POSITION PAPER

Unbinding Diversity Measures in Archaeology Using GIS

Marieka Brouwer Burg[*] and Meghan Howey[†]

Thirty years ago, a seminal volume drew together leaders in the field who were working on quantifying diversity in archaeological assemblages, *Quantifying Diversity in Archaeology* (Leonard and Jones, eds. 1989). While several papers identified space as a critical factor in structuring diversity, this concept was largely unaddressed and the analyses presented remained intrasite in scope. This was certainly due, in part, to the analytic and conceptual limitations of spatial analysis in archaeology in the late 1980s. *Quantifying Diversity in Archaeology* came out just before the geospatial revolution hit full swing in the field and the capabilities of today's geospatial technologies were unimaginable at the time. Now, thirty years later, the desire to analyze diversity across multiple sites from entire regions is easy to realize computationally. Nevertheless, key challenges identified in the original volume about quantifying diversity persist. While one can measure variation to identify diversity, we still need to understand what that means and how the categories we use to compute diversity are related to actual variation in past behavior(s) of interest. We explore various geospatial approaches that can help untether diversity analyses from traditional site-based frameworks. We argue that centering the experiences of the people producing and, importantly, perceiving the variation extant in their landscape is essential, as these personal experiences structured the past diversity we aim to study.

1 Introduction

Thirty years ago, a seminal volume on diversity measures in archaeology came out, *Quantifying Diversity in Archaeology* (Leonard and Jones, eds. 1989). The fact that archaeological settings have a great variety of material remains was recognized early in the development of the discipline, but this volume reflected a shift in archaeology towards a serious search for the best ways to rigorously characterize archaeological variation and the statistical properties of archaeological assemblages (Jones and Leonard 1989: 1). Many of the chapters in this volume implicitly acknowledged the importance of spatial scale as it pertains to the definition of site, determination of site size, collection of artifact assemblages, creation of material categories, and perhaps most importantly, the comparability of assemblages. While raised, space was not overtly confronted by the papers in the volume and the majority of approaches presented to quantify diversity remained intrasite in scope. Here, we argue that space and landscape are critical factors in structuring diversity and explore how geospatial tools have opened new horizons for analyzing and appreciating diversity across entire regions and over many eons. We contend that analyses of diversity must not be confined only to alpha or intrasite measures, focused on diversity within assemblages or sites, and we explore how geospatial technologies can be harnessed to broaden our analytical sights to include investigations of diversity at increasingly larger spatial scales, such as that of beta or intersite diversity and gamma or region-wide or total-landscape diversity.

As an example of how spatial scale was evoked but not confronted in the original volume, Jan F. Simek noted that intrasite spatial analyses have been somewhat useful for understanding past behaviors at the activity level (while also citing major caveats) and warned that "the presumptive search for activity patterning in archaeological distributions has serious problems. Such patterning may not be present (e.g., at Pincevent), and inferences of activity structuring in the absence of warranting analyses are dangerous" (Simek 1989: 68). Many authors echoed this concern, and the question left unasked from our perspective is: could differing contextual conditions (natural, techno-economic, social, ideological) have impacted this activity patterning? If so, what was the relationship between these contextual conditions and the resulting material culture, and associated patterns, produced? Furthermore, could the "presumptive search for activity patterning" perhaps be more fruitfully guided if detailed knowledge of past landscapes, and perceptions of past landscapes, were known?

David Hurst Thomas, working under the methodological rubric of the 'systematic regional approach', contended

* University of Vermont, US

† University of New Hampshire, US

Corresponding author: Marieka Brouwer Burg (mbrouwer@uvm.edu)

in the 1989 volume that "despite these significant and far-reaching changes in field strategy, methods for analyzing such regional data have changed surprisingly little from the good old 'single site' days. The truth is that many regional studies continue to rely on simplistic, impressionistic, and often unrealistic analytical methods" (Thomas 1989: 85). Thankfully, the ever growing body of geospatial methods and technologies we have available to us as archaeologists today have alleviated much of what Thomas lamented in 1989.

Geographic Information Systems (GIS) was in its very nascency in the field in 1989, with many of the major pioneering works illustrating the power of GIS for archaeology published in the years following this volume (cf. Aldenderfer and Maschner 1996; Allen, Green and Zubrow 1990; Gaffney and Stančić 1991; Gaffney, Stančić and Watson 1996, Kvamme 1999, Llobera, 1996; Lock 2000; Lock and Stančić 1995; Maschner 1996). Reading this book on its 30-year anniversary, it is clear how significant the analytical limitations were at the time and this provides a real appreciation for how quickly and profoundly geospatial technologies have opened our analytic horizons in archaeology.

In this piece, we revisit missed opportunities and laments in this seminal volume over analytical limitations and the role of space in archaeological diversity with the perspective we have now because of the geospatial revolution in archaeology. We explore how spatial scale, and a consideration of space in general (or better yet, landscape), is a key criterion impacting outset assumptions and the manner by which diversity measures are calculated. Furthermore, many ethnographic accounts have underscored the importance of space, landscape, and landscape knowledge as critical elements impacting past sociocultural behaviors. We argue herein that if future studies of assemblage diversity are to meaningfully grapple with the behavioral 'dynamics' that created those assemblages, they have to include a consideration of the contextual setting, or landscape, in which the assemblage was formed.

