Analysis of Prehistoric Land Use of the Hackberry Basin in Camp Verde, AZ

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Abstract

Archaeology of Arizona has shown many patterns for the distribution of the prehistoric people who lived in the southwest. The Hackberry Basin, east of Camp Verde Arizona, is one such location that has been studied to see how prehistoric people were able to thrive and interact in such a complex environment. For years data has been collected to categorize and develop settlement patterns using site location and artifact classification. Having better understanding of how these prehistoric people operated in the Hackberry Basin study area can provide insight for similar geographic regions. Since a significant number of archaeological hotspots in the southwest have been surveyed with similar technique that data is available to potentially repeat this study.

The purpose of this practicum is to work with archaeologists at the United States Forest Service in the Coconino National Forest who have surveyed the Hackberry Basin to see if applying current Geographic Information Systems (GIS) technologies and geospatial perspectives can help develop a land use assessment for the area. This land use assessment will use established archaeological research to define many of the spatial thresholds for the study. This will be researched regarding the prehistoric people as well as an arable soil and water source GIS assessment.

The project will use survey data produced by Dr. David Wilcox as well as Dr. Jerry Ehrhardt from a survey of the Hackberry Basin started in 2005 at the direction of Dr. Peter Pilles. As well as Terrestrial Ecosystem Unit maps and water source layers to compare the spatial aspects of the surveyed sites. The data collected focused on archaeological site identification and artifact profiles for the Sycamore Canyon and Hackberry Basin Survey. This study is trying to better understand how this area was used in prehistoric times by utilizing spatial analysis. The data collected will be transferred to a digital record in a geodatabase for spatial processing. By overlaying the soil type and agricultural sites layers, the project intends to identify any patterns to what soil is being used. Water proximity will also help define whether distance from water as a settlement factor. Then overlaying the findings of the soil and water layers against the overall site distribution will provide some insight into the prehistoric land use of this area.

Key words: Spatial Analysis, GIS, Archeology, Soil, Water

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Alex Mourtsen

Introduction

The Coconino National Forest is rich with archaeological heritage that has been the backdrop to provide insight on how people used this landscape for prehistoric development. The Society for American Archaeology defines archaeology as the study of the ancient and recent human past through material remains. In the southwest, the geographic and climate patterns often raise more questions than answers about how people were able to thrive in such harsh areas. Some archaeologist believe that the relationship between human behavior and environment resulted in certain constrains which affected settlement and land use that consequently affected the distribution of human remains across the landscape (Baldwin & Bremer, 1986). Identifying these constrains helps to develop understanding of how these human populations interacted, using artifacts and site identification (Graceffa, 2010). One major belief is that the need for food and agricultural opportunities were major causes in the settlement patterns of a nearby community, Walnut Canyon (Bremer, 1985). Since food and water have been identified as major settlement factors, they represent quantifiable data that gives relative estimates for the populations they can directly support. The measurements in these communities can further be classified for the time period when people were present, using established dating factors for the artifacts found at each archaeological site (Van West, 1994).

Since the data has coordinate that was recorded when the site was discovered, this opens up the potential for many forms of spatial analysis to analyze these settlement patterns. This means Geographic Information Systems (GIS) could be valuable tool in helping identify potential land use in the given survey area. A GIS lets us visualize, question, analyze, and interpret data to understand relationships, patterns, and trends. (ESRI, 2010). This is exactly what many areas of archaeology are trying to study when looking at the population potential and interactions of communities. GIS in this project is organized through features, attributes, and raster imagery (ESRI, 2010). Each component allows for location based spatial analysis, processes like overlay or proximity analysis, which is useful in archaeological land use assessment. This is because the patterns often develop from applying different methods to the analysis, as opposed to analyzing to find a specific answer. GIS has the ability to handle large quantities of data and provide tools to analyze data with multiple perspectives. In addition, given the large amount of data collected throughout the course of a survey for the project, it is important to create a geodatabases that facilitate data storage, management, as well as analysis.

Many discoveries in archaeology are achieved through a new perspective looking at a topic that has already been defined (Pilles, 1978). In agricultural archeological assessment, a site type referred to as field houses and sites components plays a huge part in what factors can be considered agriculturally significant. Peter Pilles (1978) furthered the research into the definition of field houses of the Sinagua People who lived in the Hackberry Basin. This research used the definition set forth by Dr. Harold Colton to create a more detailed classification for further analysis. Being able to conveniently change or update information, GIS is also an effective tool for archaeological data management. So, if a definition were to change, as in the case of the field house, it could be easily rectified against the data record. This is just one example of how a GIS and its data management techniques could be deployed to improve archeological analysis.

Background

In 2005 the Sycamore Canyon/Hackberry Basin project started at the request of Dr. David Wilcox (Graceffa, 2010). Since the survey area is located on the Coconino National Forest, permission was obtained from Dr. Peter Pilles, who is the Coconino National Forest Archaeologist (Graceffa, 2010). The survey was requested to study the ceramic and site distribution of the Sycamore Canyon area. The purpose of these surveys was to identify hilltop pueblos and their line of sight with other pueblos. The Hackberry Basin rests just below the Mogollon Rim of the Colorado Plateau. The area is very rugged with many sites being situated in precarious locations (Graceffa, 2010). Archaeologists, Dr. David Wilcox and Jerry Ehrhardt have crossed many of the ravines and steep hillsides and found very few sites. Because of similarity in terrain throughout the basin, steep hillside or ravines were not surveyed since they were unlikely areas to farm or inhabit. (Graceffa, 2010). However, since the survey began, many more sites have been recorded in the Hackberry Basin and the surrounding area, which will be the focus of this land use analysis.

These sites contain vast amount of information through the artifacts and components that are identified at each surveyed site. The sites are surveyed with the same methods so that the data is consistent throughout the overall study. The pottery that is recorded at each site is an important diagnostic tool for giving a time frame to the prehistoric sites (Graceffa, 2010).

Once a site is located, it goes through the same survey to identify its components and artifacts. The first step is to pin down a flag at the site where a GPS point is recorded as a reference point. The area is then walked over by the recording archaeologist to collect as many artifacts as can be identified. As the artifacts are collected in a survey they are recorded according to pottery or lithic types, and these artifacts are referred to as sherds. Then the artifacts were further classified as a bowl or jar, and rim or center fragment. Each sherd has a small snip taken from it, which is taken back to the Forest Service Archive so that it can be referenced. The sherds that are counted at each site are classified based on visual and geologic queues. This initial sample is sometimes called a “grab sample” around the first sample flag. A more extensive survey is performed if more than one hundred sherds are counted within the initial flag pinning; if not, the site artifact list is labeled “entire site”, ending any further surveying. If more than 100 sherds are found, 1 to 1 ½meter pin flag areas are dropped around each sherd site to be able to identify the most artifacts for analysis.

The archeologists could then apply profiles to the given artifact assemblages which would define a site type classification. The site type classifications were agricultural, small farmstead, large farmstead, field house, community center, and other. These classifications were decided on the project archeologists and recorded on the site card during survey. Along with this these surveys identified the feature of a given site. One such component is the agricultural feature of a given survey site. Using these locations in compassion with water sources and soil type can give understanding to whether or not prehistoric people in the area specifically chose these locations for their resources. These surveys provide the site classification data and geographic background for this analysis.

Problem Statement

Peter Pilles, the USFS Archaeologist for Coconino National Forest, and his team of researchers have collected years of survey data for many archaeological sites in the Hackberry Basin. The survey data collected is very valuable to location-based spatial analysis. However, since the data is recorded in physical site cards, it lacks the digital capacity for GIS based spatial analysis. This project seeks to digitize the physical records of the Hackberry Basin. Then using the newly digitized survey data can determine relationships between arable soil, water sources, and site distribution is identified using spatial analyst tools. Understanding the relationship between the water and soil resources against the settlement and agricultural distribution of the basin is the major problem being explored by the archeologists for this project. However, an addition problem the project faced was how GIS could be used to communicate this relationship.

Digitizing the data that is available so that spatial analysis can be performed using the soil, water and overall site layers is the first the major goal this project is trying to accomplish. The soil and water layer are obtained from the Forest Service. Using the physical site card data that has been collected throughout the survey, the information is digitized and geographically referenced for spatial analysis. The site card provides all the attributes for each unique site located within the study area. These points were compared against the water and soil layers, soils maps and identifying the soil types that overlap with identified agricultural features and site types. GIS is used to organize this information and perform spatial analysis. It will also provide a backdrop for any future exploration or if additional sites are discovered. Being able to use any trend that develops from the land use analysis helps better localize the analysis that can be done on habitation sites, even directing interest to specific soil type or proximity. An additional outcome of this project is that the research and data can be maintained and utilized in future research.

Based on known water and dietary needs of prehistoric people, certain conclusions are made about how many people could have possibly survived with the resources that were at their disposal. The geographic properties of these resources, including arable land and water, leave them open to the potential of more exploratory research to disclose prehistoric population (Van West, 1994). So the main issue is how the inhabitants of the hackberry basin utilized the resources available to them.

Study Area

As shown in Figure 1 and Figure 2 below, the archeological survey area and data used in will come from the Hackberry Basin in Arizona. The study area is limited to the natural basin as to exclude any outlying sites above the Mogollon rim. The basin is east of Camp Verde off of the Forest Service Road 708.

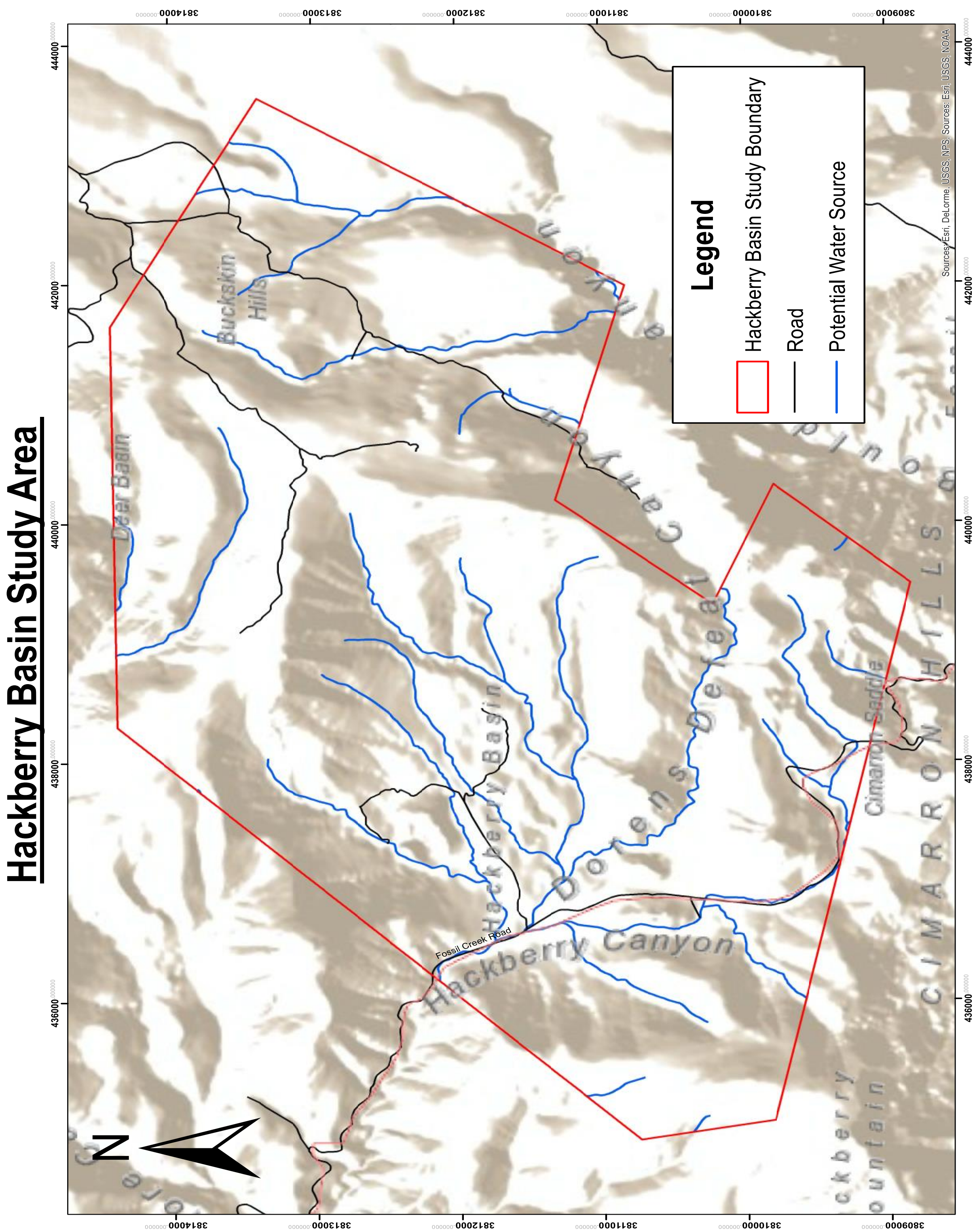

Figure 1.The Hackberry Basin study area with roads and water sources shown.

