Spatial Visualization of Environmental Factors Contributing to ^{15}N Isotope Uptake Patterns in Pre-Columbian Peruvian Populations

Sylvia Anne Cheever - Vanderbilt University Department of Anthropology

INTRODUCTION + BACKGROUND

The relationship between isotopic input and isotopic uptake in human tissues is mediated by a plethora of cultural and environmental factors, among them gender, political organization, social status, climate, ecological and geological context, and resource accessibility (Tung & Knudson, 2018; Britton, 2017; Bogaard & Outram, 2013). Most isotopic studies in bioarchaeology focus on intra-society variation, illuminating social and cultural differences in diet and nutrition (Britton, 2017). Investigation of broad, regional patterning of dietary isotopic ratios spanning multiple cultural and temporal contexts is less frequent. However, this type of isotopic analysis has the potential to illuminate a different kind of trend in isotopic uptake: trends that are environmentally influenced and therefore geospatially contingent.

This poster focuses on δ^{15}N ratio distribution from human tissue at archaeological sites across Peru. Environment plays a large role in nitrogen uptake as organisms exhibit step-based enrichment in ^{15}N as you move up the trophic chain (Minagawa & Wada, 1984). Human access to foods of varying trophic level is heavily constrained by environment, and this in turn impacts human nitrogen uptake. Marine organisms the most enriched in ^{15}N, but human consumption of marine resources in archaeological contexts is usually constrained to the coast. Freshwater aquatic organisms are also ^{15}N enriched, though less so than marine organisms. Other environmental factors that contribute to ^{15}N enrichment are climate and ecoregion. Hot, dry climates have higher nitrogen isotope ratios than cool, wet environments (Ambrose, 1991), and specific ecoregions may provide variable access to edible flora and fauna as well as impact the ability of the region to support agricultural production.