2 Part 1. Scaling Up: How GIS Can Expand our Perspective on Diversity

Since the publishing of *Quantifying Diversity in Archaeology* (henceforth "QDA") in 1989, a robust body of geospatially-oriented analytical techniques has been developed to wrangle and parse an ever-growing universe of geospatial data to answer a vast array of research questions, not least of which were developed in conjunction with and to further the field of ecology. This discipline, also heavily involved in geospatial analysis, has long recognized the importance of multiscalar research, pushing the boundaries beyond a field/site perspective to that of the region and/or total-landscape (i.e., 'wall-to-wall' modeling; cf. Pelletier et al. 2014; see Amaral et al. 2016; Crooks and Sanjayan 2006; McRae et al. 2008; Shirk et al. 2010; Spear and Storfer 2010). Ecological processes can be more thoroughly probed and explored using these broader research catchment areas (Chambers et al. 2007). Archaeology has experimented only sparingly with alternative frames for viewing sites and landscapes, most notably Foley's call

for off-site or non-site archaeology (Foley 1981). While there are many ecological practices that archaeology may benefit from, Dunnell warned in QDA that archaeologists engaged in diversity analysis must refrain from becoming no "more than a dog wagged by a borrowed technical tail" (Dunnell 1989: 149), that technical tail referring to diversity measures developed in and for ecological purposes, with very different outset conditions and premises. Thus, in some respects, archaeological practitioners of GIS are facing similar issues as those of our QDA forbearers, albeit with fancier gadgetry.

On the flipside of this coin, there are various measures of diversity developed for ecological pursuits that have been successfully translated to archaeological cases, notwithstanding Dunnell's "borrowed technical tail." There are three ecological modeling approaches that we have productively applied to archaeology. First is landscape permeability. The ecological concept of landscape permeability is the "degree to which a given landscape is conducive to the movement of organisms and the natural flow of ecological processes" (Anderson, Clark and Sheldon 2014: 960). We applied this idea archaeologically, defining permeability in an archaeological context as the degree to which a given landscape, with its specific mix of physical and social variables, was conducive to the movement of people and the flow of items and ideas (Howey 2015: 88). Specifically, a case study of the permeability of the cultural practice of food storage was selected and GIS modeling was done using resistant-kernel analysis (run in R, Compton et al. 2007). A series of relevant spatial variables to landscape permeability were produced from archaeological research on food storage in northern Michigan during the Precontact period. The variables determined to be most relevant to landscape permeability were combined into one raster resistance grid. The resistance-kernel modeling treated each cell in the raster resistance grid as the focal cell at one point in the analysis (details in Howey 2015). The resulting raster grid was a continuous surface that reflected how permeable the landscape was to the flow of the cultural practice of food storage (**Figure 1**). Adapting the ecological concept of permeability to archaeological GIS analyses offers archaeologists a robust means of examining at a total landscape scale how people were brought into encounters with diverse landscape matrices composed of some set of variables that both impacted and created potentialities for the flow of cultural processes in the past.