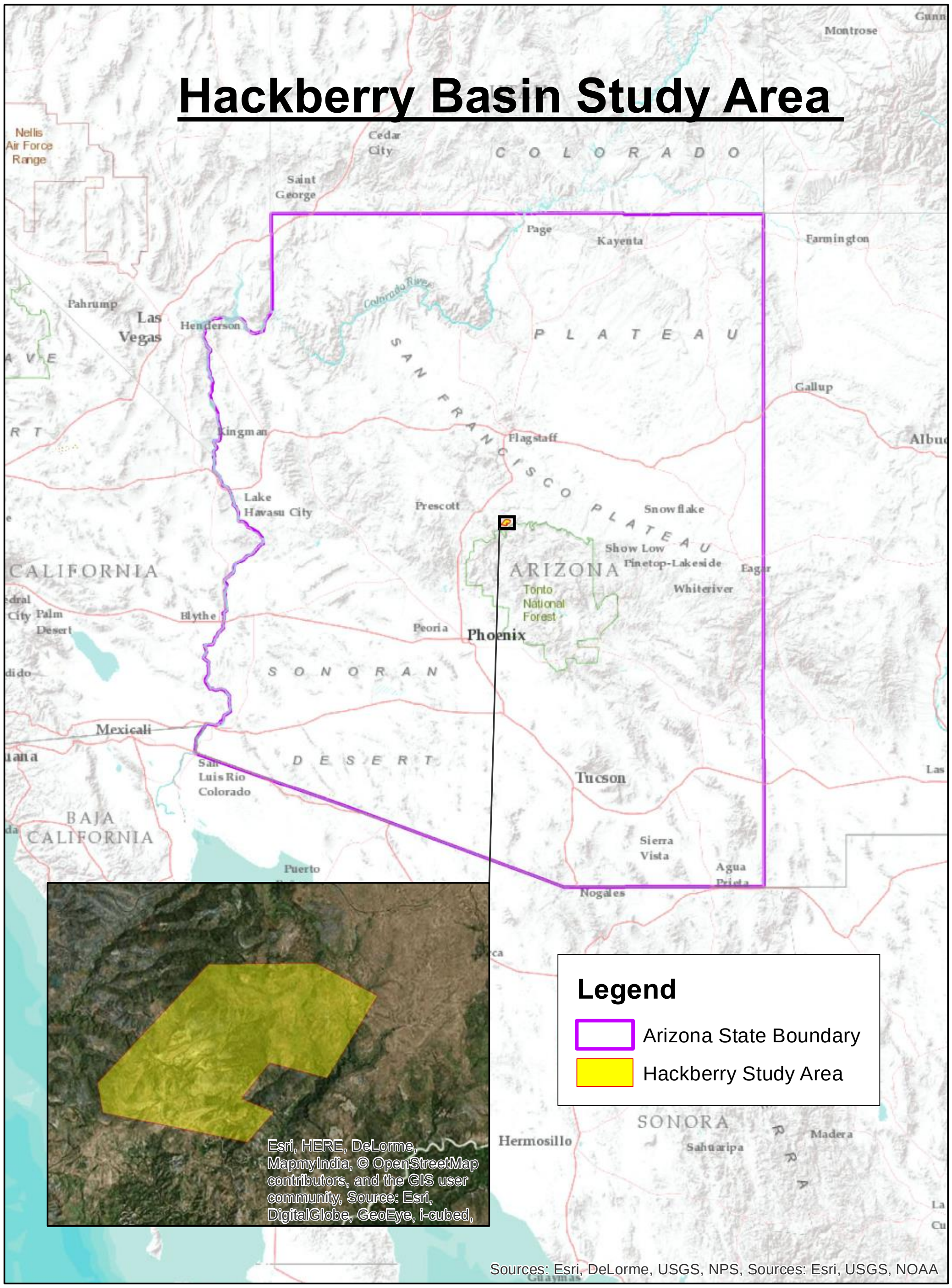

Figure 2. A map showing the study area location compared to Arizona.

Scope

The scope of this practicum is limited to the creation of a geodatabase that includes point layers for the sites, water source, and proximity layers, and TEU soil profile layer for the Hackberry Basin. Any land use discoveries from the data that is available at these archaeological sites directly relates to the prehistoric inhabitants within the study area. The patterns uncovered during the course of this practicum can provide evidence to help direct future analysis using similar data or in the same location.

Significance

The purpose of this project is to further the analysis of the United States Forest Service in regards to prehistoric agricultural assessment by applying a GIS to recorded survey data. The studies carried out by the USFS provide insights for environmental and land use management for national forests. While survey data continues to be collected, understanding better ways of processing the data will promote more efficient and timesaving techniques that can benefit the Forest Service. This practicum provides a framework and procedure of a soil, water and site assessment for the Hackberry Basin study area.

Research Questions

RQ1. Are there any patterns that arise from a distribution analysis of site points that have been recorded in Hackberry Basin?

Hypothesis: The topography of the basin will have an effect on the distribution of the sites because of the elevation change caused by the Mogollon Rim.

RQ2. Using the site distribution, how do the sites compare in proximity to water sources?

Hypothesis: Based on the need for water in arid climates communicated by past research, the most sites would be located nearest to a water source then taper as the distance grew.

RQ3. Using the site and agricultural feature distribution, was there any significance to the soil profile at these locations?

Hypothesis: The most sites and agricultural features would be located in the area that had the highest rating for soil condition and vegetation potential.

Literature Review

This literature review discusses the use of GIS as an approach for prehistoric agricultural analysis. It is done by looking at similar case studies and models for archaeological sites. It also focuses on the application of archaeological research surveys as the grounds for spatial analysis techniques. The last topic covered in the literature review concerns local studies into site dating and classification.

GIS as a Tool in Prehistoric Agricultural Analysis

While agricultural analysis has been attempted before on prehistoric surveys, not until recently have technologies and data quality reached the point for accurate analysis. Carla Van West has stated that "the data are too many, the calculations too complex, and the accurate evaluation of options too numerous" (Van West, 1994). This is in regard to climate and agricultural productivity analysis. Computers and particularly geographic information systems applications play a vital role in trying to create a spatial image for the distribution and development of an area. Furthermore Van West continues on to say, "By capturing, co-registering, and evaluating all data layers, as well as by creating new layers from reclassifications and transformations of the original data, GIS technology made a fast, accurate, and consistent (and therefore repeatable) assignments necessary to create the model, display the results, and assess patterning across space through time" (Van West, 1994). This really gives an idea of the capability of GIS when applied using the right data, if available. For Van West's model multiple study locations in the southwestern corner of Colorado were chosen. The data used was previously generated computer values that had been stored, DEM that had been purchased at the time, and newly digitized spatial and tabular data (Van West, 1994). Then using these components, she developed logical elements that would eventually be applied with the model. Figure 3 below illustrates the model by Van West:

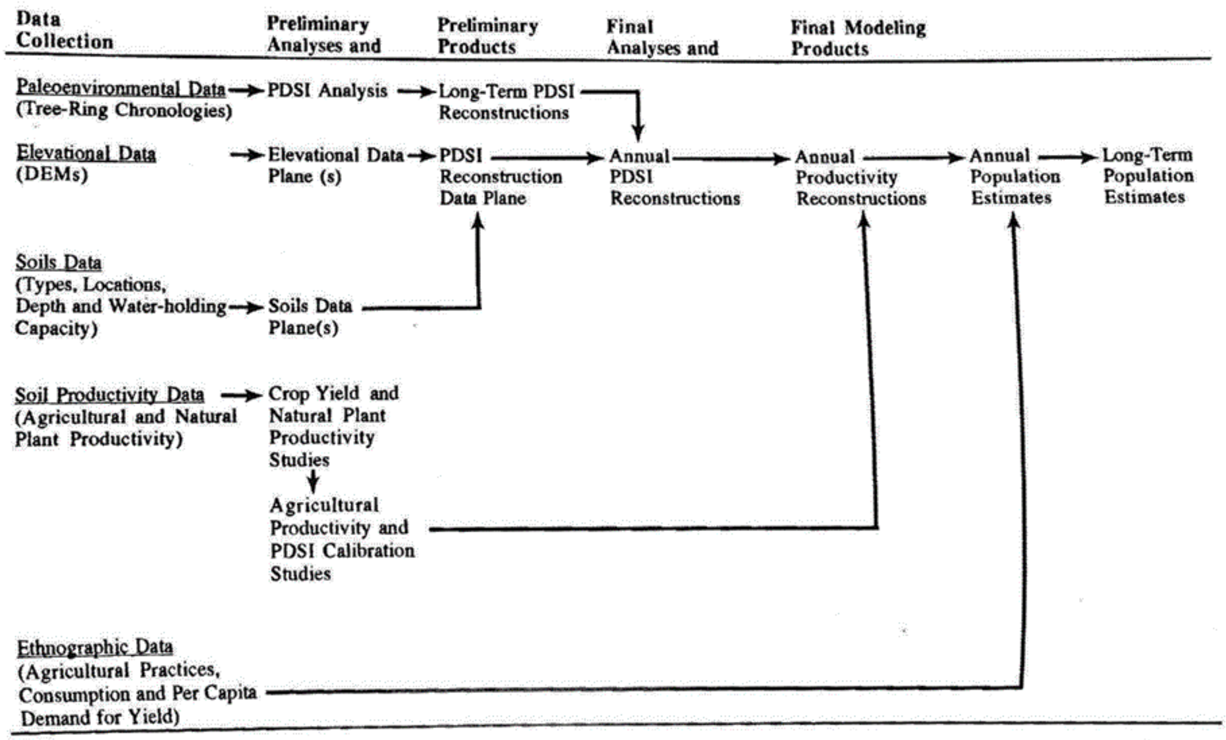

Figure 3. The model used to determine long-term population estimates (Van West, 1994).

The first logical element was soil moisture condition for each soil type. This was done to calculate the Palmer Drought Severity Indices and compare the values with tree ring records (Van West, 1994). Second, it uses the PDSI values to predict crop yields of maize. The third step was to calculate the total productivity of agricultural habitation on a year-by-year basis and to provide an estimate of maximum annul food supply. The next step was calculating the estimated yearly population density that could be supported by the calculated agricultural production, using assumptions about consumption rates and storage levels. Then finally it calculates the total population potential over a 400-year period of agriculture for the study area (Van West, 1994). This system was then refined in 2012 by Timothy Kohler, however the methods are still disputed as being parameterized and complex (Benson, Ramsey, Stahle, & Petersen, 2013).

The criticism was followed by another purposed technique to assess what factors controlled prehistoric maize production (Benson et. al., 2013). The study focused on the same area as Van West, looking at the area surrounding the Mesa Verde Pueblo in southwestern

Colorado (Benson et. al., 2013). This provides a good backdrop of comparison for the two methods analysis. Furthermore Benson et. al. outlined the components used in the model as soil moisture, soil chemistry, soil texture or type, and solar insolation. The solar energy promotes evaporation and controls soil moisture, which is why measuring solar insolation is so important because it also provides energy for photosynthesis (Benson et. al., 2013). Along with this, soil types and chemistry are important because they can regulate how much water is absorbed depending on the type and consistency of the soil. Loose sands and silts promote water absorption as opposed to thick clays, which can resist water infiltration (Benson et. al., 2013). Finally, the soil types and temperatures play a big part in the control of mineralization of nitrates in the soil, which are then used by the plant for growth (Benson et. al., 2013). This method relies heavily on the use of soil properties and contents as directly relating factor to prehistoric food production. Unlike the Van West (1994) model, precipitation was calculated using direct Douglas fir tree measurement as opposed to the PDSI.

In these two research studies, it was apparent the climate and soil chemical makeup play a large part in what makes a soil arable or not. The next paper, also by Larry Benson, looked at the factors that soil chemistry like nitrogen and salinity play in the production of prehistoric maize on the southern Colorado Plateau (Benson, 2011). The paper states, "To flourish, maize needs water, solar radiation, nutrients, and well-structured soil"(Benson, 2011, p. 100). Also the maize production based on archaeological finding was much less than the modern maize plant can produce with irrigated water and fertilizers (Benson, 2011). These factors all show how food was restricted by natural resources and climate. Using these basic factors Benson chose to use the values of organic nitrogen in the top 50-cm of the soil from 670 samples. He then compared the total nitrogen content to the average nitrogen content found in prehistoric maize. Benson found in the samples that at 1-meter deep, a 1acr-field contained an average of 37kg organic nitrogen. Then using the ratio of the nitrogen per plant, he calculated the overall potential productivity of the area against how much nitrogen was found per meter. Benson indicated that the average hybrid maize plant contains 3.3 grams of nitrogen. Through his calculation, he was able to identify that raising 2000 plants on 1 acre of land would use about 6.6 kg N. Many of the other factors are what contribute to the content of the nitrogen in the soil. Obviously water run and decomposition but it is also believed that there are plants that fix the nitrogen content of the soil (Benson, 2011). So this brings up anew topic of how Native American were able to optimize their maize yields through efficient agricultural design. Benson suggests that they were able to apply techniques in “water diversion, water concentration, evapotranspiration, mitigation, and planting” that were all used to optimize maize growth in the semiarid climate of the southwest. The control of this water is the main factor for maize growth as well as resorting nitrogen through N-fixing plants, which is needed to be able to continue growing in these area on a year-by-year basis and not deplete the nutrients (Benson, 2011).

Hydrology analysis also plays a large role in understanding prehistoric agricultural techniques. Wienhold (2013) focuses on the relationship that water has as a resource in prehistoric settlements using modern GIS techniques. Since the climate of Arizona is semi-arid, water management becomes a major tool of communities using subsistence-based agriculture. Some of the evidences of this management comes in the form of garden terracing, rock damns, or channeling run-off. These methods were used to concentrate water into organic-rich sediment locations for more efficient agriculture (Wienhold, 2013).

GIS was the basis for the analysis in Wienhold’s research using hydrology analysis created through Digital Elevation Models and GIS tools. Also since topography has been used for patterning pre-historic hydrology, Wienhold wanted to go a step further and look specifically if these hydrological assessments could be used for identifying the rock alignments and understand their effect. So Wienhold created a hydrological assessment methodology based on Digital Elevation Models that can be applied to any location using the same data. After the hydrology assessment was performed the runoff locations were identified and this was overlaid with polylines that showed any rock dams or features to divert water. It was apparent that many of the water management locations intersected many drainage streams (Wienhold, 2013).

Understanding the agricultural patterns of the prehistoric people of Arizona has been an exploration undertaken by Archaeologists. In 1977, G. Lennis Berlin and colleagues were able to identify a previously unknown prehistoric agricultural field using aerial photography and thermography in conjunction with soil and vegetation analysis (Berlin, Ambler, Hevly, &Schaber, 1977). Initially panchromatic and thermographic aerial images were overlaid, which uncovered several linear non-uniform surface features. These locations were then surveyed for vegetation and soil profile, which then uncovered that there were differences between adjacent locations in soil chemistry, temperature, and moisture content. The aerial photography reveled a rectangular field with striations that were representative patterned crop growth (Berlin et. al, 1977). Then using the soil, vegetation and surface temperature analysis conclusions were drawn as to just how the field was used and what artifacts were left. Rocks near the field were disrupted, possibly used to lessen wind damage on crops (Berlin et. al, 1977). This was one of the first localized agricultural analysis done in the region and promoted a range overlay identification techniques.

