Journal of Archaeological Science: Reports 11 (2017) 427–434

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

A comparison of suitability models to identify prehistoric agricultural fields in western New Mexico

A. Healy [a,*], C.D. Lippitt [b], D. Phillips [c], M. Lane [b]

[a] University of New Mexico, 1700 Indian Plaza Dr. NE, Albuquerque, NM 87106, United States
[b] University of New Mexico, Department of Geography and Environmental Studies, 1 University of New Mexico, Albuquerque, NM 87131, United States
[c] University of New Mexico, Maxwell Museum of Anthropology, 1 University of New Mexico, Albuquerque, NM 87131, United States

ARTICLE INFO

Article history:
Received 1 October 2016
Received in revised form 26 November 2016
Accepted 8 December 2016
Available online xxxx

Keywords:
Ak chin
Maxent
Mahalanobis Typicality
MCE-OWA
Suitability modeling
Archaeology

ABSTRACT

Suitability models can help identify prime environments for a specific form of agricultural field, ak chin, that is difficult to locate with standard archaeological field methods. Using data from western New Mexico, we applied remote sensing and a geographic information system to develop suitability models based on a small training data sample. Three models, Mahalanobis Typicality, Maximum Entropy, and Multi-Criteria Evaluation Ordered Weighted Average, were used and the resulting suitability estimates were visually compared to known patterns of ak chin agriculture and quantitatively compared using receiver operating characteristic area under the curve. Although archaeological fieldwork is needed to verify these results, receiver operating characteristic validation indicates that Mahalanobis Typicality and Maximum Entropy performed well in identifying the potential location of previously undiscovered prehistoric agricultural fields.

1. Introduction

This research aims to provide greater understanding of the agricultural practices of prehistoric cultures throughout the arid and semi-arid environments of western New Mexico. A suitability model identifies prime environments for ak chin style agricultural fields, which are often difficult to locate with standard archaeological field methods. Prehistoric archaeological sites throughout New Mexico show how humans were continuously adapting to adverse conditions, including severe water scarcity and a changing climate (Jones et al., 1999; Blinman, 2008; Wills and Dorshow, 2011; Hall et al., 2013). The earliest known domesticated crops in the American Southwest date back about 4000 years before present (bp), but it took at least 1000 years before agriculture was an important food source and commonly practiced throughout the region (Huckell, 1996; Hill and Holliday, 2011; Alshuwaikhat and Nkwenti, 2002; Bailey, 2011; Banister, 2011; Benson and Berry, 2009; Tacoli, 2009). Various cultures throughout the Southwest developed methods for collecting, managing, and exploiting flood water and runoff for agricultural development. The presence of agricultural fields indicates increasingly sedentary lifestyles which led to larger prehistoric settlements. Their populations relied on a mix of hunting, gathering, and farming.

Although ak chin fields involve minimal environmental alterations, we hypothesized that suitable locations for ak chin fields could be remotely identified based on similarities in environmental composition and cultural context, as measured by a variety of spatially explicit variables. By testing the ability of suitability models to predict likely ak chin field locations based on these spatial-environmental criteria, this study draws attention to a type of agricultural fields probably widely present in ancient New Mexico. The study also helps identify environmental criteria that are consistent among ak chin fields. The study sample used for this research consists of just 15 ak chin agricultural fields, which makes suitability modeling especially challenging. Fewer than 40 zones of ak chin fields have been verified in the Southwest, with even fewer known within the study area (Personal Communication with Phillips (2015)).

1.1. Background

In a common interpretation of regional prehistory, cultures extant between 1200 and 650 years bp survived several droughts that led to the dispersal of animal populations and reduced crop production. Changes in resource availability led to major cultural changes. Adaptations that resulted from this transformation of subsistence patterns included the development of increasingly sedentary lifestyles and the formation of large villages (Jones et al., 1999). In western New Mexico, that process involved two main cultures: Mogollon and Ancestral Pueblo (Hegmon and Nelson, 2003). Four thousand years ago, temperatures

* Corresponding author.
E-mail address: alissakhealy@gmail.com (A. Healy).

http://dx.doi.org/10.1016/j.jasrep.2016.12.020
2352-409X/

were beginning to warm and the environment was very similar to current climates (PHMC, 2015). This change in resource availability likely encouraged dependence on agricultural practices (PHMC, 2015). The development of ak chin style agricultural fields was critical for the survival of prehistoric groups in areas that otherwise did not have access to a dependable water source. Ak chin was one of several known forms of runoff/dryland agriculture that prehistoric populations used to grow crops and ultimately flourish in unwelcoming environments.

Ak chin is a Tohono O'Odham term that translates to "mouth of the arroyo." Although other forms of prehistoric dryland farming relied on a variety of construction approaches, such as check dams and terraces, to catch excess water in the immediate area, ak chin farming is unique in that it takes advantage of the natural flood patterns of arroyos and drainages (Mabry, 2008). Where the steepness of the local slope decreases at the mouths of arroyos, decelerating floodwaters deposit nutrient-rich sandy sediments on alluvial fans. The water also soaks into the sand, which acts as a natural reservoir. Ak chin style fields planted on these fans enabled agriculture in otherwise arid environments (Sandor et al., 1990). This type of field required very little manual labor to build and maintain, making them difficult for archaeologists to locate (Marmaduke et al., 1983; Phillips et al., 1993; Downum and Stone, 1999; Field, 2001; Dominguez and Kolm, 2005; Homberg and Sandor, 2011).