In a related set of studies, the ecological tool known as circuitscape modeling was applied to archaeological concepts, a tool that – much like its more commonly applied alternative Least Cost Path (LCP) analysis – operates on the premise that movement through a landscape necessarily involves encountering impediments that increase the amount of energy, or friction, required to pass through that landscape (see McRae 2006; McRae and Beier 2007; McRae et al. 2008; Shah and McRae 2008). High friction landscapes consist of very steep terrain or very dense flora; low friction landscapes might contain low grasses and present very little incline. Within circuitscape modeling, landscapes are classed by their conductivity (or resistance) to movement. In one application, Howey (2011) applied
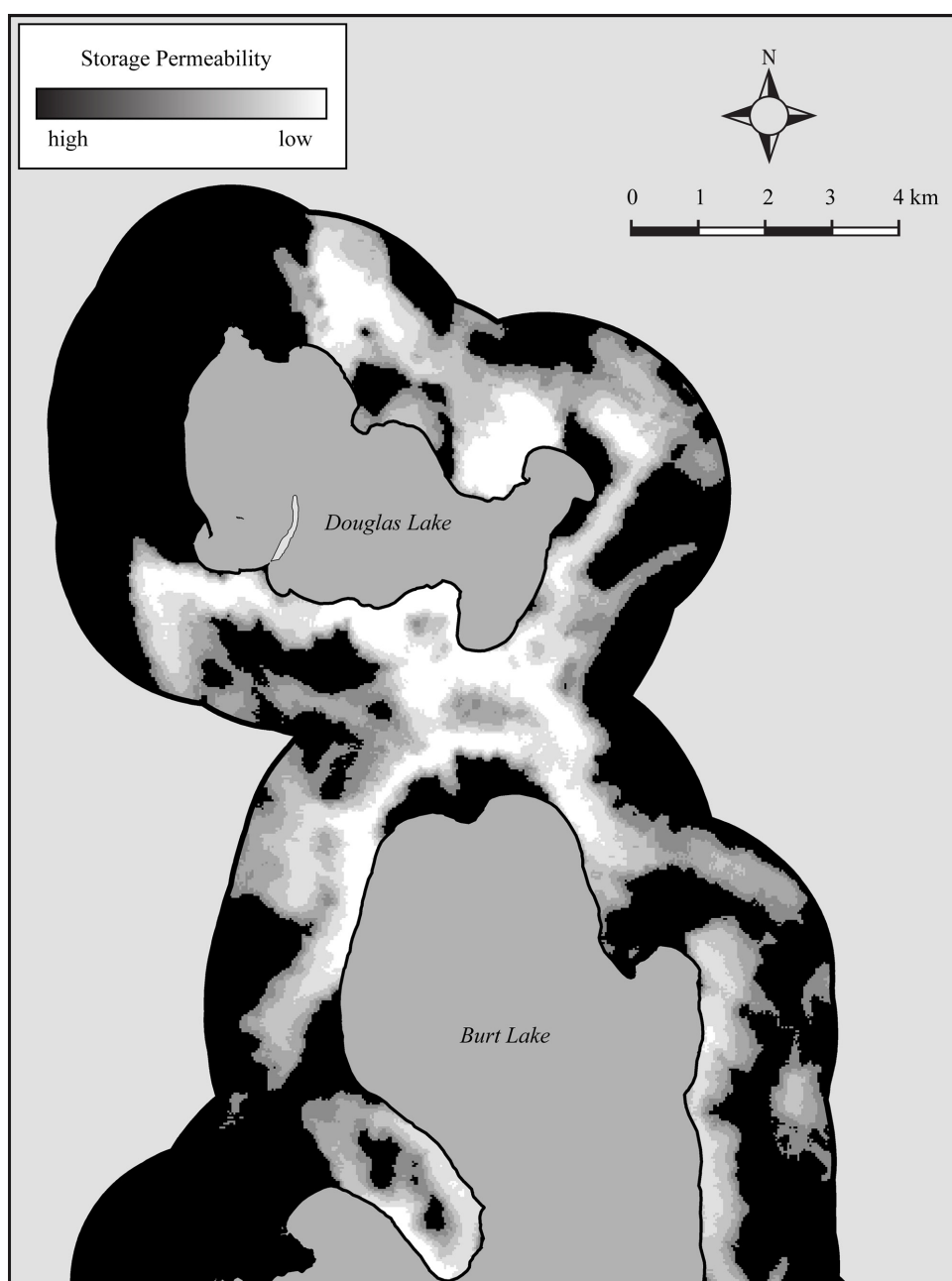
Figure 1: Storage Permeability Grid Depicting Low to High Suitability for Storage (from Howey 2015: Figure 6).

this method to investigate possible routes of travel to and from various Late Precontact earthworks in northern Michigan. She found that this total-landscape approach to exploring diverse (heterogenous) landscapes yielded invaluable insight into past processes of making decisions concerning routing between sites (Howey 2011: 2533). In another application, Brouwer Burg, Runggaldier and Harrison-Buck (2014) investigated the relative conductivity for movement between a number of Late Preclassic sites in central and northern Belize, determining that while persistent paths and routes were likely used in a regular fashion in the past, this did not preclude the decision to take diverse paths, especially given seasonal and social impacts on connectivity (**Figure 2**; Brouwer Burg, Runggaldier and Harrison-Buck 2014: 288).