Settlement Patterns of Prehistoric People in Arizona

How land was used and settled plays a large part in understanding the communities and people that existed in prehistoric times. “Settlement and land use happen to be two areas amendable to pattern interpretation, since they rely to a large degree on the distribution of archaeological materials.” Many archaeological sites have been surveyed in a similar manor to the Hackberry Basin. One such study was the Walnut Canyon Settlement an Land Use study pertaining to the Walnut Canyon to the east of Flagstaff, Arizona. During this time, the Walnut Canyon experienced an explosive growth in number of sites, both limited use and habitation sites (Bremer, 1989). According to Bremer, this expansion of population created distinct communities within the canyon and along its rims. The paper then explored the agricultural sites that were apparent throughout the habitation sites to see if there was an explanation for the settlement patterns. The reason being is that, ”at a specific point in time the Northern Sinagua identified Walnut Canyon as an exploitable niche with abundant natural resources as well as suitable locations for settlement and arable lands(Bremer, 1989). Since the area was settled, a large community grew from the initial habitation; however, whether or not that was on purpose is up for debate (Bremer 1989). Ecological stress can cause groups to shift dramatically for survival, but once a suitable location has been identified, development of a community can begin (Bremer, 1989). The analysis uncovered the greatest change in agricultural settlement as well as the biggest shift to field houses in the post-eruptive period from 1150 – 1300 (Bremer, 1989). Since this was the case, the field house and agriculture could be seen to have some sort of relationship. It was apparent that one of the main land uses in their study area was agriculture, which can be seen in the amount of field house that grew between the pre-eruptive and post-eruptive periods (Bremer, 1989) The reason this analysis can even be done is that the reconstruction of settlement structure of sedentary agriculturalist is much easier than that of mobile groups (Bremer, 1989).

Field houses have been defined as early as 1916 through the southwest as having seasonal agricultural functionality (Pilles, 1978). A study was done specifically to see if there were any patterns that existed between field houses and permanent habitation sites. According to Pilles, "Various site attributes and artifact assemblages were then examined to see if the assumed functional differences, based primarily on architectural considerations, could be supported (p. 120). This study looked at 31 sites, 20 field houses, and 11 permanent habitation sites as well as all the site attributes and assemblages associated with them. The field houses were classified as small to four room structures and the permanent habitation structures were classified by being three or more contiguous rooms (Pilles, 1989). It was then stated that, "If the functional specificity of field house is correct, functional differences should be reflected in the artifact assemblages from each class of sites" (Pilles, 1978, p.124). An index was then calculated by dividing the number of artifact categories from a single site by the total number of categories represented by all sites. A high index value means that many activities took place at the site. A low index value represents a limited number of activities took place at the site (Pilles, 1978). After looking at the index, it was apparent that "artifacts indicate a limited range of activities at field houses and suggest and emphasis on mealing" (Pilles, 1978, p.125). So a lower index is indicative of a field house, based on its discovered artifact assemblage. Similar surveys done around the Sinagua demography have suggested, "…that field houses make up a third of all sites in the region" (p. 128). This is helpful because it provides a base line of how many field houses might be indefinable in a study area.

Artifacts as a Guide for Prehistoric Classification and Dating

To classify the field houses and permanent habitation sites, Peter Pilles used specific definitions for artifacts which led to identification of site activities (Pilles, 1978). He did this classification by functionality in order to address the number of activities at each site based on what artifacts are associated with certain activities. The four classifications used were mealing activity, manufacturing, hoes, and projectile points (Pilles, 1978). The mealing artifacts in the study were most important to identifying field sites, where the manufacturing artifacts were most important to identifying permanent habitation sites. Then the secondary more specific categories, hoes and points, added proof of the site classification. Points were generally found more often at permanent habitation sites and are more often found at field sites (Pilles, 1978). Using collective knowledge about artifacts allows for classification that encourages pattern and trend analysis at sites and across settlements.

The dates for which the Sinagua people inhabited Northern Arizona are often reexamined as archaeological surveys progress. The inhabitants of the Hackberry Basin potentially resided there from the 700 A.D. into the 1500’s (Graceffa, 2010). The way these dates have been purposed was through artifact and ceramic dating (Graceffa, 2010). There are twenty types of pottery that have been identified as originating in the Verde Valley (Graceffa, 2010). The phases can be defined by the innovations and added decorations on pottery and artifacts as the phase’s progress over time. Furthermore ceramic can be classified by usage and by date providing a valuable tool when trying to identify density of inhabitants and populations (Graceffa, 2010).

Prehistoric Agricultural Techniques

The tactics used by prehistoric people to manage their limited resources is a major topic of anthropology around the world. Some of the methods used pertain directly to environment or society development. In areas with high volcanic activity, like Arizona, one of the agricultural techniques deployed is called Lithic-Mulch (Lightfoot, 1994). Lithic-Mulch incorporates volcanic materials like, “volcanic ash and cinder, pebbles, gravel, or stones as mulch to improve crop growth.” (Lightfoot, 1994). Lithic-Mulch agriculture involves surface mulching of gardens with lithic materials to help improve water retention and reduce evaporation loss. This also helps control weeds and raises the soil temperature, which in turn advances germination, growth, and overall production of crops (Lightfoot, 1994). Along with wind damage reduction, the mulch also reduces erosion, which protects the soil surface from raindrop splash and runoff (Lightfoot, 1994). This method is especially useful in restricted arid environments.

Lithic mulching has been seen as being used as far back as 200 B.C. in Italy near volcanic areas (Lightfoot, 1994). In certain regions, this type of agriculture is actually superior to other forms of agriculture (Lightfoot, 1994). Among the groups that have been identified to use lithic-mulching one is a local group to Arizona, the Sinagua People. The volcanic material found at this site can be directly related to the volcanic eruption that occurred in the area between 1064 and 1067 (Lightfoot, 1994). These practices can be directly correlated with trying to regulate the evapotranspiration of soil in northern Arizona.

Along with mulching techniques, gridding of crops may also be used to deter water runoff. The mulching and the gridding often would take place together to keep the mulch inside a border. Dominguez (2002) looked into how patterning and application of gridded gardening helps water retention. He states that it is useful to think of the gridded plots by employing a hydrologic model and thinking of the plot in terms of the surface and soil moisture components. The paper uses a GIS based hydrology analysis to show area with various levels of mulching as compared with position of discovered cobles at a sight in New Mexico, where gridded plots are usually associated with large drainage as they are rarely eroded away by runoff. When a hydrologic model is deployed the mulch depth, coble size, and spacing all can play a factor in the control of water. These areas were often found in specific soil profiles and with slope that would promote precipitation accumulation (Dominguez, 2002). Snow was an important part of this accumulation as many locations with cobles were able to build up more snow from their strategic location. According to Dominguez, snow was also important for preventing evaporation before the growing season (2002). The design and control of water as a resource was essential throughout all season as represented by the careful planning seen in the mulching and cobles.

Methods

Figure 4 is a flowchart that shows the methods used in the current study. To begin this project, the physical site card forms needed to be processed in order to digitize the attribute information that was needed for analysis. To do this, 115 site card forms were read and physically entered into the attribute fields to create site points layer. All this sites that had been recorded during the survey were digitized into one compressive points layer. This included site number, site type, room numbers, garden totals, garden area, agricultural totals, agricultural area, and the UTM coordinate location. Sites could have many features, however, for this study the main interest was in agricultural potential, which is why agricultural features were added as attributes of the site. Additionally the agricultural features were then split into subcategories of garden or agricultural feature. A garden was any feature smaller than 500 square meter, where as an agricultural feature was greater than 500 meter square. As Table 1 shows, sites were diverse: some sites had multiple agricultural or garden features and some site had none. The site types are categorized by field house, small farmstead, large farmstead, agricultural, community center, and other all with the potential to contain agricultural or garden features. To identify the total growth area, all identified gardens and agricultural fields are calculated for their areas using the measurements defined by the site cards. All of this information is valuable to compare locations through the Basin. Understanding why certain features or site types are found in proximity to water or in a given soil profile is used to uncover addition information about what the prehistoric people of this area understood about their resources. The archeological site points layer can serve as a reference for to compare proximity or density. Proximity is important for both water locations and dwellings in regards to the sites that were identified as having agricultural features or specialized site type.

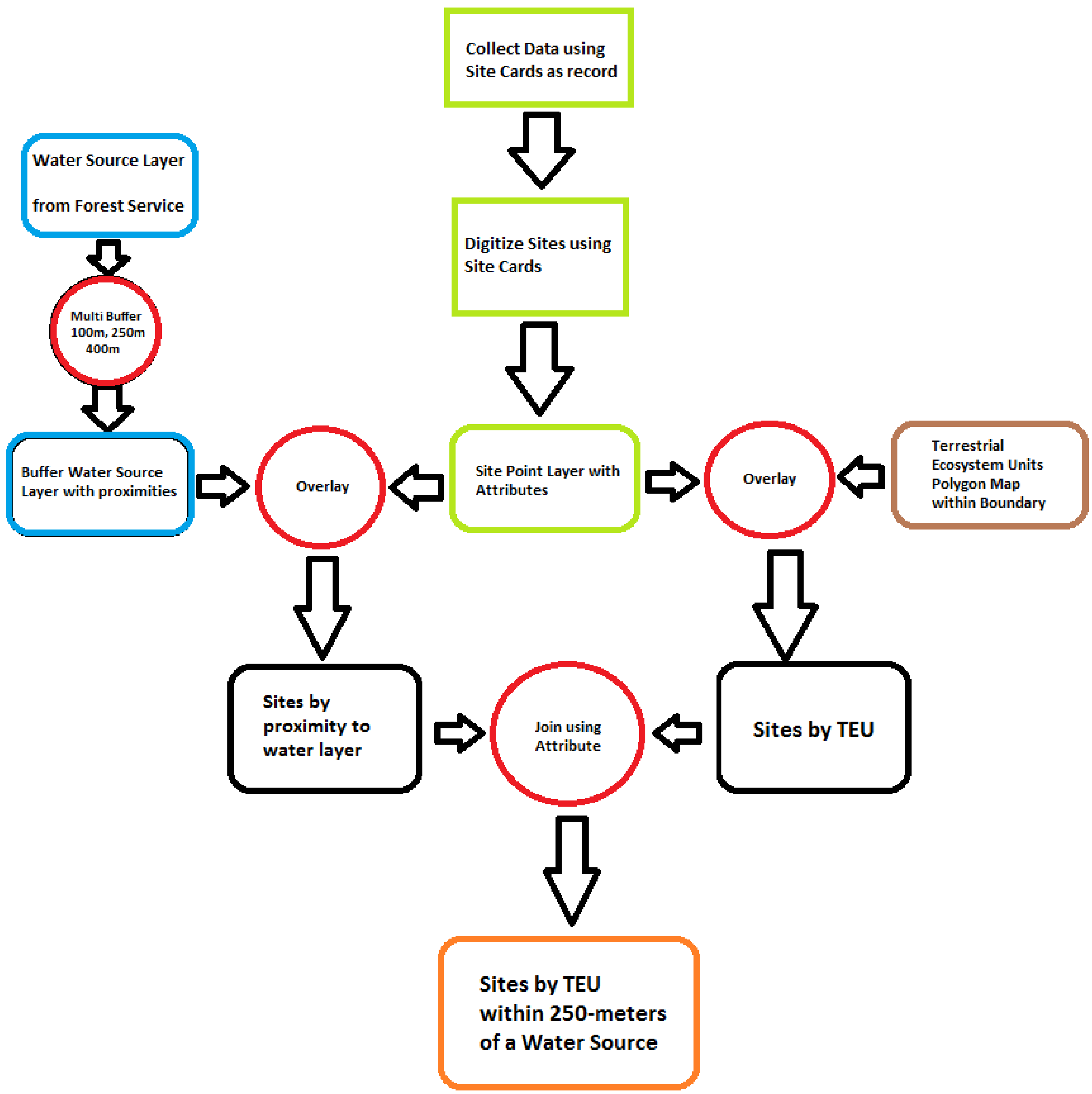

Figure 3. Flow chart of the methods used.

Table 1

An Example of the Attribute Table Created for Site Classification

OBJECTID *	Shape *	Ref	Site	E	N	Rm_Num	Gar_Tot	Gar_Ar	Ag_Tot	Ag_Ar	SiteTyp
1	Point	3040	100	381242	43741	45	0	0	1	1100	Community Center
2	Point	3040	646	381043	43676	4	0	0	1	2000	Agricultral
3	Point	3040	676	381109	43699	5	1	25	0	0	Farmstead-Small
4	Point	3040	1600	380949	43923	1	1	16	0	0	Farmstead-Small
5	Point	3040	1601	380948	43958	5	0	0	0	0	Farmstead-Large

The soil condition and vegetation potential play an important role in identifying which areas are suitable for growth. This analysis was done using the Terrestrial Ecosystems Units Map for the Coconino National Forest from the Forest Service. This layer was curated and provided by Chris Barrett from the Rocky Mountain Research Station. This vector layer takes into account the soil type, based on samples that have been taken in the area, and has some identifying features like slope and aspect incorporated to help describe ecosystems organization based on soil profile. These terrestrial ecosystem units are predictors of what kind of relationship exists between the resources and organisms at any given location. In turn this is valuable because it also represents a good pattern for locating suitable growing locations in association with each TEU, so it may provide a backdrop that the completed analysis can then be compared to. The TEU layer obtained from the Forest Service has information attached to the coded TEU profiles. These profiles are labeled as a number but refer to a cache of information regarding the ecosystem for a given location. These codes can be reference to identify what locations have been surveyed as being the best or worst conditions for soil and vegetation potential. This layer contains soil map unit data that has overall descriptions of the soil type and content. Using this along with the known agricultural features provides some detailed information about TEU's preferred farming locations.

Water is essential for farming. A hydrologic assessment was done to locate stream for water runoff. The layer is a combination of a streams polyline layer acquired from the forest service compared will a study area watershed analysis. The streams layer will be used to see where running or standing water was in proximity to agricultural features and sites. Even in the Southwest's dry climate, there were perennial natural springs as well as ephemeral runoff especially considering the rocky conditions. Locating the watershed and ephemeral runoff should provide an indication of water source locations and their proximity to prehistoric agricultural sites, as it can be assumed the geologic landscape hasn't changed drastically in the last 500 years.

A DEM maintained by the Forest Service as provided by Chris Barrett, was used in the watershed analysis, which was then used as a comparison to the forest service layer.