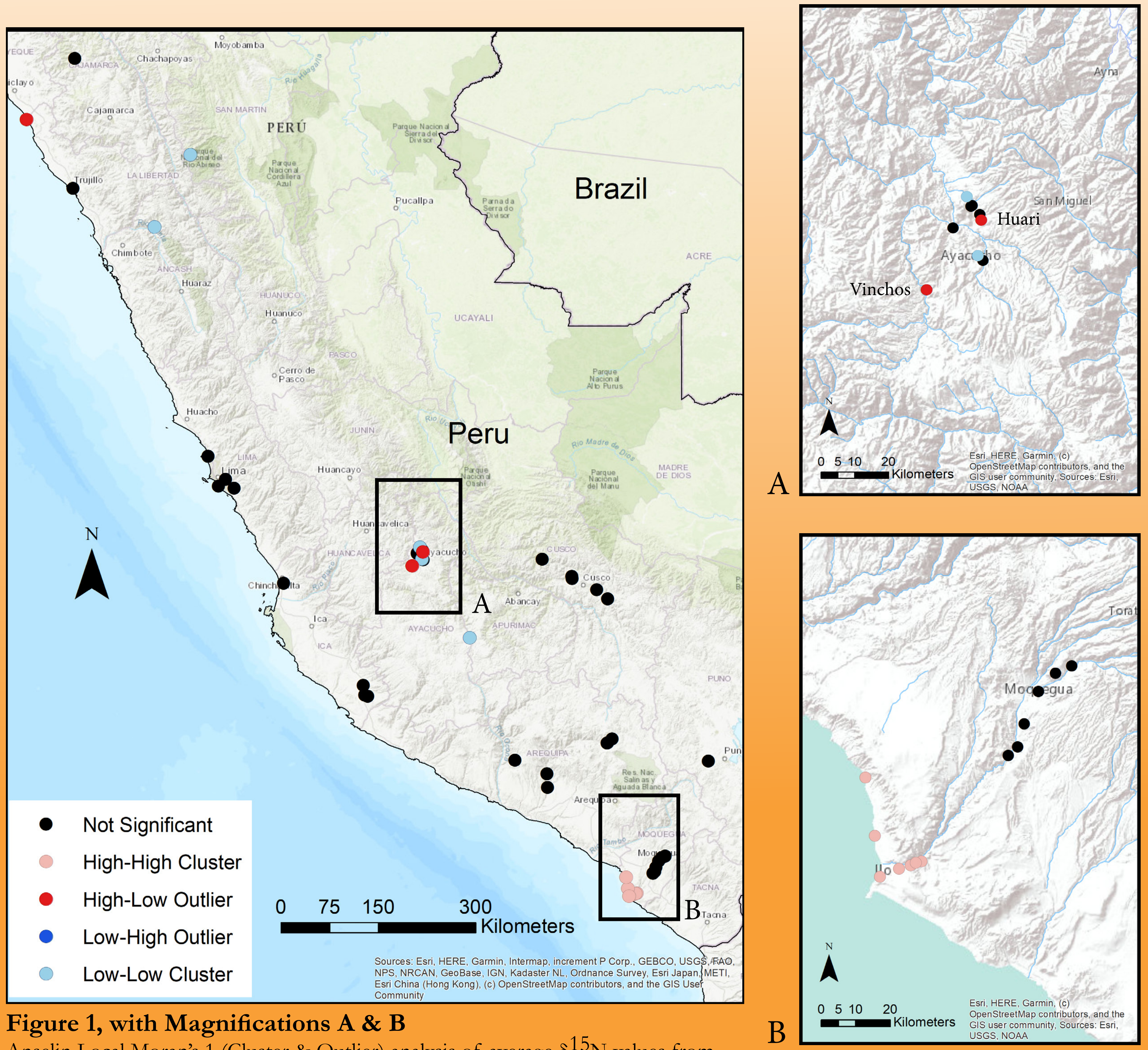

Figure 1, with Magnifications A & B
Anselin Local Moran's 1 (Cluster & Outlier) analysis of average δ^{15}N values from human remains collected from 49 distinct archaeological sites across Peru.

ACKNOWLEDGEMENTS
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OBJECTIVES

In this poster, I seek to confirm or contradict long-established hypotheses surrounding environmental δ^{15}N value distribution:

1. **That the highest δ^{15}N values will cluster in coastal regions where individuals consume more marine proteins with high trophic levels, followed by communities with access to freshwater aquatic proteins.**
2. **That greater dependency on domesticated terrestrial proteins such as camelids will result in higher δ^{15}N values in the highlands.**
3. **That varied access or dependency on terrestrial proteins, C4 and C3 agricultural products, and wild native plants and animals will produce a mosaic of values in mid-altitude areas and grasslands. This could appear either randomly distributed if there is substantial local-cultural variation in diet, or as homogenous, lower-value clusters if the types of terrestrial proteins and plants consumed produce similar δ^{15}N values in human remains.**

This project also seeks to map correlation of specific δ^{15}N value ranges in human bone to various ecological zones within Peru, if such patterning exists. This type of patterning has yet to be modeled from archaeological data, so there is no existing hypothesis to be tested beyond an expectation that different ecological zones will provide different nutritional resources with unique isotopic signatures.

MATERIALS + METHODS

This study evaluates the spatial distribution of average δ^{15}N values derived from human remains sourced from 49 archaeological sites across the Peruvian Andes. The isotopic metadata for this analysis was Dr. Tiffiny Tung and the Tung Laboratory. For sites with multiple data points, outliers were eliminated and δ^{15}N values averaged to establish a mean value.

Calculations of spatial autocorrelation via Anselin Local Moran's 1 establish δ^{15}N isotopic value clusters and identify outliers (Figure 1). Distribution of δ^{15}N values is evaluated in relation to the coast, to site elevation, and to ecological attributes such as coverage type, bioclimate, and phenological type that may produce unique nutritional resource signatures. Spatial location for each site was established using GoogleEarth Pro. Geospatial analysis and spatial statistics were executed in ArcGIS 10.8.1. Non-spatial statistical analysis and distribution visualizations were executed in R Studio.