Despite their minimalism, ak chin fields were effective for taking advantage of less than ideal environmental conditions to cultivate crops. Ak chin fields are known from several locations in western New Mexico (Phillips et al., 1993; Sandor et al., 2008); however, the extent and density of these features throughout the region is unknown. To date, little research has been completed to further understand this type of field, partly because they are so difficult to locate, in fact, the precise environmental conditions of these fields have not been well documented, since so few are known. The current research used remotely sensed imagery and spatial environmental data to identify consistent environmental features of 15 known ak chin style dryland agricultural fields and to test the ability of three different suitability models to identify previously unknown ak chin agricultural fields (Sandor et al., 2008).

1.2. Site suitability modeling

Site suitability modeling is increasingly used to assist in archaeological fieldwork. By using remote sensing and spectral analysis of land cover changes, archaeologists can identify where archaeological sites are likely to occur. Scott Kirk et al. (2016) examined the use of remote sensing based suitability modeling to find large archaeological sites. Despite encountering issues involving vegetation changes due to elevation, they were able to identify larger sites in somewhat homogenous regions such as basins or plains. Kirk et al. state numerous times that this type of work is not a replacement for traditional field methods, rather a supplement to such work (Kirk et al., 2016).

This type of analysis has begun to expand into other aspects of archaeological landscapes, including agricultural fields. Kailihiwa (2015) analyzed rock mulch/alignment/pile agricultural fields using Maximum Entropy presence-only modeling to identify general distributions of such features across the landscape. Kailihiwa used rainfall, elevation, slope aspect, slope degree, and soil fertility as inputs for his modeling to help locate ideal locations for archaeological agricultural fields. The results showed that Maximum Entropy, a model commonly employed to characterize habitat suitability, is effective in identifying agricultural features. The work also indicates that presence-only modeling can be effective for these purposes (Kailihiwa, 2015).

Before the current study, site suitability modeling had not been applied to ak chin fields. Methods similar to Kailihiwa's were used to develop the most effective suitability model for identifying such fields, and a similar series of environmental variables was considered.

2. Material and methods

2.1. Study area

The study area was western New Mexico. General training data locations are represented by red stars in Fig. 1. There are four such fields in the Mimbres region, three in the Zuni area, three in the Acoma area, and five in the Laguna area. Some of the training fields are prehistoric but others are known because ak chin agriculture continued to be used in the study area until recently. We do not know of New Mexico farmers who use the technique today but farther west, Hopi farmers still do.

2.2. Data

To begin this analysis, four sets of raw data were collected: Landsat 8 satellite imagery, a 10 m digital elevation model (DEM), a database containing the location of known ak chin style agricultural fields, and a polygon shapefile consisting of Mimbres and Ancestral Pueblo large settlement archaeological site data. These archaeological site data were limited to a time frame of 200 CE–1450 to ensure that the sites used were fully within the agricultural period. From these data, six environmental variables were created: Elevation, slope angle, cost-distance, solar radiation, Normalized Difference Vegetation Index (NDVI), and a Normalized Difference Water Index (NDWI). Ak chin style agricultural fields within western New Mexico are known to be found within an elevation range of 1800–2200 m and on a gentle slope between 0–3°. To further limit this analysis, the cost-distance variable was used to identify locations within 5 miles of known sedentary archaeological settlements that would require the least amount of effort to travel to and from on a regular basis. Solar radiation was used to help identify environments where the slope angle, elevation, and soil moisture are most ideal for growing crops. NDVI and NDWI were also included to further limit the environmental context (e.g., water availability) for where these fields would be found (Table 1).

To begin this research, known ak chin style fields were plotted in ArcMap 10.1. The location data for known ak chin style fields were collected from various researchers throughout the state of New Mexico. The file of known ak chin field locations was then used to train and validate three different suitability models. The results of the analysis are presented as a series of suitability maps in conjunction with a discussion of what the results mean in terms of the archaeological record and the potential of presence only suitability modeling for targeting archaeological field work.

2.3. Training data

A training data file was generated using the 15 known ak chin style agricultural fields within western New Mexico (De Cunzo, 2010, Sandor et al., 1990). The training data consist of a limited number of verified ak chin style agricultural fields that were used to calibrate the two empirical models (i.e., Maxent and Mahalanobis Typicality). The information extracted from each spatial-environmental input variable at the training field locations was used in the calibration.

The training file was created using a UTM center point for each known field and a Comma Delimited file (.csv) was created from the Northings and Eastings of each training site. The file was converted into a vector point file and then into a Boolean raster file, with 1 representing the presence of agricultural fields and 0 representing unknown locations.

2.4. Suitability models

Three suitability models, Maximum Entropy (Maxent), Mahalanobis Typicality, and Multi-Criteria Evaluation Ordered Weighted Average were constructed to estimate ak chin field suitability. The results of