The site cards will develop the main data source as a points layer that will contain all the information to the site features and location. Site Points Layer includes all the agricultural features that are recoded at each site as well as room number and site type. As a site could have different agricultural components, it is important to differentiate between these features in order to make better land use assumptions. Both personal gardens and large growing fields are apparent in the Hackberry Basin. With many of the sites showing signs of terraced gardens, there is some belief that this was due to a lack of good growing locations. This means prehistoric people had to exert extremely difficult levels of rockwork to build raise platforms especially for farming, of which evidence is apparent. Additionally a goal of this project was to do a date range analysis for each site to show progression throughout the basin. Unfortunately over the course of the project, it became apparent that there was a lack of date ranges for all the sites. So some dates were recorded; however, they were unused in this analysis.

The two main analysis techniques used are proximity and overlay analysis. Along with this, overlay was performed on the site layers against the TEU and water source proximity layers. To see if the existing agricultural locations are related to features in the TEU or water source layers, statistics are performed to show the overall distribution and conduct density by classification. Using the classifications of soil provided by the TEU classes allows for analysis into whether the soils that were best suited for soil production were the one that coincided with agricultural locations. Then locations are matched to the suitable conditions to refine identification of potential agricultural locations.

Results

Site Distribution

After the site cards were processed and the site points layer was created, a visualization of the site distribution was produced. As Table 2 displays, 115 total sites have been recorded though surveying and excavation, all of which were used in this analysis. Since the main focus was land use and the potential agricultural options of the basin, the two fields of study that were used to compare the proximity and overlay analysis were the classified site type and the general agricultural feature that were recorded at a given site. The first site type was chosen as a classification because it provided a comparative backdrop for the land use and overall distribution of the sites. Since the site type was the culmination of all of the sites information and features as classified by archeologists represented the most consistent classification for the dataset.

As can be seen in Table 2, the majority of the sites are divided between small farmsteads and field houses (91 out of the 115 of the sites). Small farmsteads represent sites that were believed to have been inhabited year-round whereas field houses were more likely to have been used seasonally during the growing season. These classifications are known because of the artifact assemblages and sherd counts at any given site. Along with this were only five large farmsteads, which were classified as being 5-12 rooms in size, as well as one Community Center. The Community Center is named Doren’s Castle and has 45 rooms. Doren’s Castle was classified as the community center because during analysis room distribution was skewed by the size of this site over all the other sites.

Table 2

Table Showing the Site Totals by Site Type Classification

Site Distribution							
	Agricultural	Large Farmstead	Small Farmstead	Field House	Other	Community Center	Total Sites
Total Number of Sites	12	5	36	55	6	1	115

The second analysis is to determine whether or not a site had any agricultural or garden features and their total area, as this provided a baseline for the agricultural land use in Hackberry. As can be seen is Table 3, garden feature was defined as a singular feature if its area is less than 500m^2while an agricultural feature was defined if its area is greater than 500m^2. This is because any site type could have an agricultural or garden feature regardless of its site type classification. With the total area of these features recorded, this also provided and important tool for measuring a baseline for the potential agricultural production of Hackberry Basin. Table 3 presents the totals and areas of all the agricultural and garden features in the study area.

Table 3

Table Showing the Totals and Areas of All the Agricultural and Garden Features in the Study Area

Agricultural Distribution

Agricultural Features (Area greater than 500m sq.)	Agricultural Area (Sq. Meter)	Garden Features	Garden Area (Sq. Meter)	Total Garden and Agricultural Area
9	22,466m^2	80	4,962m^2	27,428m^2

Along with the structure based sites there was also an agricultural classification of feature that were identified as being agricultural in nature like terraces, rock gardens, or fields. This classification was assigned by the archeologist and was not the final labeling feature to whether or not a site had a garden or agricultural feature, it did however provide a visualizing factor when trying to compare site types in the overall distribution. Finally there was another category these sites were classified as such because they represented either a roasting pit or a recreational feature. These sites were non-essential to the study but were still included from the surveys so were labeled as such.

One of the significant obstacles for the distribution of sites is the physical boundary of the Mogollon Rim, which divides the basin sites from the rim sites. This gives some proof to the hypothesis that topography effected site distribution. As Figure 5 shows, there are 69 sites located in the basin that was defined as being between 1,100m-1, 500m in elevation and there are 46 sites located on the rim, which was defined from 1,500m to 1,900m in elevation.

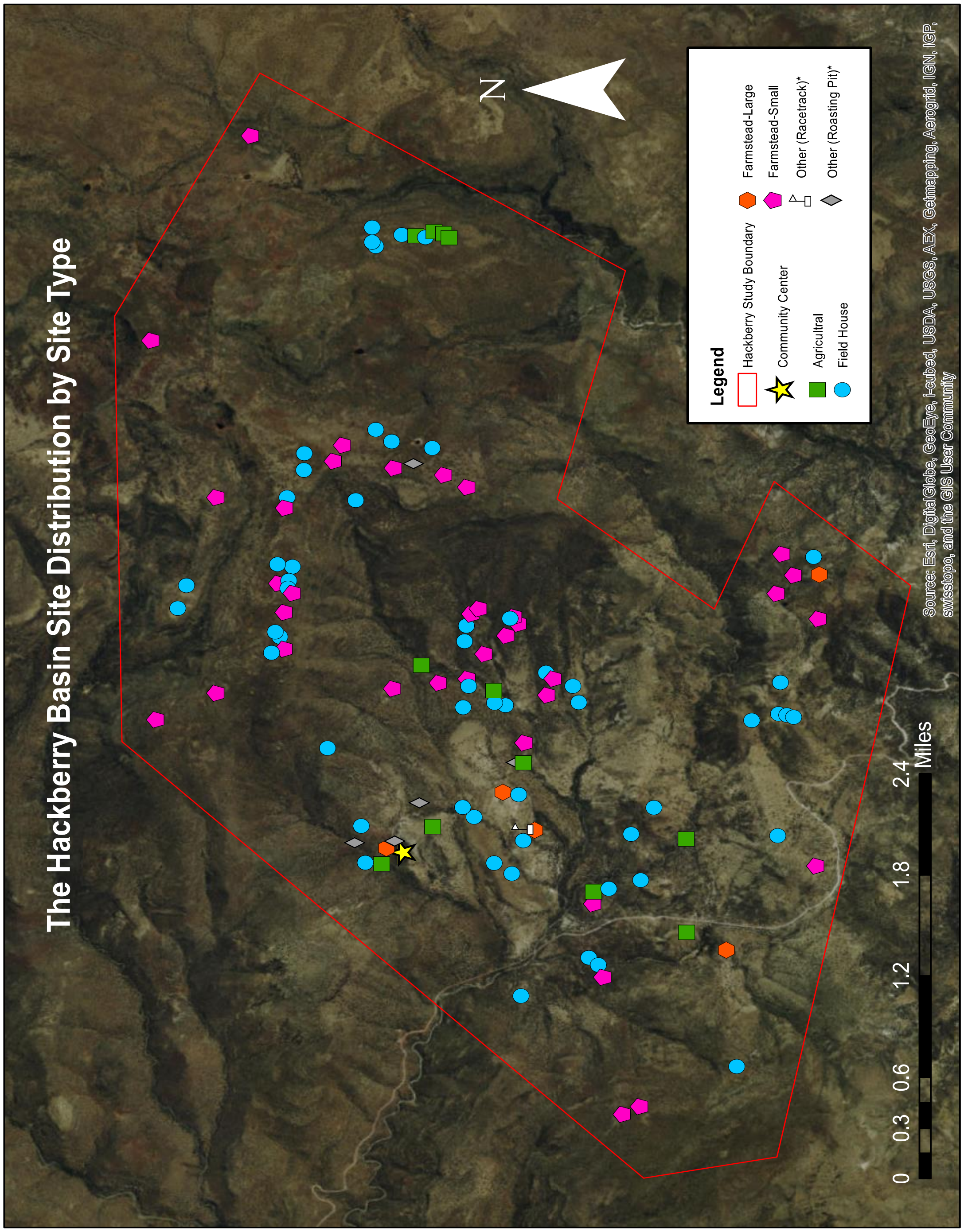

Figure 4. Map showing the site distribution throughout the study area.

Since the majority of the sites are either field houses or farmsteads, the sites are distributed in a way that small farmsteads seem to be situated near field houses or groups of field houses. Field houses are important because of their status as a seasonally used location that was generally not used for permanent habitation. The small farmsteads, however, were considered permanent habitations, so their association with the field houses could be important to agricultural land use. Along with this, the ratio of field houses to small farmstead seems to be similarly distributed between the high and low elevation sites in terms of the total site counts against the counts of both the field houses and small farmsteads.

The majority of the large room sites (both the community center and the large farmsteads) seem to be located in the lower elevation areas within the basin itself. Of the distribution of the basin sites, many of the settlements also seem to be situated in area's look out from or atop an elevated location, as in the case of Doren's Castle or the small farmsteads situated in the eastern corner of the basin. Also, there seems to be a seasonal agricultural area in the far eastern part of the study area near the boundary. These sites relate to the agriculture of the area because they provide the known location where artifacts can be collected to classify a sites usage. Based on the artifacts and characteristics recorded in the survey, these sites were connected to their agricultural features or classified as permanent or seasonal dwellings.

Water

Water presented one of the most unique problems of the Hackberry Basin. The basin itself has its open watershed from the contributing water features that flow down off the Mogollon Rim (see Figure 6). The rugged topography of the area results in many drainage streams throughout the basin. Although the rugged terrain creates many unique drainage streams within the basin, they all collect at the lowest stream point in the study area near Fossil Creek Road. The lower elevation sites received run-off but the higher elevation sites were able to use the snowmelt from the winter months giving an additional water source. Since there was such a large gap in between the high and low elevation sites, each group was analyzed separately.

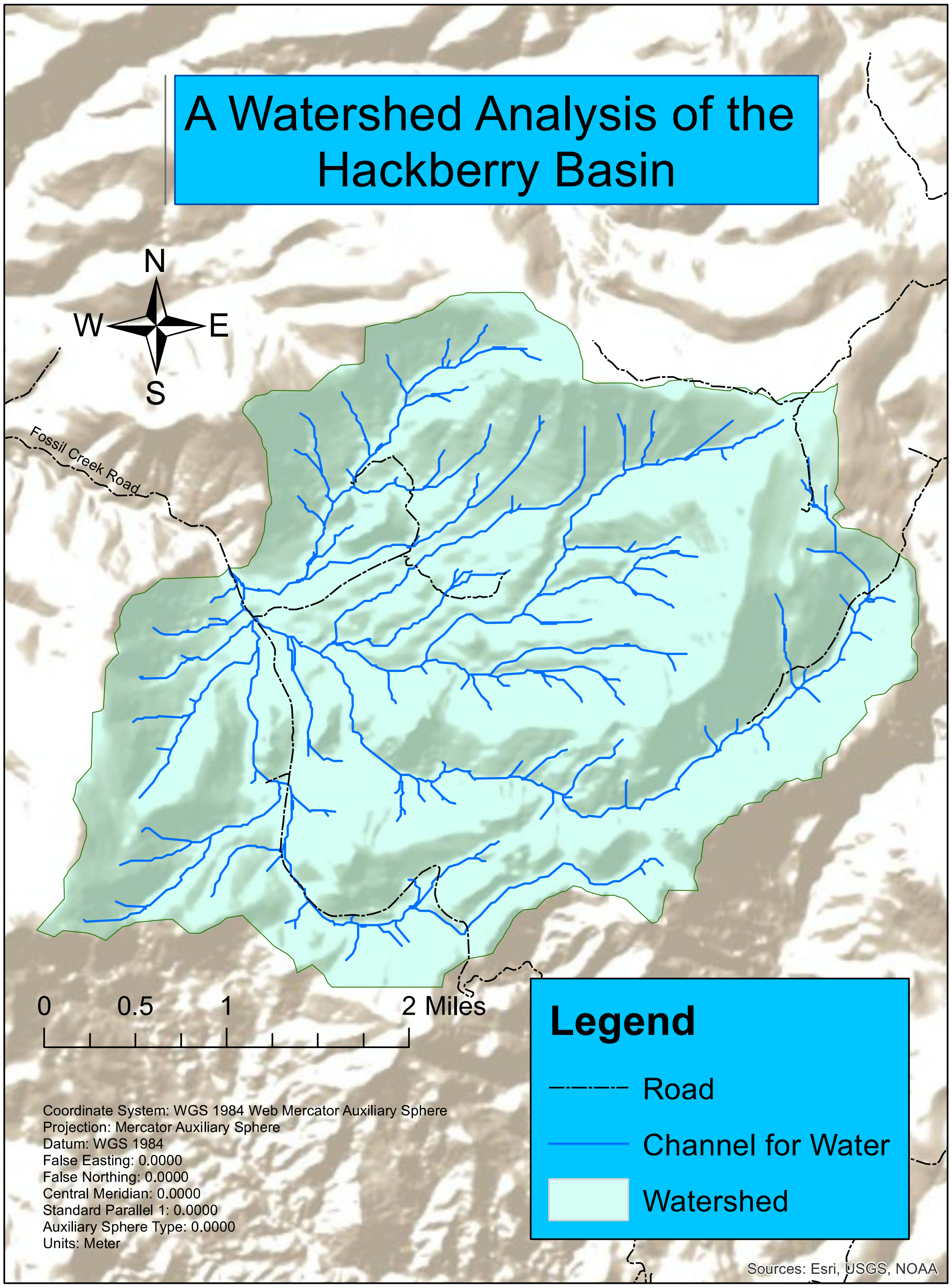

Figure 5. Map showing the Hackberry Basin watershed.

The low elevation sites were provided with the most run-off due to the high degree of elevation change between the Mogollon rim and the Verde Valley. However these water sources were intermittent streams that only flow when weather or snow melt is present. This would have presented a challenge to any inhabitant of the basin who was trying to maintain daily water intake or irrigation. One of the apparent techniques used to manage these flows were terraces or rock dams used near agricultural or structural sites that had high degree of slope. These areas would stop water or divert the stream so that the run-off could be utilized for irrigation.
Since terraces were seen at some site locations, it eliminated the ability to do any sort of slope analysis, relating to gradient as a controlling factor for agriculture. It would be impossible to say that past a certain angle of slope plants wouldn't take root when the former residents of the area moved boulders and soil to create flat terrace locations.

