Supplementary Materials

GE Results

Post-fieldwork analysis of our results leads to the following conclusions about the effectiveness and inherent limitations of the GE method and pedestrian survey on Pleistocene terraces and mesa tops above drainage floodplains:

1. Vegetation and shadows can hinder identification of sites that might otherwise be visible in GE. This can be a problem in upland areas above 6,500 feet (1,981 meters) above sea level where forest canopy obscures the visibility of the ground surface, and in lowland areas where sagebrush is abundant.

2. Gravel mulch fields, cobble border grids, and cobble terraces that are 100 square meters or greater are more easily identified and digitized in GE than smaller features (100 square meters or less). Small fields are visible in GE (and can be digitized) but the likelihood of missing them while scanning the landscape is greater than it is for moderate to large fields. The borders of extensive mulch garden complexes that exceed 1,000 square meters and that contain multiple internal rock divisions and/or overlapping garden plots are defined more precisely (and quickly) in GE than in pedestrian survey.

3. Isolated gravel mulch gardens containing diffuse or partially obscured (buried) boundaries also are defined more precisely with GE than pedestrian survey. Isolated rock alignments, rock piles, rock concentrations, and borrow pits or reservoirs are not typically detected by GE due to the scale of satellite resolution relative to the small areal extent covered by these features.

4. Natural ground alteration (e.g. erosion or burial) or human impacts that significantly obscure the boundaries of gravel mulch gardens on Pleistocene terraces can hinder the positive identification of these features. This can occur in highly dissected and eroded areas.

5. “Chaining” or plow rows on Pleistocene terraces (a common occurrence on federal lands in the sagebrush west) negatively impact the integrity of gravel mulch gardens and their borders, but these impacts may not completely obliterate features that are still visible on GE. Areas that have been completely scraped or leveled by earth moving activities are more problematic. But, these instances often are limited to individual home sites or areas of commercial development, which have a smaller footprint than field complexes and are a fraction of the surface area of undeveloped lands on Pleistocene terraces.

6. GE and pedestrian survey also fail to detect features in low visibility field areas where geomorphic processes result in the burial of features. Partially buried or obliterated cobble border grids or cobble terraces are more readily detected through pedestrian survey. Similarly, GE may fail to detect those features located in geomorpologically active landscapes such as alluvial benches and/or in arroyos or washes. Low visibility fields in these areas may be identified by the distribution of agricultural tools (stone hoes or axes) identified during pedestrian survey (Anschuetz 1998).

GE provides a conservative methodology for the discovery of gravel mulch, cobble border grid gardens, and cobble terraces on Pleistocene terrace and bench landforms, and these constitute the largest agricultural features in the landscape, accounting for 61 percent of all agricultural features present in pedestrian inventories of agriculture features in the Rio Chama watershed (Camilli and Banet 2012a). Other features such as ditches, pits, rock piles, clusters, rock alignments, spreaders, check dams or berms are less visible in GE, generally, and while contributing to overall feature counts, they do not contribute significantly to the calculation of agricultural output in relation to the subsistence needs of the prehistoric population.

Supervised Classification Multispectral Dataset

The present analysis used imagery acquired from the National Agricultural Imagery Program (NAIP). NAIP is administered by the USDA's Farm Service Agency (FSA), and acquires aerial imagery during the agricultural growing seasons in the continental U.S. The NAIP imagery is acquired at a one-meter resolution with a horizontal accuracy that matches within six meters of photo-identifiable ground control points, which are used during image inspection. The default spectral resolutions are in the visible red, green and blue (RGB) bands, and imagery products are acquired as Geotiff formatted, digital ortho quarter quad tiles (DOQQ) measuring a 3.75 x 3.75 minute quarter quadrangle. They correspond in area to the USGS topographic quadrangle series. Individual tile images are rectified in the UTM coordinate system, NAD 83, and cast into UTM Zone 13 north for the Chama Basin region.