Finally, we have recently begun investigations into the exploratory power of principle known as Maximum Entropy (MaxEnt), a statistical measure that has seen productive applications in a number of disciplines (see Phillips, Anderson and Schapire 2006 for examples). While developed specifically for exploring presence-only plant and animal habitat suitability (Amaral et al. 2016; Algeo et al. 2017), MaxEnt has revealed itself to be a strong predictor of archaeological spatial distributions, provided that carefully informed consideration is devoted to selecting spatio-environmental criteria that are appropriate for past human behavior. In one study, we applied this model to the distribution of Late Precontact food storage cache pits in northern Michigan (Howey et al. 2020). Twelve spatio-environmental criteria were selected to run the model, and results indicated that the makers and users of these pits–for whom they were of great importance for survival–were well aware of the particular constellation of landform features required to create an effective storage pit,
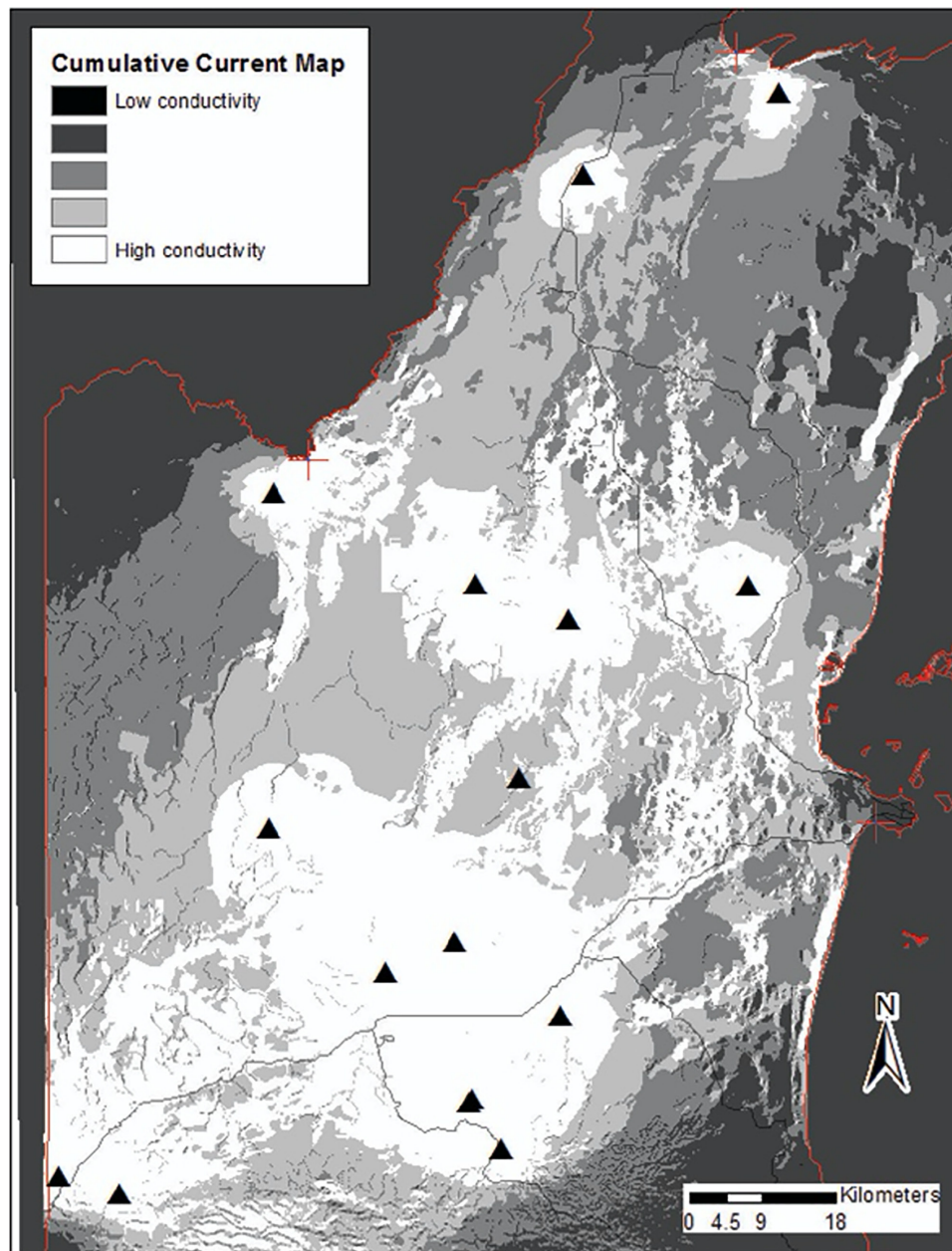
Figure 2: Circuitscape Modeling Results Depicting Cumulative Current Map for Linking Contact Periods Sites in Central and Northern Belize (from Brouwer Burg et al. 2014: Figure 9a).

that is, a location and depth that would most effectively prevent food rot and/or disturbance (**Figure 3**). When the predictions of this model was ground-truthed (i.e., when we investigated an area determined by the MaxEnt model to be of high cache pit potential), our team found a number of such pits. In another application, we used MaxEnt to explore the distribution of earthen monuments in Michigan, and revealed that distinct types of earthen monuments (mounds versus earthwork enclosures) were differentially situated in the landscape according to varying but specific constellations of criteria (Howey, Palace and McMichael 2016).

Despite these advances, there are still other critical issues that most authors in the original QDA volume flagged as important and that we would like to address here before moving on. First is the effect of sample-size on diversity measures. In general, larger samples have greater richness, and researchers need to determine "whether one has a greater *relative* richness when the effects of sample size are removed" (Kintigh 1989: 27) or at least accounted for. This is something to keep in mind as we tackle data gathered from increasingly large spatial scales, as is the case in most archaeological applications of GIS.