Along with this, how the low elevation sites were situated restricted any sort of aspect analysis due to the shadows cast by the boundary of the basin at Sunrise and Sunset. With the Mogollon Rim rising 700 meter in elevation, at different times of day the area some areas of the basin received different amounts of light. So most aspect analysis can assign different values to the different directions of hill face and then score those directions for sun or agricultural potential based on the amount of sun for a specific direction. An example would be how north facing slopes receive less light from the sun then south facing slopes because of the angle of the sun as it passes from east to west in the sky. However because of the significance of change in elevation on both the east, north, and west sides of the Hackberry Basin and the overall topography in the basin it would be difficult to set a consistent measurement for all the directions using a 10 meter resolution digital elevation model. Some areas can maintain more moisture because there lack of contact with the sun, so it would be difficult to say that the crops grow better on a specific facing slope that may receive more sun or shade.

Since the duration of a stream's flow would have been a controlling factor of the availability of water, residents must have needed to focus on their proximity and positioning to water. The distribution of sites by proximity to water provided some insight into the patterning of the lower elevation sites in the basin (see Figure 7).

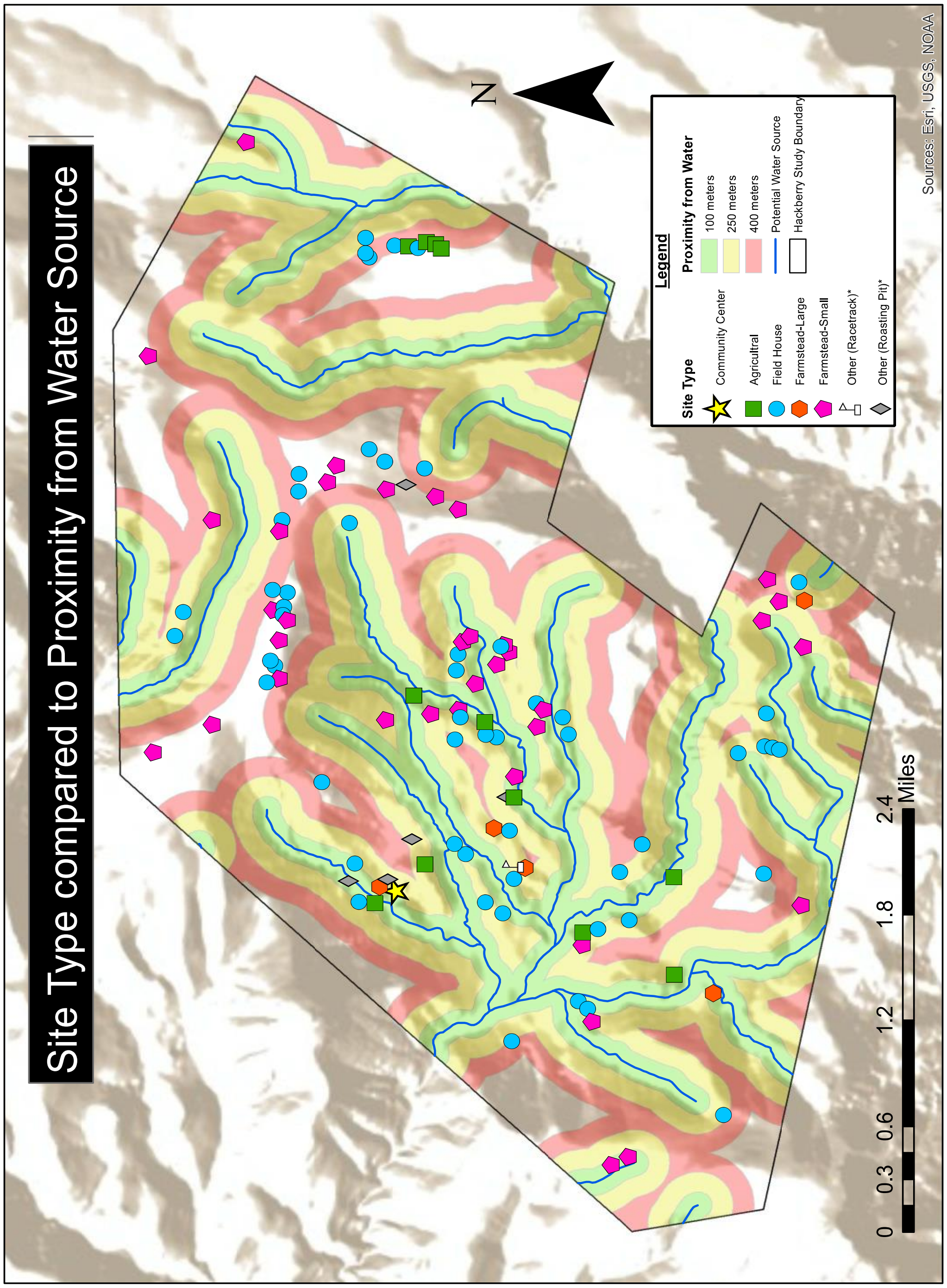

Figure 6. Map showing site type with proximity to water visualized.

As shown in Table 4 below, archaeologic sites are classified into three categories based on their proximity to water using distances 100 meters, 250 meters, and 400 meters. These distance were chosen based on consistency of measurement as well as the maximum distance being close to a quarter of a mile, on the basis that water may have been needed to be transported. The maximum distance provided by Dr. David Wilcox in regards to human transport of water is ¼ mile, this is because of the difficulty of carrying water over long distances. This distance discussed in the project planning held true by trying to apply equal interval three band proximity analysis.

Table 4

Table Showing Site Type by Proximity to a Water Source

Site Type by Water Proximity							
	Agricultural	Large Farmstead	Small Farmstead	Field House	Other	Community Center	Total
Sites within 100-meters of a water source	5	2	7	12	2	1	29
Sites within 250-meters of a water source	8	5	23	34	5	1	76
Sites within 400-meters of a water source	9	5	25	43	5	1	88
Total Number of Sites	12	5	36	55	6	1	115

Out of the total site distribution over 76% (88 sites) of the sites were located within 400 meters of a water source. One of the most significant discoveries when looking at the proximity is the change in the number of sites between the 100 meter and 250 meter proximity. The initial hypothesis was that many of the sites would be located within the 100-meter buffer and then tapper in value as the distance increased; however, this did not prove to be true. In the 100-meter proximity there were 29 total sites and of these sites there were 28 combined agricultural or garden features with a total area of 8,983m2, whereas at the 250-meter proximity there were 76 sites within the buffer, including those within the 100-meter buffer, with 61 combine agricultural or garden features with a total area of 22,777 m^2.The 400-meter proximity contained 88 sites with 74 agricultural or garden features with a total of 26,742m^2. Between the 100-meter and 250 meter buffers, there is more than 2.5 times the number of both sites and agricultural features. Then between the 250 and 400-meter proximity there is only marginal growth in the number of sites, only about 15% in both sites and agricultural features.

So for the total distribution of sites in the Hackberry Basin, 66%of all the sits can be found within 250-meters of a water source. Since this is the case the hypothesis that the greatest concentration of sites would be located nearest to water was proven to be false. Along with this all the large scale habitations (the Community Center and Large Farmsteads) are located within 250 meters of a water source as well. Looking at site type ratio between the proximity total and a given site type classification, the distribution is consistent as the proximity increases. There is no site type that grows abnormally as proximity increase or decrease; the distribution remains the same. This defied the hypothesis that the proximity to water would be the most important determining factor for a sites location. This lends more evidence to the claim that there seems to be a finite pattern as to how far sites would have been located from water within the basin itself.

Soil

To combine the information derived from the water source analysis and some sort of soil analysis to give a profile for agricultural site distribution, the soil analysis involved taking the sites at a given location and overlaying coded Terrestrial Ecosystem Unit polygon layer for the Coconino National Forest. These values are representative of an ecosystem and will give a description of what the soil profile for growing crops or any erosion that might take place. As Figure 8 shows, all of the sites in this case fell within five unique TEU map codes. The sedimentary geology of the Mogollon Rim diversifies the soil types between the upper rim and the lower basin. All of the TEU‘s were listed as having high susceptibility to erosion, which can change the profile of the soil, but for the current version of the survey, this information can explain the general make up of an ecosystem.

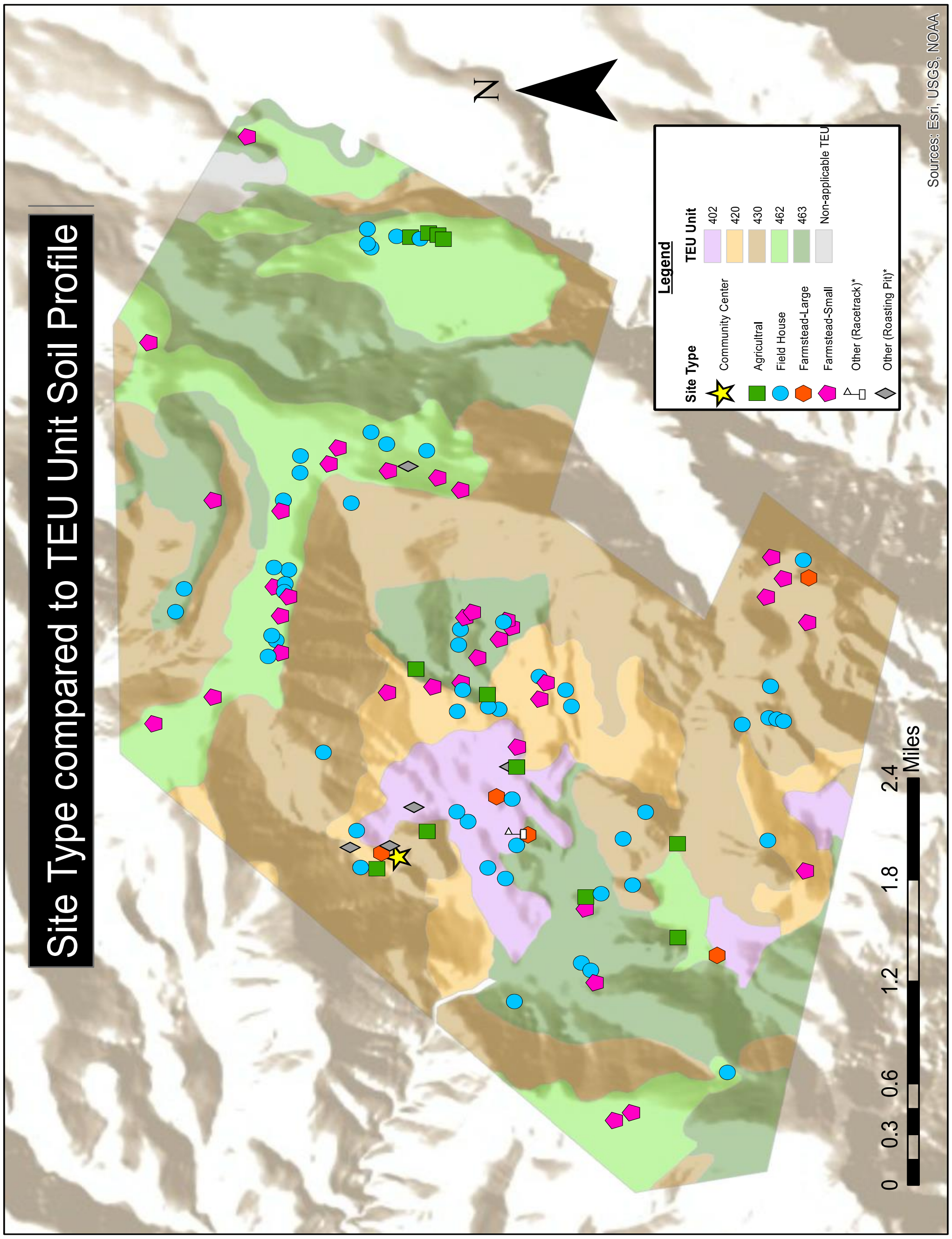

Figure 7. Site type compared with TEU regions.

Table 5 presents a comparison of the percentage of area for each TEU against the percentage of sites located within them. As shown, the distribution of the sites can be seen between the soil types in the high and low elevation sections of the study area. Almost all of the sites (40 out of 46) in the high elevation sites fall within the 462-soil code. This code type was recorded as having a clay base soil layer with a Basalt/cinder residuum left from the volcanic activity in Northern Arizona. This soil layer was listed as having moderately deep soil with clay loam giving it a moderate soil vegetation rating and it is satisfactory for overall soil condition. This was the highest rated TEU for agriculture and also happens to be where the most agricultural site types (5) and the most agricultural and garden features are located. Along with this the 462 TEU code also has a significant number of small farmsteads and field house site types located in the upper elevation area.

The coded TEU region with the second most sites is the 463-coded area in both the upper and lower areas of the basin. This soil type was categorized as having moderately deep clay loam with a high percentage of rocks or pebbles. Also the soil was made from a basalt/cinder residuum rated with low vegetation potential and a satisfactory overall soil condition. There were 26 sites located throughout the 463 coded regions with it also having the second most agricultural site types (3) and second most agricultural and garden features. Also again there were significant numbers of small farmsteads and field houses, the second most of all the TEU codes.

Table 5

A comparison of the Percentage of Area for Each TEU against the Percentage of Sites Located within them

Percentage of Area a TEU represents in Hackberry Basin				Percentage of Sites within a TEU Unit		
	Area in Square Meters	Percentage of the Total Area			Number of Sites	Percentage of the Total Sites
Total Area of 402 TEU	1,581,983	5.52%		Sites within the 402 TEU Ratio	11	9.57%
Total Area of 420 TEU	2,747,369	9.58%		Sites within the 420 TEU Ratio	17	14.78%
Total Area of 430 TEU	11,475,449	40.01%		Sites within the 430 TEU Ratio	21	18.26%
Total Area of 462 TEU	5,297,764	18.47%		Sites within the 462 TEU Ratio	40	34.78%
Total Area of 463 TEU	7,239,944	25.24%		Sites within the 463 TEU Ratio	26	22.61%
Other*	342,308	1.19%				
Total Area	28,684,817					

The third most populated TEU is the 430-code, which is wide spread throughout the transition area between the high and low elevations. This TEU is categorized as having low vegetation potential with most of the terrain being too steep for proper agricultural growth. The soil profile is again basalt/cinders residuum with the soil condition ranked as unsuited for use. Because this TEU is situated in the basin, sites located in this TEU seem to have a unique distribution with a small focused pocket in the south of the study area. This area has 21 sites, with 2 agricultural site types and 13 field house site types. Additionally, there are 20 garden features which was the second most out of all the TEU’s.