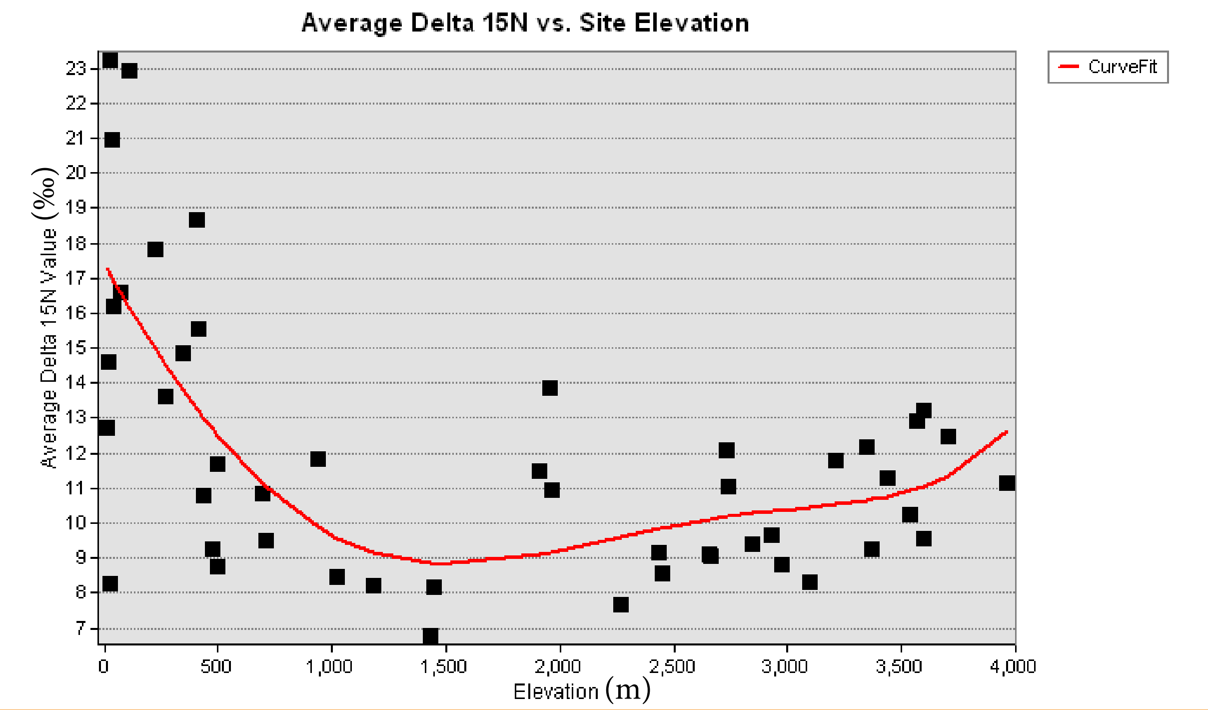

Figure 2
Scatter plot of δ^{15}N site means agains site elevation in meters.

Scan this QR code for a PDF containing References Cited and an extended bibliography.

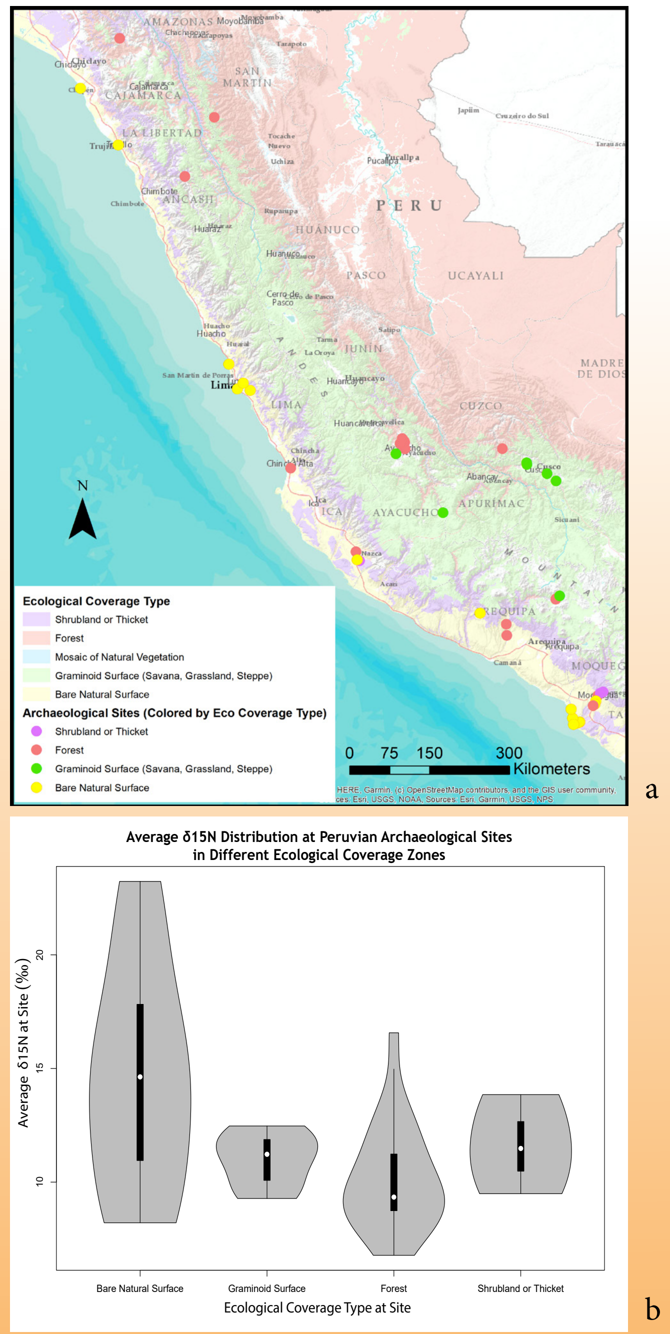

Figure 3
(a) Spatial distribution of archaeological sites mapped onto ecological coverage zones; (b) Violin plots of the distribution of mean δ^{15}N values by ecological coverage type in site area.