Another persistent issue facing archaeologists engaged in geospatial analysis involves the congruency of spatial data gathered at diverse scales and degree of detail, driven by varying research agendas and funding sources, as well as the translatability of spatial statistic measures designed with very different kinds of samples in mind. As to the former, we are fortunate that software companies like ESRI have designed geo-rectifying, scaling, and transformational procedures in their packages to facilitate, with more or less ease, the 'fitting' of diverse data to one another. But we cannot rely wholly on computers to complete this
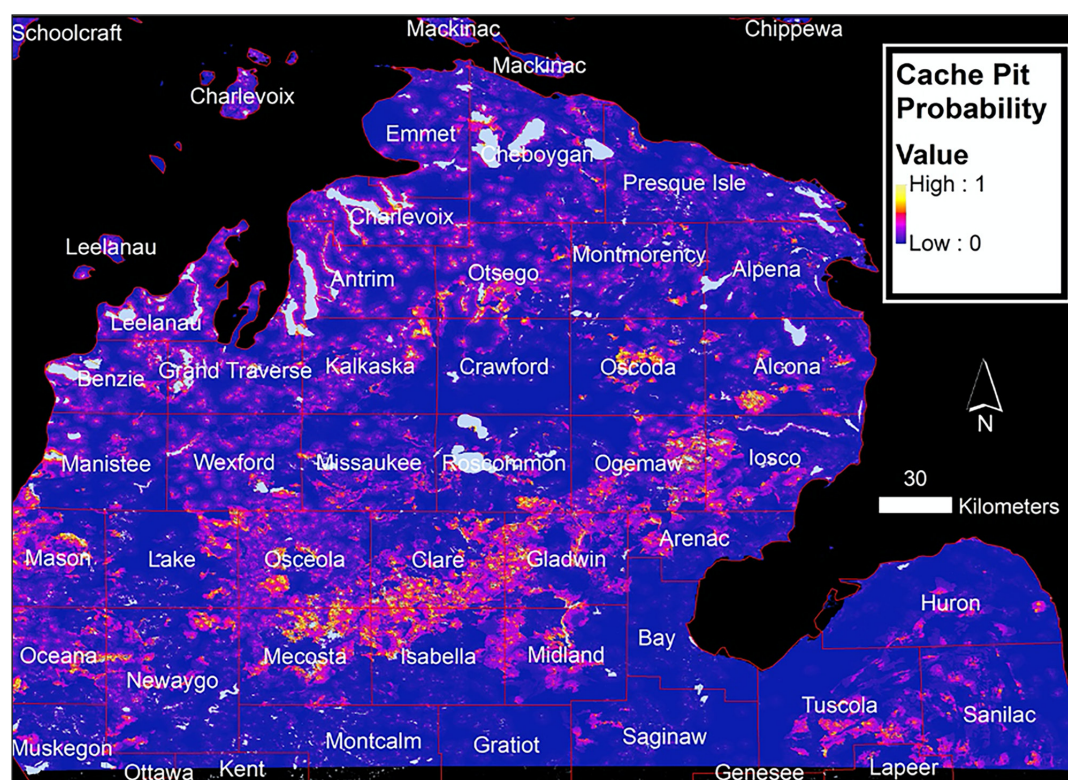
Figure 3: Results of Maximum Entropy Analysis of Cache Pit Probability in Northern Michigan (from Howey et al. 2020: Figure 4).

often thorny task and thus it is incumbent on the geospatial modeler to be attentive to the comparability of datasets and be actively engaged in their integration. As to the former, we have already discussed some routes by which statistical measures from similar disciplines can be fruitfully, but also cautiously, applied to archaeological settings.

Following this argumentation, we must also mention the increasingly serious methodological issues associated with the phenomenon of 'big data,' which some have referred to as the "massification" of archaeological data collected primarily through ever more efficient and affordable remote sensing techniques (McCoy 2017, 2020; VanValkenburg and Dufton 2020: S5). Of course, more data does not directly or necessarily lead to better data or more thorough understandings of the past, which we have previously commented upon (Brouwer Burg 2017). In fact, despite the apparent benefits of more data, archaeologists are now saddled with the additional and time-consuming task of mining massive data sets for useful points of information, suitable to a project's research goals and within computing capabilities. Now more than ever, as geospatial software and associated analytical modeling tools become more widely available and user-friendly, archaeological modelers must beware of incautious data selection. Targeted, thoughtful, and reflexive data selection must be implemented to help us make the best use of the double-edged sword of big data.

Regardless of the above-defined issues, we believe the exploratory power of these new geospatial techniques, which demand that we take a broader and more encompassing view of archaeological data, has and will continue to improve our efforts to unravel past behavioral practices. Which brings us to another key question: how do we (as archaeologists in the present) assign meaning to the 'diversity' we find in our statistical or geospatial analyses?

3 Part 2. Real or Contrived? The meaning we assign to values of diversity

This header, which is paraphrased from a line at the end of Jones and Leonard's opening chapter in the original QDA volume, cuts to what we feel is the most important issue facing studies of archaeological diversity today, and that is: are these measures actually representative of categories that were real or recognized in the past? As Cowgill succinctly put it, "diversity in the archaeological record often bears a complex relationship to diversity (or any other aspect) of ancient behavior […] we must also think much more about the *meaning* of diversity" (Cowgill 1989: 132). Yet, so much can confuse the direct linking of the 'statics' we analyze in the present to the 'dynamics' that created them in the past, to evoke an oft-quoted Binfordism. As Schiffer details in his original chapter, "the use of pattern-discovery analytic techniques on artifacts and deposits of unknown formation processes will seldom yield behaviorally meaningful results. That is so because the statistical patterns reflect varying mixes of effects produced by formation processes and by the past behaviors of interest" (Schiffer 1989: 58). In addition, there is the issue of sample/assemblage representativeness, the degree of completeness of our sample, which will greatly impact the validity of diversity measures applied to it (see Cowgill 1989: 133). And arguably, there is the unavoidable issue that we can *never* know for certain the degree

of representativeness of any (or most) archaeological samples/assemblages. Equifinality is another factor that must be considered, adding difficulty to our ability to understand the meanings behind diversity measures (**Figure 4**). As Dunnell wrote "artifact function is not generally equivalent to activity since a given function (e.g., cutting) can be expected to participate in a variable number of different activities (cf. Simek 1989) which themselves can be expected to have variable representation in the archaeological record" (Dunnell 1989: 145). Thus, while increasingly sophisticated statistical analyses may reveal new and interesting patterns in our archaeological data, we can never be certain about the direct linear, or "one-to-one relationship between activities and [artifact] categories" (Cowgill 1989: 137).