However, the last two TEU's, 402 and 420, are ranked as having the worst possible soil conditions and contained the fewest overall sites. The 420 TEU contains 17 sites including the Community Center, Doren's Castle, has the fewest agricultural or garden features of any TEU. Both the 402 and the 420 TEU's were ranked as unsatisfactory for use under the soil condition with contributing factors being that it was too rocky or had too many large rocks. Both TEU Units were listed as being basalt/cinder residuum with very low vegetation potential.

Additionally, a TEU's overall area to site ratio is performed against the total Hackberry basin study boundary area. This analysis is done because the TEU area's varied greatly between the different classifications, so there was interest in seeing whether or not the sites were evenly throughout the area.

As can be seen from Table 6, the sites are not evenly distributed by area. In fact, the third smallest area contained the most sites. 18% of the area is responsible for 34% of the entire sites in the study area. There were 40 sites within the 462 TEU and most of which were Agricultural, Small Farmstead, or Field House site types. This area also happens to be the location of most of the higher elevation sites. Coincidentally this is also one of the TEU's that ranked the highest on the soil condition and vegetation potential.

The 463 TEU contained the second most overall sites with 25% of the area and 22% of the sites. Again, most of these sites are Agricultural, Small Farmstead, or Field House site types. Once again this layer is also ranked as having satisfactory soil condition but rated as low vegetation potential attributed to a higher occurrence of rocks and pebbles. This TEU's area spreads over three independent areas, with the majority of the sites being located in the two areas in the lower basin. Since both of these TEU's

The largest overall area was the 430 TEU, whose area is 40% of the total study area. The 430 TEU only contains 18% of total sites. This area is described as being rocky and steep, but it makes up most of the transition area between the lower basin and the Mogollon rim. Most of the sites in this area are field houses, many of which are situated toward the higher elevation areas with views. The last three TEU's have a slow declining distribution but seems to be relatively evenly distributed considering their overall area. These units also represent the worst potential for agriculture based on the soil conditions and ranking.

Combining TEU and Water Proximity

Overall the distribution of the different site types combined with the backdrops of the water proximity and TEU soil condition and vegetation analysis provided valuable insight into some of the site locations in regard to these resources. Since the greatest significance is seen at the 250-meter water proximity, a TEU analysis indicates that combining these two factors would provide new insight into the problem. This was done to see if the sites' agricultural features within the 250-meterproximity also fell within TEU's that favored soil condition and vegetation potential (see Table 7).

What can be seen is that in many of the TEU's nearly all of the site fall within the 250-meter proximity to water. This is especially true for the lower elevation sites within the basin. The most significant difference comes in the change of sites in the 462 TEU that fall within the 250-meter proximity. The tally of sites drops from 40 sites in the 462 TEU to only 7 that fall within the 250-meter buffer. This also sees a significant drop in agricultural and garden features going from 26 total features with an area 8,863m^2 down to one feature with only 72m^2. So water as a factor in the 462 TEU may not play as large of a part as the other four TEU's in the study area.

Table 6

Site Distribution within the 250-meter Water Proximity by TEU

Sites by TEU Unit and 250-meter proximity to Water							
	Agricultural	Large Farmstead	Small Farmstead	Field House	Other	Community Center	Total
Sites within the 402 TEU & 250m of Water	1	1	1	7	3	0	13
Sites within the 420 TEU & within 250m of Water	2	1	5	5	1	0	14
Sites within the 430 TEU & within 250m of Water	2	1	3	11	1	1	19
Sites within the 462 TEU & within 250m of Water	0	1	4	2	0	0	7
Sites within the 463 TEU & within 250m of Water	3	1	10	9	0	0	23

Table 7

Agricultural Features within the 250-meter Water Proximity by TEU

Agricultural and Garden Features by TEU that fall within the 250-meter Water Proximity					
	Agricultural Total (Area greater than 500m^2)	Agricultural Area	Garden Total	Garden Area	Total Garden and Agricultural Area
Sites within the 402 TEU & 250m of Water	1	1,800m^2	12	694m^2	2,494m^2
Sites within the 420 TEU & within 250m of Water	0	0 m^2	13	1044m^2	1,044m^2
Sites within the 430 TEU & within 250m of Water	3	7,916m^2	13	1021m^2	8,937m^2
Sites within the 462 TEU & within 250m of Water	0	0 m^2	1	72m^2	72m^2
Sites within the 463 TEU & within 250m of Water	3	9,500m^2	15	730m^2	10,230m^2

Conclusion &Discussion

This project has developed a geodatabase that can be used for archaeological site analysis. The geodatabases is managed as a location for the site point, water source, and TEU soil layers. Additionally the layers that were created through the overlay and proximity analysis have been sorted in the respective water and TEU datasets. So as new information is discovered, it can be added to the database for further analysis. Understanding the land use tactics of Prehistoric people by looking at their site locations, organization, water sources, and soil potential gives a profile of how the inhabitants of this area chose their living and growing locations. Having a better understanding of Prehistoric life in the hackberry basin may help provide insight into other areas of the Verde Valley. The main factors that played a role in this analysis were site distribution, water proximity, and Terrestrial Ecosystem Units. The project finds relationships between site locations and water proximity and TEU.

Site Distribution

A location analysis is performed to show the overall site distribution and to examine if there are any abnormal clusters. A general comparison of sites against the topography of the Hackberry basin and Mogollon Rim shows that the basin has more sites with greater diversity and the rim has less sites with less diversity, although the physical boundary between the Mogollon Rim and Hackberry Basin is quiet obvious when looking at the site distribution.

For every site type besides small farmsteads, the lower elevation sites had greater totals, although in terms of percentage of the site types, both high and lower elevation regions tend to be similar. Two site categories, small farmsteads and field houses, stood out as having more sites than any other site categories. Along with this based off Peter Pilles' research into habitation sites and field houses, it seems that many of the small farmsteads, which were assumed to be a permanent habitation, can be seen as having a close association to seasonally inhabited fields houses (Pilles, 1978).

There was one large scale dwelling located in the study area called Doren's Castle, which is a 40-50 room site that eclipses the size of any other site. Besides this Doren's Castle, no other sites were greater than 12 rooms. There is not any particular clustering around this community center, in fact most of the site in the lower basin seem to be evenly distributed except for a small cluster of small farmsteads in the northeastern pocket of the basin. The higher elevation sites on the rim, however, follow an L-shaped pattern that is made up of a spackling of most field houses and farmsteads. The situation of many of these sites puts them in close proximity to the rim that overlooks down to the basin.

The agricultural site types are used for some level of classification when looking at site type distribution, but a better description comes from using site cards that classify the sites as having agricultural or garden features. This was because there are many habitation site types that also have gardens or agricultural features, but this is not the dominant type based on the currently available survey results. Agricultural and garden features are predominately found in the lower elevation area within the basin. 84.2% of all the identified agricultural area can be found below 1,500-meter elevation. This gives significance to the basin being the preferred location for agriculture. Although there are such a large number of sites in the high elevation region of the study area, agricultural features are difficult to identify, so the analysis is conducted by using the total number of sites.

Water Proximity

The water analysis for the study area provided some very good information for the distribution of sites as well as flow of water over the topography. Initially a watershed analysis is conducted to see how the water flows over the topography and all the possible locations that water can come from. Hackberry Basin has its own watershed with the drainage originating from the Mogollon Rim. This is important because other than the water sources within the watershed, no additional water should be coming in from any surprise sources.

After looking at all the potential stream channels, one of the main interests was how a prehistoric inhabitant could get water. My initial hypothesis was that the high need for water along with difficulties in storage and transportation would result in the highest density of sites within closest proximity to water. Then as the proximity to water decreases, there would be a progressive decline in sites, especially sites with agricultural features. However, through the course of the analysis, it became apparent that this hypothesis would not be supported.

Proximity is indicated by using a range of distances between sites and water sources: 100-meters, 250-meters, and 400-meters, which are set to have equal spacing while ending near a distance of a quarter of a mile. At the 100-meter proximity, there were only 29, which is only about 25% of the total sites in the study area. At the 250-meter buffer, there were 76 sites, which was more than 2.5 times more sites then were located within the 100-meter buffer. Then moving on to the 400-meter buffer, there were only 88 sites, growing only by 12 sites. As can been seen by the values, there is some significance to sites located within 250-meter buffer zone and also this obviously disproved the hypothesis that a sites nearness to water was the most important environmental factor for site location.

Along with the overall site distribution compared to water proximity, it was also important to look at the distribution of each site's agricultural and garden features by proximity to water source. Following the discussion of Wienhold (2013) on prehistoric hydrology, this research also analyzes distance from water into agricultural features that may use rock dams or terrace gardens to manage the resource. In the agricultural proximity analysis, a similar distribution was uncovered. A small amount of agricultural features exist within the 100-meter proximity, with only 32% of the overall agricultural area. Between the 100-meter and 250-meter proximity the amount of agricultural features grows 2.5 times bigger, going from 8,983m^2 to 22,777m^2 in just 150-meters. Finally the within the 400-meter proximity 97% of all the agricultural area exists. Only 686m^2 of agricultural land fell outside of this range. In both cases, overall site distribution and agricultural feature distribution, the sites seemed to be more commonly located within 250-meters of a water source. One shortcoming of the point analysis is it does not take into consideration the size and direction of the agricultural or garden features, so some of the features may start within a particular proximity but may extend outside of it.

Soil

The final independent analysis conducted was the soil analysis. This analysis was done using Terrestrial Ecosystem Unit polygon map, which provides a soil profile and vegetation potential for an area based on a land survey conducted by the pedologists at Forest Service for the Coconino National Forest. The TEU map covers the whole Coconino National Forest, but for this analysis it was resized to the extent of the Hackberry Basin study area. Upon clipping the TEU layer down to size, there were eight total codes identified within the study area; however, sites only fell within the boundaries of five of the TEU's. The five TEU values that were identified were 402, 420, 430, 462, and 463. These TEU soil codes were listed in a Soils Classification database from the Forest Service that provided the conditions for the soils as recorded in the most recent soils survey. The 462 and 463 TEU's were the only two classified as having satisfactory soil conditions and moderate vegetation potential. The 402, 420, and 430 TEU's are listed as having condition of either too steep or too rocky for vegetation. All TEU's were listed as being basalt residuum, which is a made-up of pulverized volcanic sediment. Since

462 and 463 TEU's are soil types that are preferred for agricultural, they are used as the foundation for a hypothesis that there would be more sites located within the 462 and 463 TEU's that have had agricultural features.

Using the sites overlaid atop the TEU layer, one could see what sites were contained within each TEU region. A significant majority of all the agricultural features were located within the 463 and 462 TEU's. The agricultural and garden features within those two TEU's made up 19,193m^2 of agricultural area, which is 70% of all the agricultural area that can be found in the study area. However, this still leaves 30% or 8,235m^2 of agricultural area that falls within TEU's that were considered unsatisfactory for vegetation and soil condition. This may stand to show for the diversity of agricultural techniques deployed by prehistoric people in substandard growing locations. One effect the TEU does not take into account is the erosion that has taken place over the year, so one argument maybe that some of the unsatisfactory TEU's once had different soil profiles. Although the general soil geology has existed longer than the time the area has been inhabited by humans, the analysis still stands for the 462 and 463 TEU's.

A percent of area to site density comparison was calculated to make sure the statistics of how many sites fall within a given TEU value was based on the overall area the TEU covered within the study area. The total area of a given TEU was calculated as a percent against the overall total study area. Then each TEU's site count was also calculated as a percentage of the total number of sites. Then the percentages were compared to see if some of the sites are really distributed based on the fact one TEU's area is greater than another. As it turned out, this was not the case because the 462 TEU contained the most sites but it was the third smallest in area. In contrast, the 430 TEU is the largest in area, but it contains the third lowest amount of sites. This helps defend the findings that sites locations were actually chosen with a preferred soil type or TEU.

Combined Analysis

After examining the two hypotheses from the soil and water analysis, a comprehensive analysis was conducted to see if the majority of sites located within the satisfactory TEU's, 462 and 463, are also located within the 250-meter proximity to water. In looking at the water and TEU soil features the idea was that most of agricultural features are located within 250-meters of water and also contained within either the 463 or 462 satisfactory TEU regions. There are a total of 76 sites located within the 250-meter proximity with a total of 22,777m^2 agricultural area. In looking at the site distribution by TEU and water proximity, it was expected to see the greatest number of sites within the 462 TEU, as this was the case with the initial TEU analysis, however this is not the case. The smallest number of sites, at 7, is located within both the 462 TEU and 250-meter to water which rejected the hypothesis that the sites within the satisfactory TEU's would be primarily located within 250-meters of water. Although the opposite is true for the 463 TEU as it contains the greatest number of sites and also the largest amount of agricultural area. In this case, the hypothesis was true because 23 out of the 26-recorded sites within the 463 TEU were also located within the 250-meter proximity to water. So when looking at the 463 TEU, there is a strong possibility that those locations were preferred for their proximity to water and soil productivity.

Future Analysis

The current research is an ongoing archeological study, which means that it will continue beyond the scope of this project. A goal for the project was to organize the data that has been recorded into a GIS database that can be used for further use for expansion as more sites are discovered. Based on data in the geodatabase, a basic analysis was conducted on the agricultural potential of the basin using soil TEU categories and water source. If more time were available, advanced analysis would be possible. The time restriction of the project does not limit the analysis that was done but it does limit the scope of the project because there was information that simply couldn't be collected in the available timeframe. With this being said, there are a few ideas of the direction that the research could go that would be a good platform for extending this project and the GIS.

This is an active archeological survey being done; so as time permits, new data may be collected as the survey progresses. Classifications can evolve as more sites are discovered and surveyed. Although for this study specialized classifications are used for the farmstead or the agricultural features, in future analysis these could be manipulated to change the information output. For this study, the data was limited to a few agricultural sites with descriptive information. With the geodatabases as a backdrop, new information can be added to the existing sites and new sites can be added as they are discovered and classified. Since most of the sites haven't had a full excavation, there is not a finite description that can be given as a permanent reference. Since the data has been organized into working datasets, edits can easily be made to include new survey data as it is collected.

As it turns out with the Hackberry Basin survey sites it will be difficult to apply any sort of date range because many of these site do not contain the necessary assemblage data to create a range using the sherds on site. There is no potential to further date analysis because of these limitations although it had been when of the goals, even having been included in the attribute table.