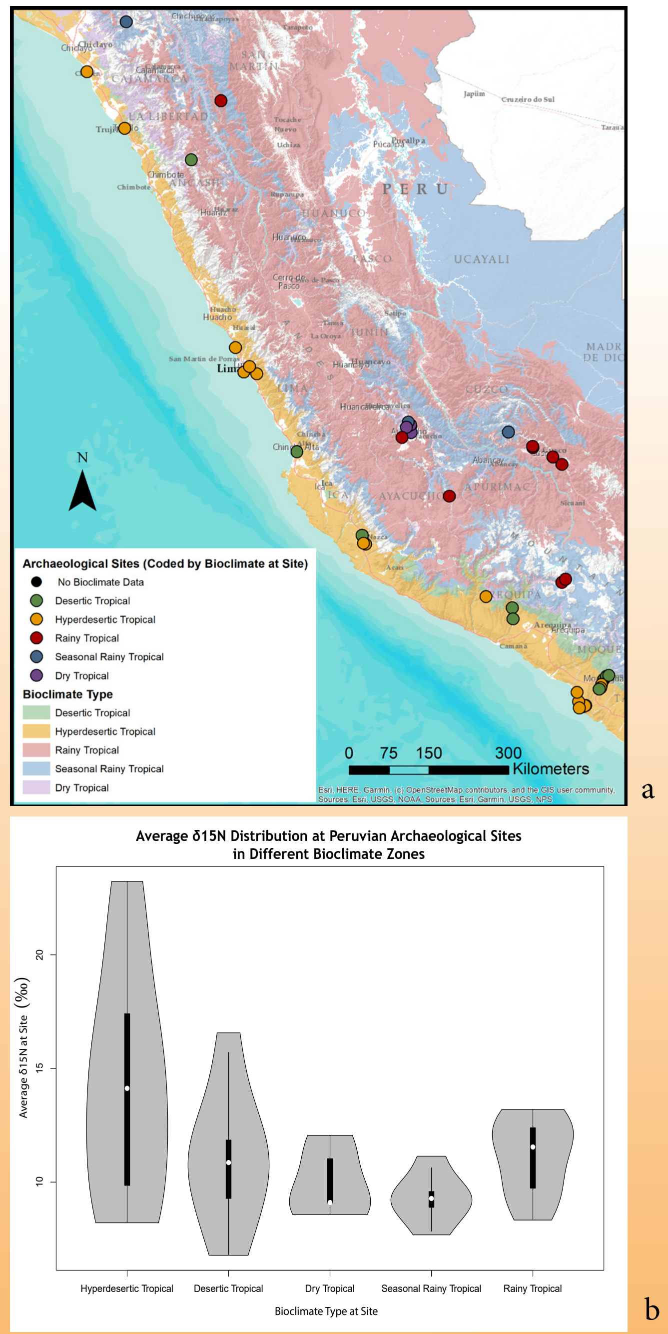

Figure 4
(a) Spatial distribution of archaeological sites mapped onto bioclimate zones; (b) Violin plots of the distribution of mean δ^{15}N values by bioclimate type in site area.

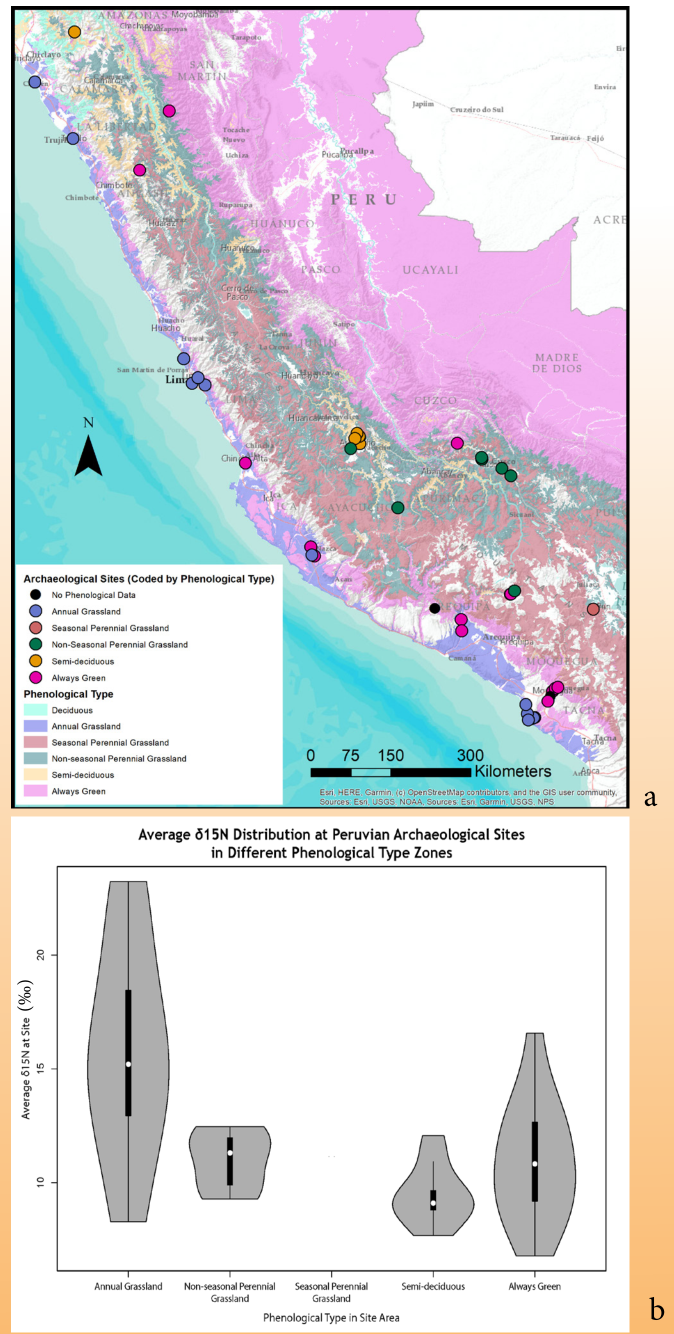

Figure 5
(a) Spatial distribution of archaeological sites mapped onto phenological zones; (b) Violin plots of the distribution of mean δ^{15}N values by phenological type in site area.

RESULTS + DISCUSSION

- **The Anselin Local Moran's 1 test identified at least 1 cluster of high δ^{15}N values on the southern coast, as was hypothesized (Figure 1B).** Surprisingly, a cluster of sites in close proximity near the central coast were not identified as a high-value cluster, suggesting either more variability and less reliance on marine foods in the diet, though this could have also been caused by overrepresentation of some other areas in the sample.
- **The Local Moran's test also identified the high-altitude sites of Vinchos and Huari as high δ^{15}N outliers (Figure 1A).** This might support the hypothesis that at least certain high-altitude populations were relying more heavily on terrestrial proteins such as camelids. The best fit curve of the graph of δ^{15}N plotted against site elevation provides additional support for this hypothesis **(Figure 2)**.
- **As expected, the variation in the δ^{15}N values of inland sites overall resulted in non-significant and seemingly random distributions with respect to spatial autocorrelation tests.**
- **There is clear variability in the distribution of average δ^{15}N in relation to all three environmental attributes (Figures 3, 4, 5).** The variability in distribution was confirmed to be **statistically significant with Kruskal–Wallis H Tests** for ecological coverage type and phenological type, which returned p-values of 0.0279 and 0.004413 respectively. Bioclimate did not exhibit statistically significant variability in distribution, with a p-value of 0.07083.
- The most distinctive environmental attribute types in terms of δ^{15}N distribution were the categories: Bare Natural Surface (Coverage Type), Forest (Coverage Type), Hyperdesertic Tropical (Bioclimate), Annual Grassland (Phenological Type), and Always Green (Phenological Type)
- Due to sample size, identification of clusters and outliers was overall inconsistent with the Anselin Local Moran's 1 test **(Figure 1). The metadata utilized in this analysis should be expanded substantially to provide more nuance in future analyses.** The community of stable isotope researchers in Peru should strive for more even spatial distribution of data collected if they wish to pursue regional, metadata-type studies.

Overall, this poster supports the assumption that regional environmental patterns do play a significant role in nitrogen uptake in human populations. This is a topic that is worth exploring further in Peru, and possibly in other global regions with robust and well-distributed isotopic datasets. Environmental attributes have predictive potential with respect to isotopic uptake.