Cowgill goes on to provide us with some solace: "we must do our outmost to identify good 'diagnostics'" (Cowgill 1989: 136), which he describes as specific artifacts used exclusively for specific activities, and concludes that "studies in ethnoarchaeology, experimental archaeology, and taphonomy must be pursued to the fullest in order to expand the number and quality of recognized 'diagnostics'" (Cowgill 1989: 137). And to this we would add a consideration of indigenous perspectives on landscape diversity. In a fascinating study on Native American bundles, Zedeño (2008) argues that through taxonomic study of archaeological assemblages (and by extension, investigation of intra-assemblage diversity), we may "better understand variation in systems of thought" and makes a call to "bridge the gap between Western and non-Western ontologies by expanding and reformulating the study of material culture" (Zedeño 2008: 376). She notes "after all, classification is the foundation of archaeological analysis and thus should be reflective of subjects we study" (ibid 2008: 376). We would add, importantly, that *landscape* should also be considered as a critical factor when we are thinking about the nature of diversity in archaeology.

There are various ways of incorporating indigenous perceptions and beliefs about landscape into GIS analysis,

and many important contributions have been made to steep archaeological applications of GIS in more inclusive social frameworks (e.g., Bevan and Conolly 2004; Bongers, Arkush and Harrower 2012; Fitzjohn 2007; Garcia-Moreno 2013; Gillings 2012; Hacıgüzeller 2012; Llobera 1996, 2001, 2003, 2007, 2012; Lock 2001; Lock, Kormann and Pouncett 2014; McCoy and Ladefoged 2009; Mitcham 2002; Rennell 2012; Supernant 2017; Van Dyke et al. 2016; Wheatley 1995; Wheatley and Gillings 2000, 2002; Williams and Nash 2006, among others). A critical branch of this research has focused on incorporating participatory Geographic Information Systems as a way of engaging indigenous non-specialists in the collection, storage, and mobilization of local spatial knowledge, especially in regard to archaeological or other traditional heritage sites (to name a few: Álvarez Larrain and McCall 2019; Atalay 2012; Barlindhaug 2013; Byrne 2008; Colwell-Chanthaphonh and Ferguson 2010; DeGraff and Baldwin 2013; Duin et al. 2014; Flexner 2015; Guilfoyle and Mitchell 2015; Harris 2012; Heckenberger 2009; Purser 2012; Smith et al. 2012; Thomas and Ross 2013). Below, we highlight three case studies that interweave indigenous landscape conceptions into formal geospatial inquiry.