Another addition to the current analysis could be to perform soil nutrient analysis using the method of Bensons (2011) if soil samples are available for the specific area with agricultural or garden features. This would be valuable as it might give a better understanding of the nutrient profile of the soil and possibly why these sites were used for agricultural purposes. The current analysis is broad reaching of the whole study area, but the specifics at a particular location are somewhat overlooked in this analysis. Once the sites with agricultural features have been identified, that would open up the possibly for comparison between TEU units with various soil types at different proximities to water.

In addition, one thing that has interested the archeological team is whether or not view shed was important to the distribution of the sites in the hackberry basin. Unfortunately when the sides were recorded there wasn't any particular significance given to the direct a sites faces. So it is difficult to see whether or not a site was to be situated with a particular view of something like a field or another site. This is however a major interest of the archeological team working on Hackberry, so for an addition project you could revisit all the sites and classify them with a direction and a ground height so you could then perform a proper line of sight analysis.

Additionally you could look into viewshed using the same data because this concerns more of the idea of what can be seen from a given site rather than who. This would also be valuable for looking into what fields or agricultural areas can be seen by other sites. The topography of the basin works in such a way that some areas are hidden from one another, which many make for some interesting analysis, especially if you were to include the sites situated on the edge of the Mogollon Rim.

The area is a great location in terms of data and support. There is much more information included with the site cards that could be applied to the attribute tables. Because of this looking at the sites in terms of there actually shape and position by using polygon data instead of point. The point data in this research was limited to being in a precise location however some of the sites or agricultural features span much larger distances. Perhaps looking into these features in their actual size or position may uncover more information about how these sites were situated. For instance some fields could be in a position that they straddle multiple TEU's, could there be reason for this?

Finally in looking into the conclusions made by this project, the Terrestrial Ecosystems Units seem to really influence the location of some sites and agricultural fields. With this study only skimming the surface of how these TEU's really impacted site location doing a more in depth analysis into specific TEU's and the sites they contain could be an interesting study to add onto the work that had been started in this project. Since the TEU database is such a depository looking into more parts beyond just the soil condition and vegetation potential may uncover even more information about the condition of the TEU at a given site.

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Appendix

Part A: Geoprocessing

Hackberry Basin Prehistoric Land Use Assessment using site distribution, water proximity, and Terrestrial Ecosystem Units

This analysis was looking in the relationship between archeological site distribution by their distance from a water source and from the TEU that the site was located within. This analysis was done using the TEU data from the Coconino National Forest.

The digitized points layer and geodatabase was submitted back to the Forest Service for potential further analysis at the conclusion of this project.

Geoprocessing for the Site Distribution Points Layer

AR-03-04-01-2029

NA ___________ , **Ariz**. : : _______________ (ASM) **Project:** Sycamore Canyon Survey **Proj. No.:** 2004-57
State: Arizona **County:** Yavapai **T12 N**, **R 6 E**, **Sec.1** , SE 1/4 of SE 1/4 of SW 1/4 of SW 1/4
UTM: Zone 12 S 04 | 37 I 091 | *East*: 38 | 11 | 082 *North.* **From:** Map **OR** GPS Model: Garmen Etrex **GPS Datum:** 1927 North American Datum **Comments:** **Land Status**: Coconino National Forest, Beaver Creek Ranger District
Other Ownership :
Road Access: From the intersection of Interstate 17 and State Road (SR)260, go east on SR260 past Camp Verde towards Payson for 10 miles. Just past Mile Marker 228 on SR260, turn right (east) on Forest Road (FR) 708, Fossil Creek Road. Take FR708 for 8.4 miles and go past the intersection of FR 708A about another 0.2 miles distance and park on the east side (left side) of the road in the open space off the road. **Additional Location Data:** Note, directions are from true north. From parking area, hike southeast (112 degree bearing) for 200 meters. This route will go down through the lowland below the roadway and up to the top of a low mesa. On the mesa, continue at the 112 degree direction for another 100 meters to the middle of the agricultural site.
Map Ref.: Hackberry Mountain, 1:24,000 **Elev.**: 4083 ft **Aerial Photo Ref.:** **Year:** ___________ **Photo No.:**
Culture(s): Southern Sinagua **Phase(s):** Honanki **Date(s):** 900-1275 AD **Basis for Culture, Phase, & Dates:** Ceramics.
Site Type: Agricultural. **Structures (No. & type):** None, an open field with a few rock alignments in the ephemeral washes. **Describe Construction Technique:** N.A. **Rubble ht. Now:** N.A. **NO. COURSES HIGH:** N.A. **Originally (estimated)** N.A.. **Stone:** N.A.. **Storage:** None **Hearth/Burning:** None, however, there is a lot of ash and burnt rock spread out in the field as though the prehistoric farmers were using the ash as fertilizer or a soil conditioner. **Trails:** FR 708A is an old road that is still used by the local rancher to access the spring and cattle tank at Cedar Spring. It could have been the central access through this area in prehistoric times too, since it connects most of the sites in Hackberry Basin in an east-west direction. For example, this trail has access to the western routes towards Hackberry Mountain Trails and easterly up the hill towards the upper rim sites and sites near Walts Tank and Boulder Canyon, where there is a stand of Ponderosa Pines. (A trail map is attached to field house site card AR-03-04-01-2015.) **Rock Art:** None. **Trash: Type, location, density:** Sheet scatter. ***(ID ceramic & lithics on back***) **Ceramic Density:** Sparse. **Lithic Density**: Sparse. **Ground Stone Density**: Sparse
Additional Site Data: Site is located on a gently sloping mesa above the wide and deep Dorens Defeat Wash. It appears that the sloping incline was used for agricultural fields of the pueblo ruins of site AR-03-04-01-676. This agricultural field is about 3500 sq.m. in size. **Site Condition:** Good. **Rank:** 0, undisturbed. **Site Size: (*m. by direction*)** 70 m. NS x 50 m. EW = 1500 sq. m. **How Determined?** Tape measure and GPS unit.. **Discuss site re: local/regional settlement?** Along the perifery of Hackberry Basin, there are hillside fingers of good soil. The prehistoric farmers utilized these gradual slopes to grow and irrigate their crops using the sheet flow of rain water coming off the steep hillsides of the basin. **What's typical or unique?:** From our previous surveys in the surrounding Sycamore Canyon area, the method of dry farming and using the hillside slope to water their agricultural fields is very typical of these settlements. **Other Comments**: This site had the unusual fact that there was evidence of the prehistoric farmers were using ash and fire burnt rock/debris from roasting pits as fertilizer and soil conditioner. In fact, we had at first thought that he site was one very large roasting pit. **Site Tag Location:** Site tag was placed on the large Pinyon at the above UTM(S) approximately in the center of the site. **Site Tested** ____, **Excavated** ____, **Documented** ____ **Date**: ____________ **By**: ____________**Chronometric Dates (identify date technique):** **References/Publication:** Map and survey records of the Hackberry Basin area. **Site Name/Other Site Numbers:**

Museum of Northern Arizona – Coconino National Forest - Archaeological Survey *(9/01)*

NA ___________ **AR-03-04-01-2029** Lab Accession No. __________
Recorded by: Jerome Ehrhardt, Hanna Flagg, Ned Greeneltch, John Schaefer, Jerry Walters, R.J. Smith, Scott Newth, Susan LaGuardia, Larry LaGuardia, Steve Peake **Date: March 4, 2014** **Photo:** B/w ____ Color Print ___ Slide ____ , Digital ____
Identify Artifacts: field id X_ , controlled collection ___ , grab sample _____, _Total site count.
Ceramics: Verde Plain (4), Tuzigoot Plain (1), Tuzigoot Red (1), Sunset Plain (1), Sunset Corrigated (1), Tusayan WW (11), Sosi (2), Flagstaff (4), Tusayan (3), Black Mesa (7); Little Colorado WW (10), Walnut A (4), Walnut B (1), Walnut (5), Holbrook A (2), Holbrook B (3), Padre (1). **Lithics:** Obsidian flakes (6), Fine Grain Basalt (FGB) flakes (6), Quartz flake (1) **Artifacts:** FGB Hammer Stone (2), Vesicular Basalt uniface mano fragment(1), Tbular basalt agave knife fragment (6), FGB knife (1) . ______**Items collected:** None.____
Location Map:

Site Card Example

Using classifications defined by archeologists on the project the site points layer was digitized from physical site cards used to recorded data. (Refer to the Example above.) The site cards were obtain and maintained by Jerry Ehrhardt out of Sedona.

The UTM and attribute data was taken from the site card and recorded digitally in the site distribution layer. Then using the recorded UTM point from the attribute I was able plot X, Y were reference as point on the map creating the layer with the attributes attached to the point. The resulting layer was called Hackberry_Sites_Final_Data.

Geoprocessing for the Water Proximity using the Site Distribution Layer

The water source layer was obtained from Chris Barrett at the Rocky Mountain Research Station, which is maintained by the Forest Service. This layer shows all ephemeral drainages throughout the basin. I clipped this layer against the study boundary to create a new layer called Hackberry_Steams_Clip.

I then used the multi-buffer tool provided by ArcGIS on the Hackberry_Streams_Clip. I applied a 100, 250, and 400-range buffer and then changed the units to meters. The buffer ranges were chosen from input by the one of the archeologist on the project, Dr. David Wilcox. The distance of 400 being the maximum distance and individual would carry water. This created a new layer called Hackberry_Steams_Buffer.

I then used the Hackberry_Steams_Buffer layer and overlaid the Hackberry_Sites_Final_Data points layer. I used the "is contained by" feature to make sure the sites that were located within each buffer were counted. The layer created was called HB_Sites_by_Water_Proximity.

I then used the resulting spatially joined information to tally the overall distribution using the "Statistics" button for the attribute table. The results of this can be seen in table 4 and figure 7.

Geoprocessing for the Terrestrial Ecosystem Units Analysis using the Site Distribution Layer

The Terrestrial Ecosystem Units polygon map was also obtained through Chris Barrett at the Rocky Mountain Research Station. This layer had polygon defined by specific TEU codes that could then be referenced against the comprehensive code database. In this study for each code I was concerned with the Soil Condition (SOILCON) and Vegetation Potential (VEGPOT).

I then clipped the layer against the study boundary to create the Hackberry_TEU_Clip polygon layer.

I then took that newly created Hackberry_TEU_Clip Layer and used it as the base for overlay against the Hackberry_Sites_Final_Data layer to see which site points fell within each unique TEU code. I used the “is contained by” as the option for overlay. The layer created was called HB_Sites_by_TEU and the “statistic” button was used to tally the overall sites and features within each TEU. The results of this can be seen in table 5 and figure 8.

Geoprocessing for the Area Analysis by TEU:

I used the Hackberry_TEU_Clip to look at the area in square meters by TEU code. I then added all the areas up for a total and then divided each TEU’s area against the total, the result was percentage for the total area covered by each TEU. Input this information into a table, which can be seen in Table 5.

Additionally the sites by TEU were recalculated as percentage of the total number of sites.

Then using each TEU code I compared the percentage of sites against the percentage of area.

This was done to eliminate the possibility that the sites were divided up in a way because the area that each TEU covered.

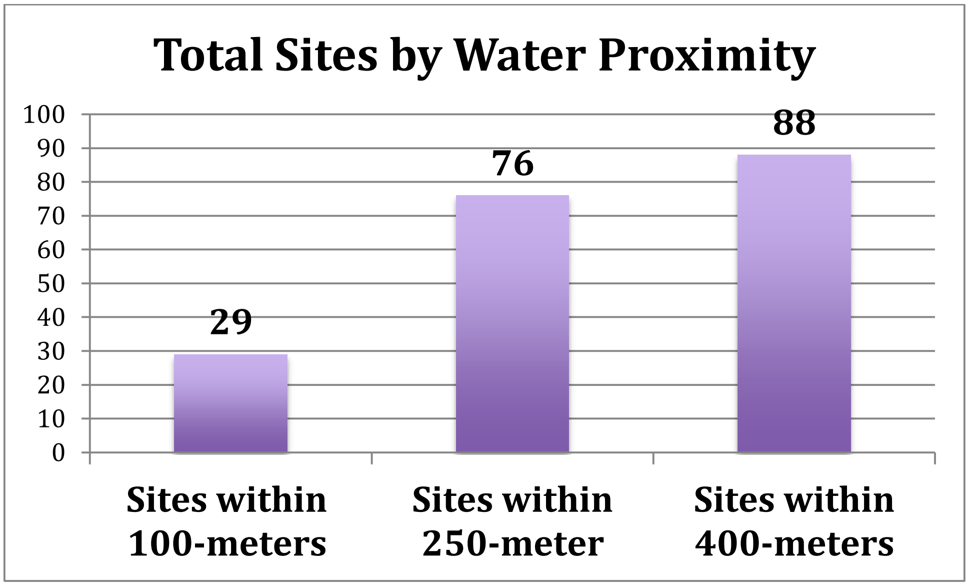
Geoprocessing for Combined Analysis of Water Proximity and TEU:

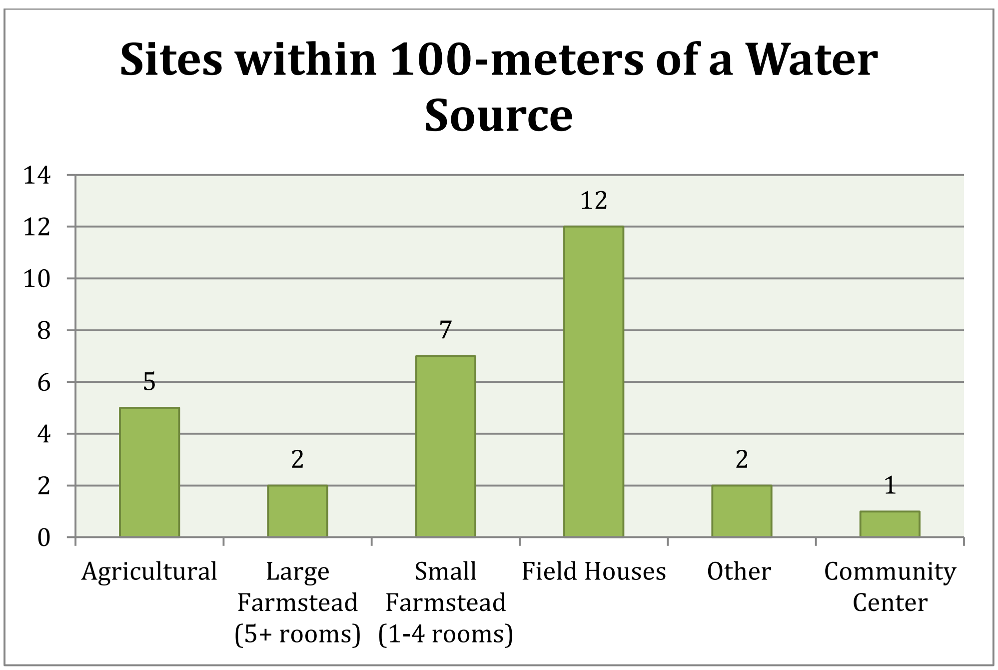
Using the HB_Sites_by_TEU layer I performed a buffer analysis using the 250-meter buffer created by the water proximity process to eliminate the sites in the TEU layer outside of the 250-meter buffer. The 250-meter buffer was used because the biggest growth in site distribution occurred at that level so it seem pertinent to see if there was any correlation between the two most popular TEU’s. The resulting layer was called HB_Sites_by_TEU_250_Buffer.