For this study, the most recent comprehensive images available for the study date to 2011, and were acquired from the Earth Data Analysis Center at the University of New Mexico, Albuquerque. To capture those areas that encompassed the primary Ohkay Owingeh ancestral sites, all scenes covering the Rio Chama, El Rito, the Rio Ojo Caliente, and the Rio del Oso were downloaded. The first step in the supervised classification process flow involved mosaicking adjacent images together to provide single composite scenes for each of the drainage basins cited above (NAIP 2013

All supervised classification runs were completed using the Geographic Resources Analysis Support System (GRASS), version 6.4.3. GRASS is an open source software suite employed for geospatial data management and analysis, image processing, spatial modeling, visualization, and graphics and map production. Originally developed by the US Army Corp of Engineers, GRASS is known worldwide as a powerful utility with a wide range of applications in many different areas of applications and scientific research. GRASS is currently used in academic and commercial settings around the world, as well as many governmental agencies including NASA, NOAA, USDA, DLR, CSIRO, the National Park Service, the U.S. Census Bureau, USGS, and many environmental consulting companies (GRASS 2013).

Eiselt and Darling (2013) selected a subset of gravel-mulched gardens that had been verified (ground-truthed) in the field. These were used as the training areas for the “Agricultural Field” class of the subsequent supervised classification. This polygon layer was imported into the GRASS GIS system so that the additional training class polygons could be digitized and added to the layer of training areas. In short, 6 additional land cover types were defined to capture most of the primary variation observed in the DOQQ scenes. They included grasslands, piñon-juniper woodland, ponderosa pine forest, desert scrubland, open water, and cliff/barren rock. Polygons representing each of the classes were digitized based on a combination of visual interpretation of the DOQQ imagery and inspection of the distribution of different land cover types in the Southwest GAP classification (GAP 2013) vegetation GIS layer. Once all training area polygons were completed and defined, the entire training area vector layer was translated into a raster layer where pixel values were set equal to the unique ID representing each class type.

The supervised classification used a two-step process. The first step uses the GRASS command *i.gensigset*. The utility reads the rasterized training map, and then extracts spectral signatures from the DOQQ set of three bands based on the classification of pixels in the training map. Together, these spectral signatures are grouped for each class, and are stored as a class signature file that is used for the second step, the actual classification of the 3-band DOQQ imagery. The class signature file essentially defines the statistical properties (e.g. spectral mean and covariance) that characterize each of the different classes chosen by the investigator. The second step of the process makes use of the GRASS *i.smap utility*. This utility is essentially an algorithm (known as SMAP) that uses the class signatures to inspect the entire 3-band DOQQ image scene and assigns each spectral signature (or pixel stack) to one of the classes defined and characterized in the first step of the process. SMAP assumes that nearby pixels in an image are most likely to be of the same class. It proceeds by classifying the entire image at different scales, starting with the coarse scale and progressing to finer resolutions. The method is known to reduce the number of misclassifications, and generates classes with larger connected regions. The output is a version of the map re-interpreted to represent the spatial distribution of different derived spectral classes.

The final post-classification operations are employed to generate the areal coverage of all locations that are interpreted as prehistoric fields. The so-called “Agricultural Field” class generated by the supervised classification is extracted from the map of all combined classes. The output raster map of the “Agricultural Field” class is then transformed into vector format. The vector layer is then run two filtering operations. The first is to clip off all polygons falling outside of the unique radius assigned to each of the ancestral habitation sites. The second step is remove those polygons that fall within the floodplain of the appropriate drainage so as not to count these areas twice. The last step requires the use of a separate raster map of slopes to filter out all “Agricultural Field” class polygons that coincide with slopes of more than 10 degrees. This slope map is in turn derived from a 10 meter digital elevation map (DEM). Once all of these clipping and filtering operations are performed, the resultant vector map contains all polygons/areas that are classified as “Agricultural Field”, that fall within the given site radius, that are on slopes of 10 degrees or less, and that do not fall within the floodplain. Floodplain areas in turn were defined by using the DOQQ images to digitize the boundaries of the river drainage
and floodplain polygons.