Focusing on the Dutch Mesolithic, a period lasting from the melting of the last continental glaciers to the onset of agriculture in the Netherlands (c. 10,000–6000 BP), one of us (Brouwer Burg) consulted ethnohistoric accounts and archives of Canadian First Nations, Scandinavian Saami, and Siberian Khanty groups to extract information about how people make decisions about land use (e.g., settlement placement, mobility, resource extraction, sociopolitical boundaries, and meaning emplacement; see Brouwer 2011). A series of nested decision chains were developed based on previous work by Whitley (2000: 55) and Peeters (2007) to approximate how these land use decisions are made, and these were extrapolated into the past to explore in a heuristic manner hypothesized spatial behavior of Mesolithic gatherer-hunters (**Figure 5**). As noted above, this approach also employed a total-landscape
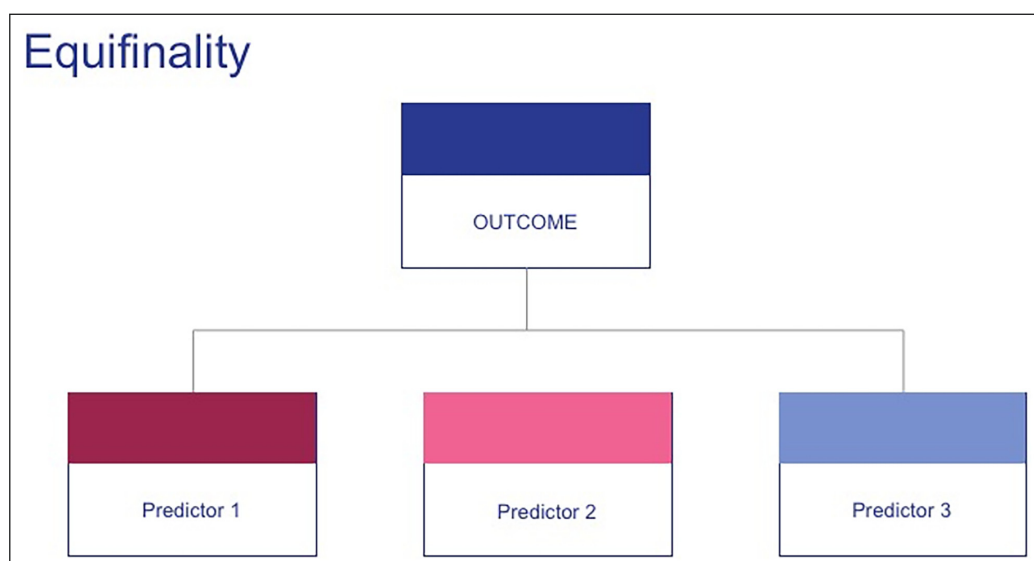
Figure 4: The Challenge of Equifinality in Parsing Archaeological Diversity Measures.
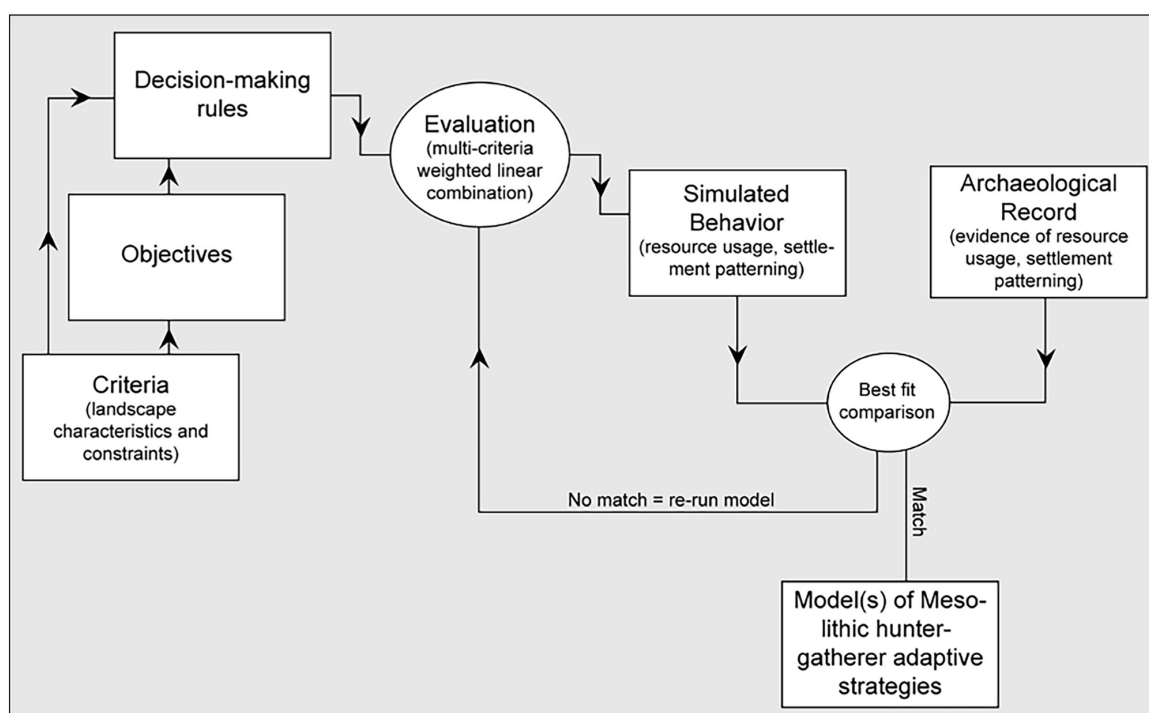
Figure 5: Decision Tree Used to Predict Hypothesized Hunter-Gatherer Behavior in the Dutch Mesolithic (from Brouwer 2011: Figure 5.1).

perspective, situating the decision-makers within detailed paleolandscapes, a necessary step for obtaining encompassing explanations of past land use behavior (Brouwer Burg 2013).

In another intriguing study, Supernant (2017) strives to build a more nuanced and inclusive GIS that is engaged with and attentive to indigenous communities and perspectives. Critically, the author reminds us that caution be evoked when attempting to use GIS to understand the spatial practices of any indigenous group, as varying worldviews will drastically change the way in which the landscape is understood and experienced. Best practices should involve community-based interaction and collaboration as much as is possible. Applied to the past, this caution must be heightened appropriately. In her case study, Supernant compares industry-standard geographic criteria used in Least Cost Path (LCP) modeling (i.e., slope and water) with that of historic trail data from 19th century indigenous Métis people (ibid 2017: 64). She concludes "developing an Indigenous GIS approach [to archaeology] requires more work with the community to identify variables, incorporate these variables into LCP travel modes according to Métis landscape knowledge, or perhaps develop specific analyses or new algorithms to integrate a Métis way of knowing into GIS" (ibid 2017: 71).

Furthermore, in a preliminary analysis of Late Precontact (AD 1200–1600) earthworks in the Great Lakes, we found that these highly significant, ceremonial places were emplaced very intentionally within the landscape by their makers (see Brouwer Burg and Howey 2019). These people, known as the Anishnaabeg, had an encompassing view of the land and everything upon it, and viewed themselves as but one equivalent being within this totality of beings. In our GIS analysis, earthwork locations and randomly generated points were overlain on existing landform maps, comprised of an array of different landform classes and ecoregion subsections. We found that earthworks tend to be located in places with higher landform class richness (e.g., much landform diversity) and more types of landforms (**Figure 6**). Additionally, earthworks were frequently located in proximity to open water (lakes or rivers). These results, while preliminary, allow us to explore how regional indigenous communities perceived landscape diversity and incorporated it into their decision-making processes of emplacing sacred structures. It also helps us to appreciate how geospatial technologies can be used to unbind diversity analysis from artifacts and single-sites to evaluate diversity at the landscape-scale.

4 Concluding Thoughts

In the above examples, we describe various ways in which investigations of archaeological diversity can begin to unbind itself from site-based, alpha measures and scale up – or *zoom out* as the case may be – to statistics derived from a much broader, encompassing, and illustrative scope. In fact, new developments in the field of ecology can be fruitfully applied in archaeology when done so in a purposeful way that is fully aware of places and procedures where no parallels exist, so that we avoid Dunnell's "borrowed technical tail."

We have also probed the question so neatly put by Cowgill (1989: 132) about exploring the *meaning* of diversity in the archaeological record, whether it reflects real behavioral variation in the past or if it is a byproduct of the tools and methods used. For a true untethering of archaeological diversity measures from artifacts and sites to occur, we must also think deeply about the meta-cognitive frameworks we bring to our analyses – regardless of
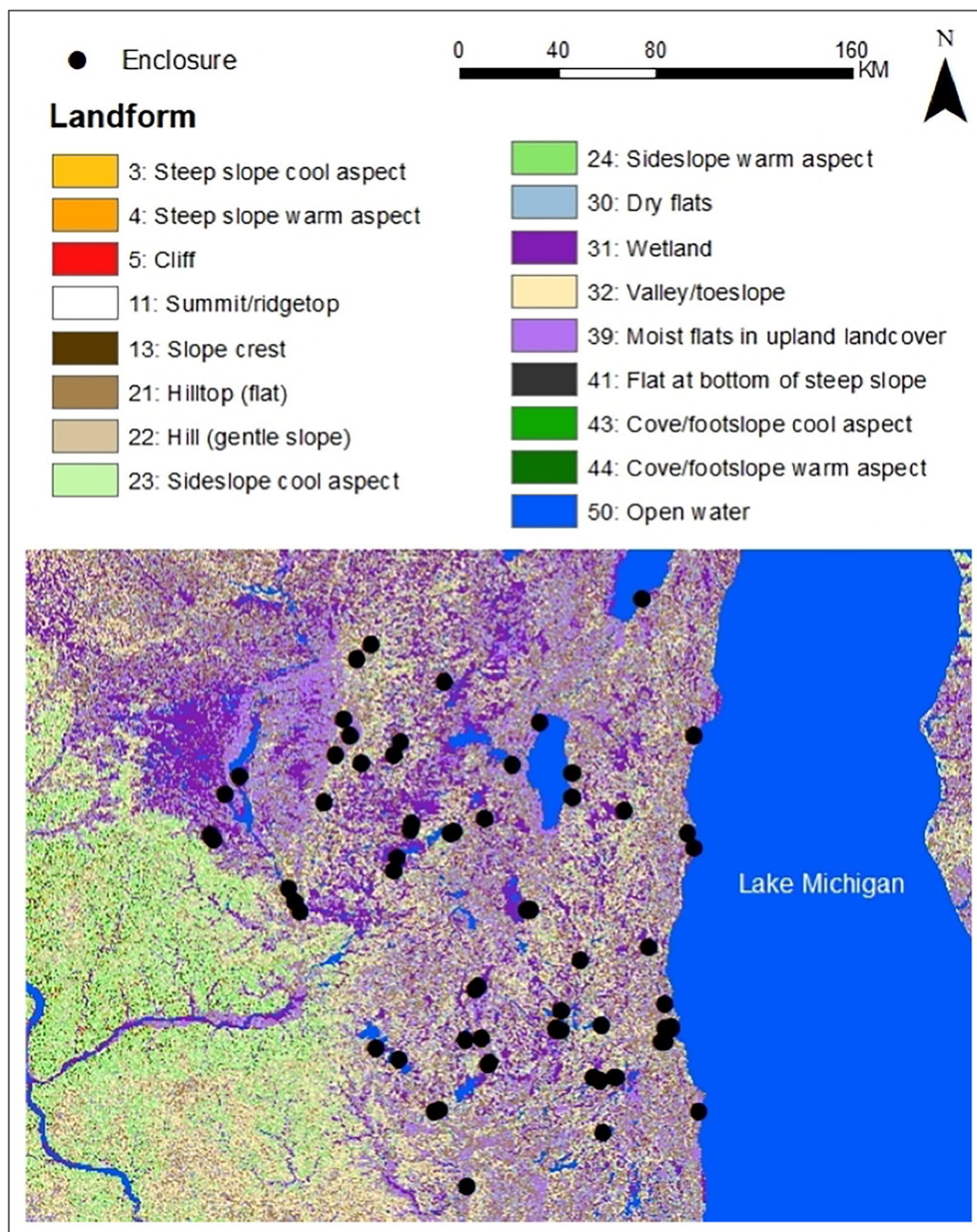
Figure 6: Potential Late Precontact Enclosures in Wisconsin (Brouwer Burg and Howey 2019).

the techniques in place – remembering the importance of incorporating indigenous conceptions of both animate and inanimate objects as well as the broader landscape. Especially in the case of archaeological GIS, if we do not keep landscape foregrounded in our analyses, we risk falling into Simek's "presumptive search for patterning" (Simek 1989: 68) that may not have been meaningful in the past. While GIS and statistical analyses offer quantifiable metrics of landscape richness and abundance, for many of the past societies we study, the land and everything upon it was alive, the relationship of people to the land was personal and so too, then, were their experiences and understandings of landscape diversity.

Competing Interests

The authors have no competing interests to declare.

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