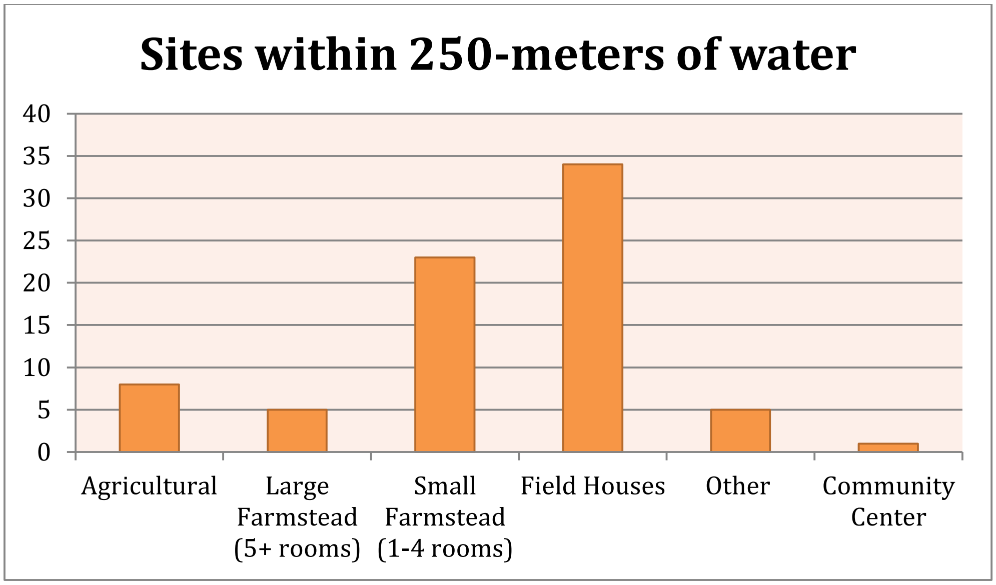
Then using this points layer a tally of the sites and features was made using the “statistic” button for the attribute table.

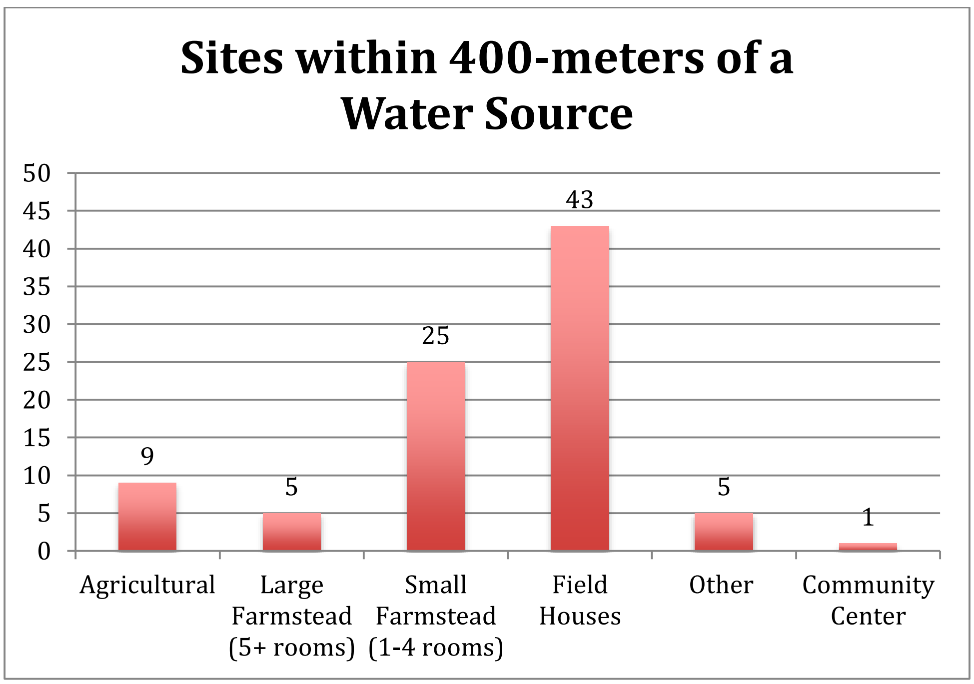
Part B: Graphs

Water Proximity:

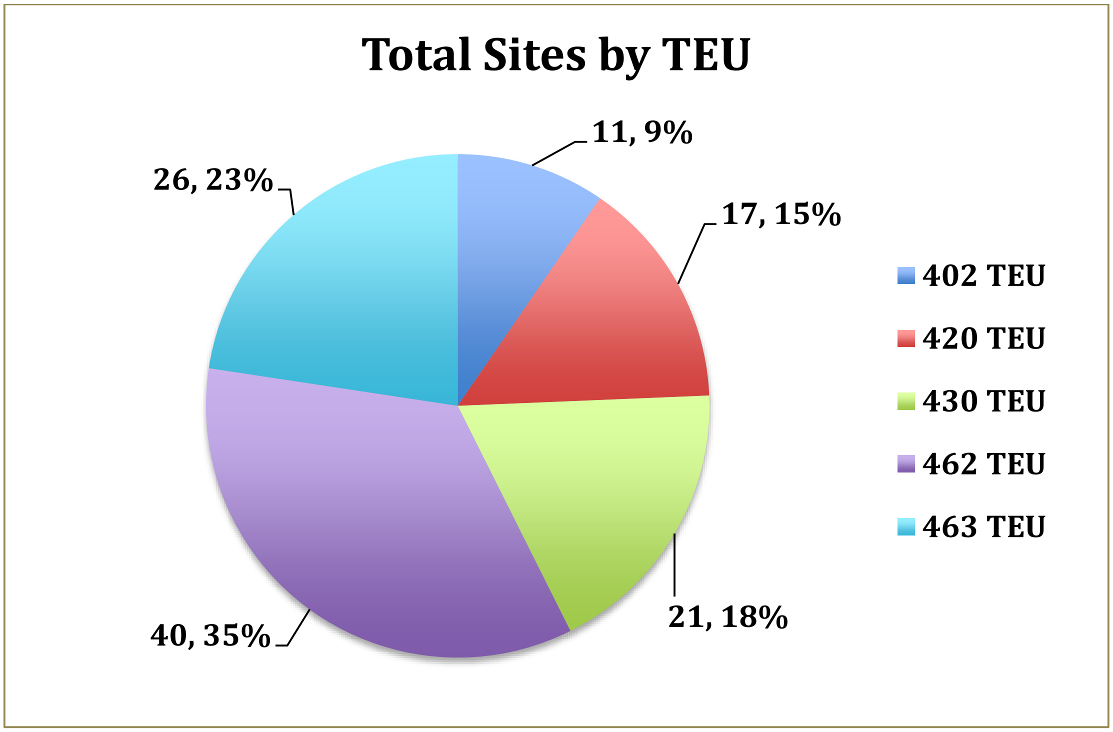


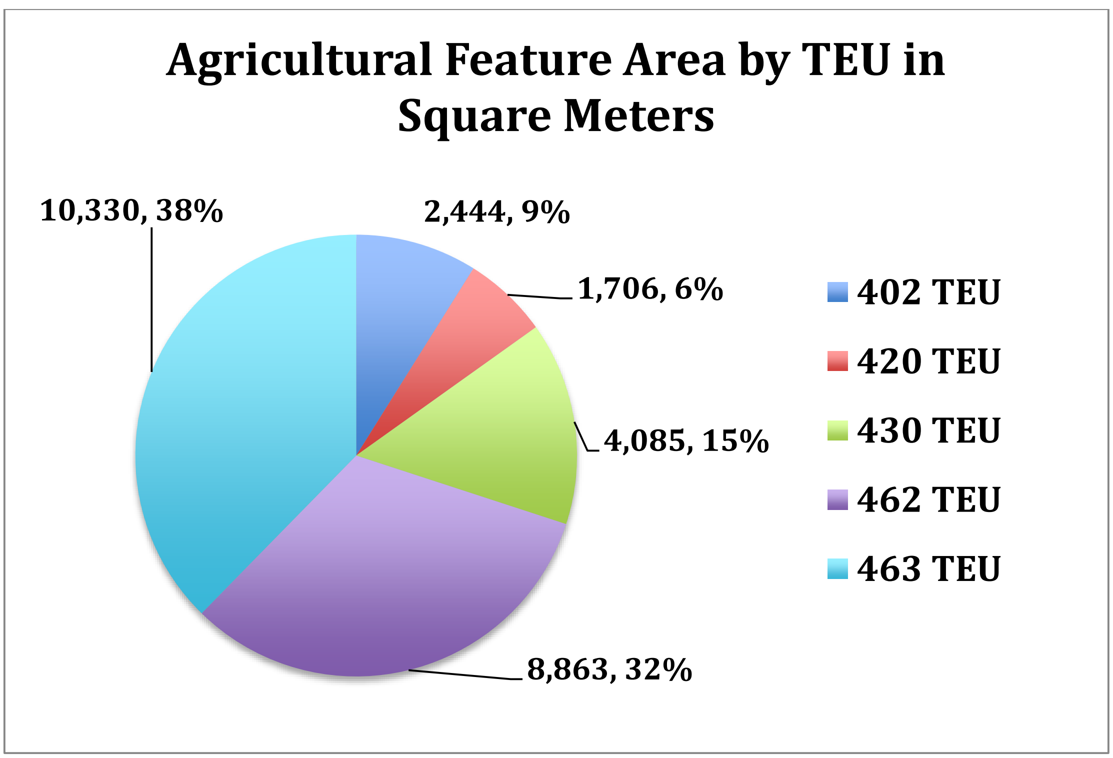


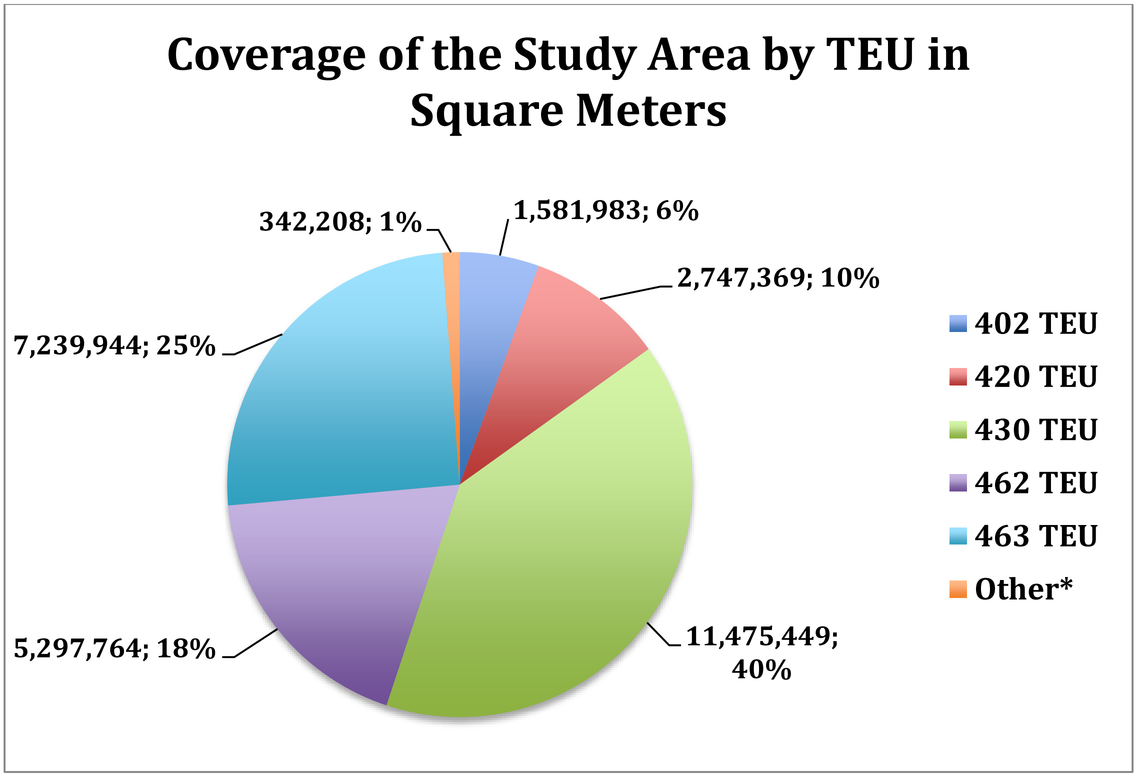

Sites within 250-meters of water
40
35
30
25
20
15
10
5
0
Agricultural
Large Farmstead (5+ rooms)
Small Farmstead (1-4 rooms)
Field Houses
Other
Community Center


Sites within 400-meters of a Water Source
50
45
40
35
30
25
20
15
10
5
0
9
5
25
43
5
1
Agricultural
Large Farmstead (5+ rooms)
Small Farmstead (1-4 rooms)
Field Houses
Other
Community Center

Terrestrial Ecosystem Units:






Coverage of the Study Area by TEU in Square Meters
342,208; 1%
1,581,983; 6%
2,747,369; 10%
7,239,944; 25%
5,297,764; 18%
11,475,449; 40%
402 TEU
420 TEU
430 TEU
462 TEU
463 TEU
Other*

Combined Analysis: