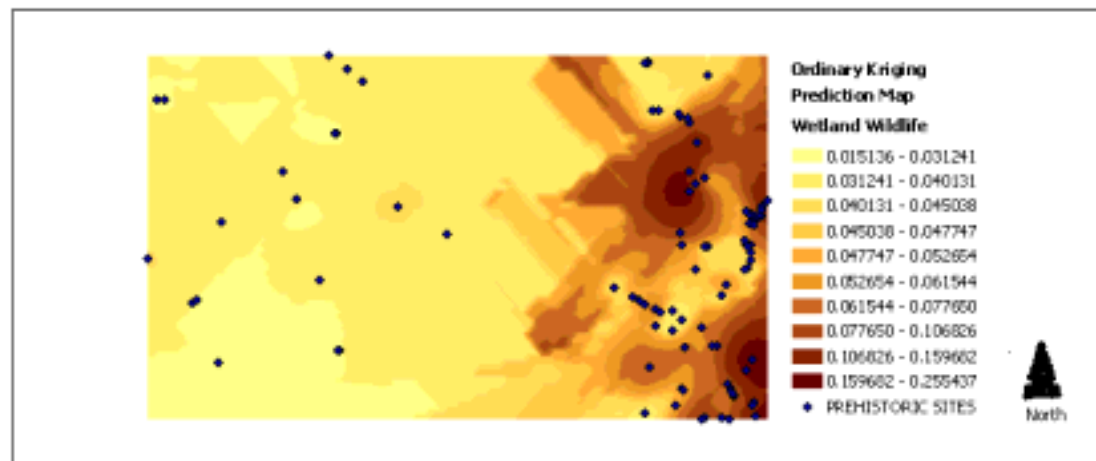
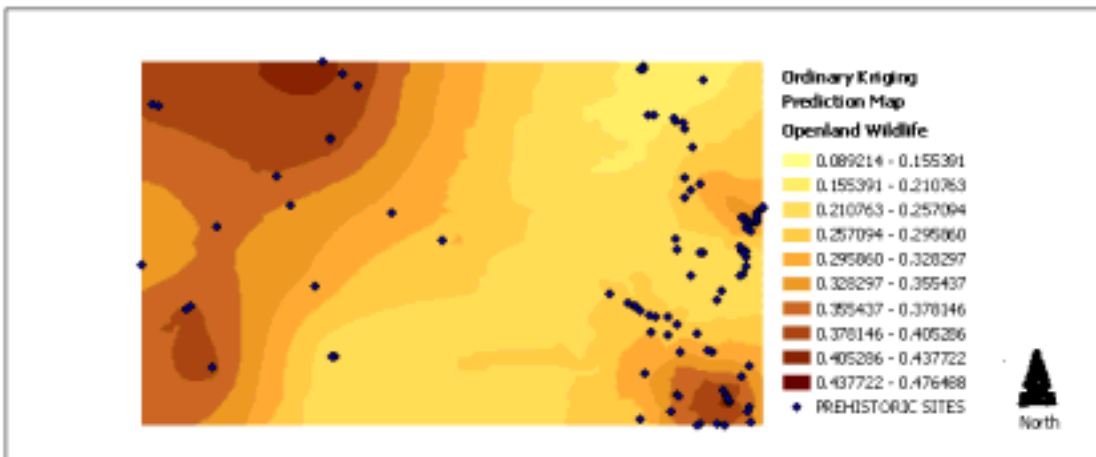
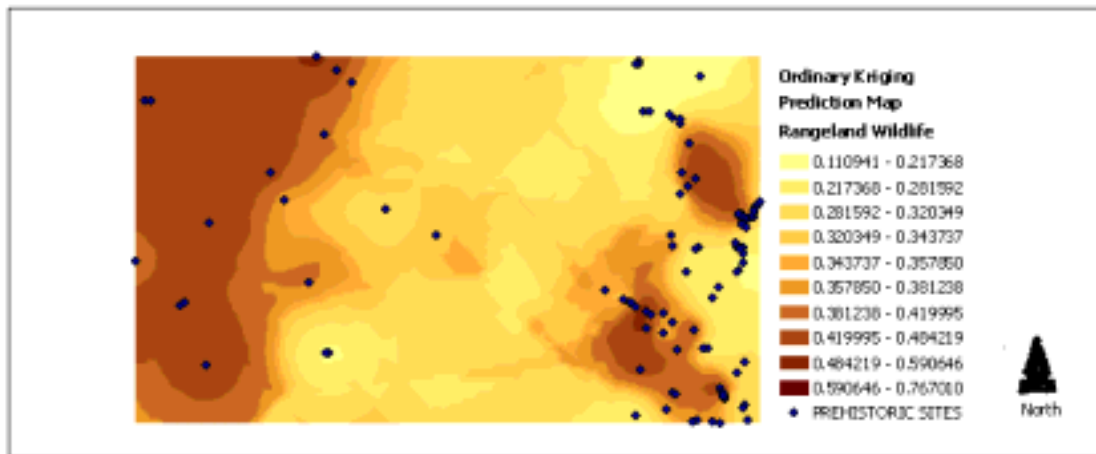


Figure 16. Site Distribution and Sample Predictive Map for Wildlife Potential

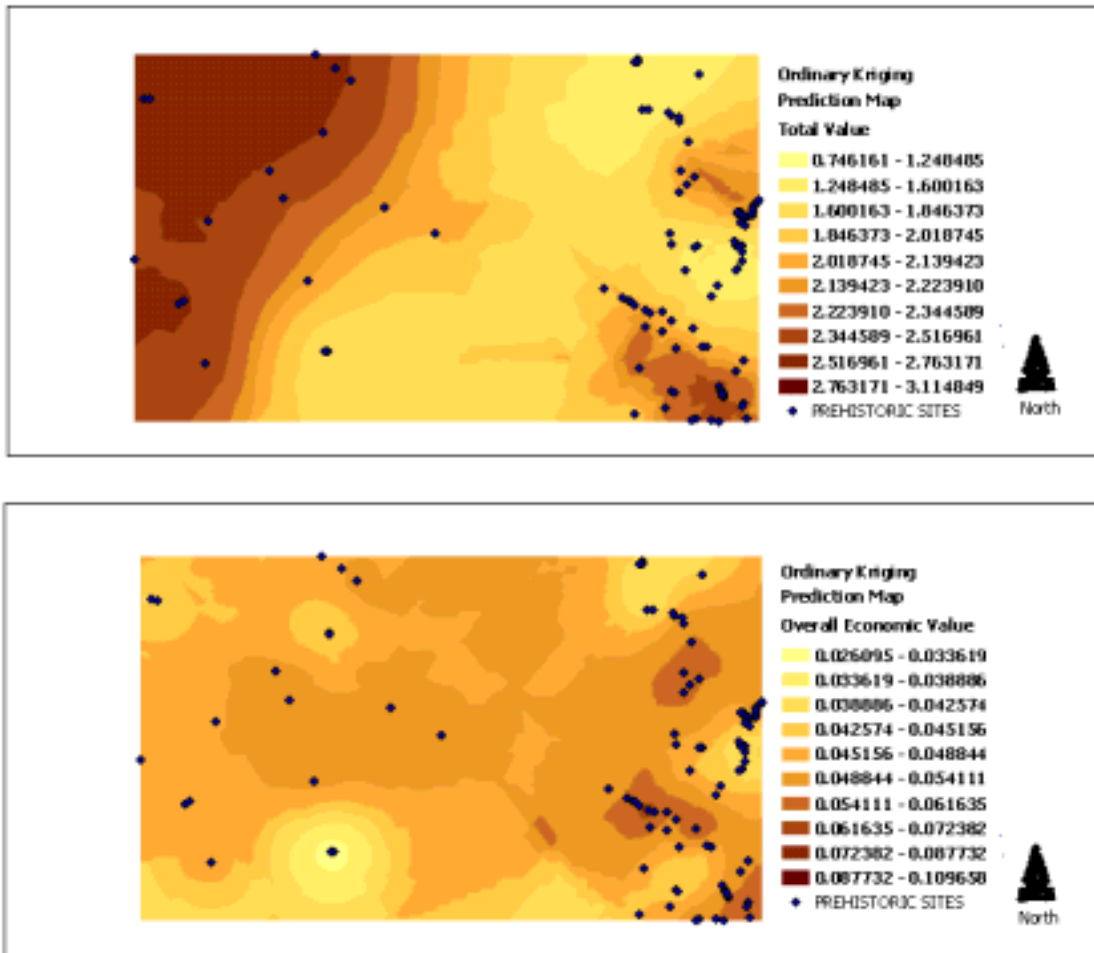


Figure 17. Site Distribution and Sample Predictive Map for Total Economic Value

These predictive maps provide the basis for modern data layers (e.g. roads, parcels, lakes, stream networks) to preplan survey. At the other end of the spectrum they provide informative density maps based on predictions formulated by research values associated with environmental data (i.e. soils data layers). This approach embedded in a dynamic interface helps explain why certain site locations were selected over other locations repeatedly or ephemerally. Ground-truthing of the environmental data that forms the basis for the geostatistical model can be accomplished during survey and help improve the predictive power of this cultural resource management tool.

DISCUSSION

Archaeology as a discipline has only been academically active for a little over 50 years. As such, experimentation with research methodology and excavation techniques is still in progress. A plethora of archaeological methods have been innovated since the inception of archaeology as an academic discipline. These methods have provided

focused efforts and increased efficiency in terms of time management while contributing pertinent and valuable information to the archaeological record. However, the associated data and information often becomes lost in the shuffle along with the exclusion of data from the site context that could provide important data for other investigations. As a result, many scientific inquiries become redundant procedures and comparability is limited to the research methodology under which the initial excavations were conducted. While attempting to establish a regional model much time has been consumed by re-entry of data and information. In addition, there is a significant amount of data exclusion due to the unavailability of resource information. Archaeology should be a cumulative discipline that is organized and accessible. Regardless of the situation in the archaeological community land development continues and site reports accumulate in inaccessible locations. What is lacking in this system of piecemeal cultural resource preservation efforts is a standardized methodology to guide local archaeological societies, academic institutions, archaeological consultants and consulting firms. While these entities are due creative process, there needs to be an established set of minimum requirements in place for data collection and reporting, in order for excavation efforts to benefit future research and facilitate comparability. In addition, there needs to be a mechanism in place to centralize and organize these data for future investigations. GIS technology provides the perfect organizing mechanism that is well suited to the character of archaeological data. The ultimate goal is the creation, maintenance and password protected web-based distribution of centralized regional databases that links the archaeological data to spatial location, documentation and interpretive information. The construction of a database of this nature can facilitate a variety of archaeological, statistical and spatial analyses. With this in mind, the current research was designed to create a proto-type of a regional archaeological database that is incorporated into a GIS interface, linked to an interpretive environmental database and analyzed accordingly. Site catchment analysis was the established research methodology selected to create a model of prehistoric settlement patterns. The design is such that multiple analyses can be performed and various research methodologies employed. There is a growing necessity to organize the data that has been collected so that it can be accessed and synthesized for cumulative analyses. In order to fulfill these goals a mechanism must be in place to organize our prior knowledge so that it can be used analytically. Otherwise we will continue to piece together a past that is biased by the available data collected to fulfill particular research methodologies and the record will remain as fragmented in reports as it is in the ground. There is assuredly data that is irretrievable. However, simply organizing what the archaeological community already has and establishing nationwide standards for future data collection is a step in the right direction. Future excavations should include analyses beyond the archaeological remains that employ active field surveys and excavation of environmental and wildlife habitat information. The current challenge is to begin fashioning and structuring databases for the archaeological record that incorporate integrated systems to record the existence of prehistoric populations with as much detail as possible so that we can learn from the behavior of our geographical ancestors and archive this information for future generations.

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