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GEOSPATIAL TECHNOLOGIES IN SOCIAL SCIENCES

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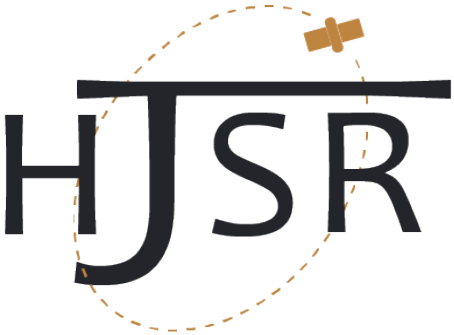

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GEOSPATIAL TECHNOLOGIES IN SOCIAL SCIENCES

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INTRODUCTION GEOGRAPHIC INFORMATION SYSTEMS IN THE SOCIAL SCIENCES

The purpose of this special issue is to highlight the myriad of applications of geographic information systems within the social sciences. As access to geospatial technologies continues to increase, we are seeing new forms of research that highlight how different approaches to spatial analysis can answer complex questions on topics ranging from contemporary urban policy to ancient civilizations.

The academic articles in this issue demonstrate the range of disciplines working with geospatial technologies in research projects, with contributions from Sociology, Geography, Anthropology, and Economics. This diverse range of research illustrates the unique ability of geospatial technologies to transcend disciplinary boundaries and provide insight within numerous frameworks.

Madurapperuma et al. creates a novel approach for identifying social values and issues of fragmentation at a protected coastal area. In this article, the authors explore the Ecological and Social Values of the Dunes, the degree to which human-induced impacts, such as recreation trails, have on the ecosystem, and the resulting effects on native plant and animal populations. The authors detail a methodology on the use of geospatial technology, such as sUAVs, to monitor changes in a coastal dune environment.

Perdue designs an agent-based model to understand human-urban interactions in transportation systems, allowing individual entities within the model to be characterized with cognitive and behavioral properties. This paper discusses the role of agent-based representations of pedestrian transportation systems, detailing the underlying assumptions and techniques behind different types of pedestrian models and illustrates the differences between aggregate and individual agent representations. The paper concludes with a discussion and specific frameworks for employing agent-based models to support transportation planning decisions.

McFarland and Cortes-Rincon examine innovative methods of relief visualization of LiDAR-derived digital elevation models, and classification of secondary data to identify archaeological remains on the ancient Maya landscape in northwestern Belize. This study aims

to answer questions of population estimates, mobility costs, and effectiveness of ancient technological agricultural systems.

Smith and Morse use innovative remote sensing techniques to investigate the geotechnical construction of wall structures, as well as the soil properties resulting from their implementation and use, at the Central Lowland Maya site of Yax Ch'am. The results show that comparable designs in two retaining wall structures at the site have varied responses to lateral earth pressures and change the soil composition between the two sites.

Cobb uses innovative geospatial techniques to examine the distribution of key housing, economic, health, and educational indicators in metropolitan Hartford, with a particular focus on factors that bear upon the lives of children in this area. The results reveal substantial disparities in the geographic distribution of important resources and outcomes across the racially and economically stratified region. Cobb concludes the article with recommendations for more comprehensive, cross-sector policy interventions as well as regional collaboratives.

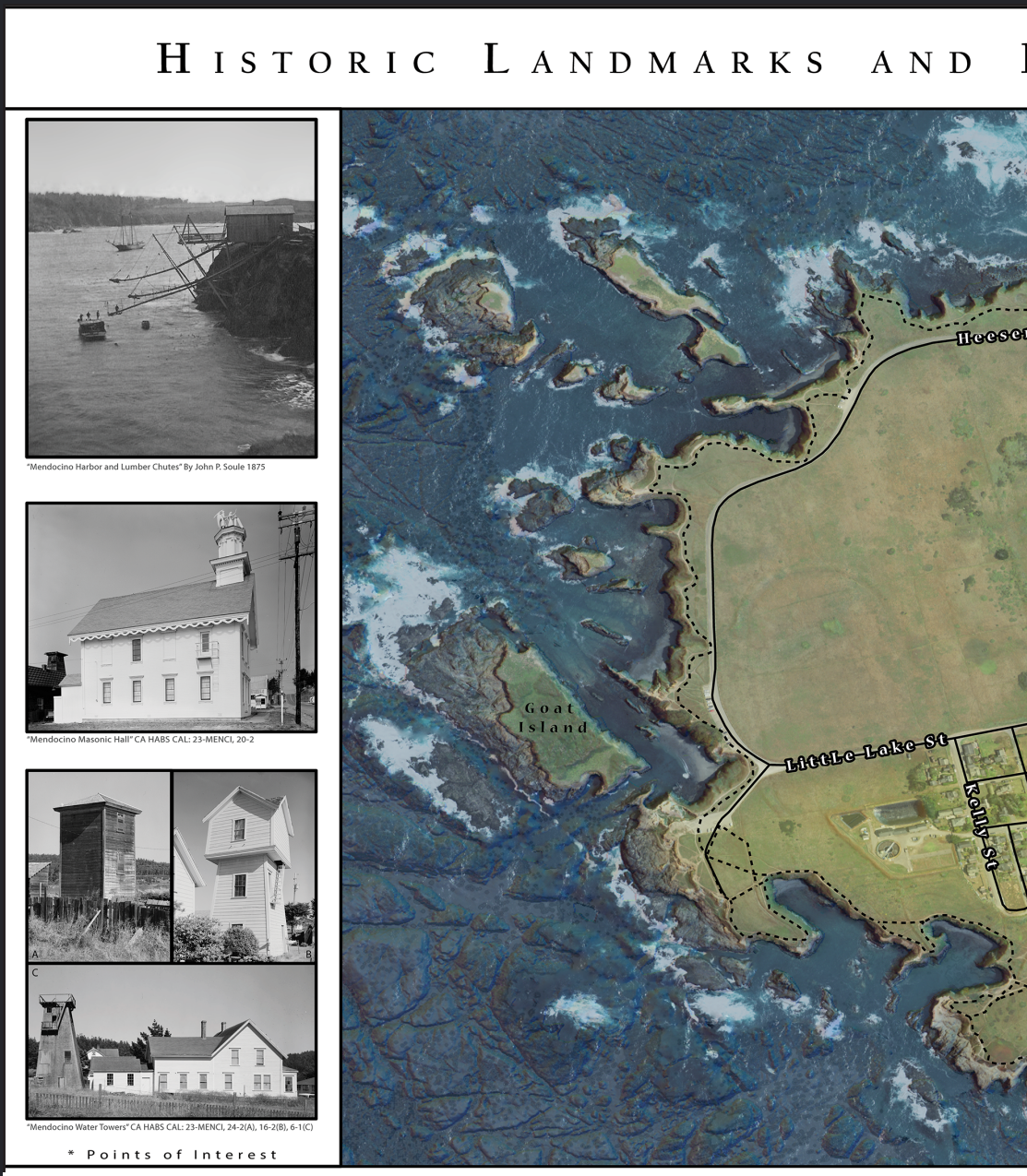
Finally, Sugata explores the spatiality of debt with a mixed-method study that illustrates the role alternative financial service providers contribute to the uneven economic decline and the dramatic reconfiguration of space in many communities across the country. Sugata argues that debt is an embodied experience that happens through space and not simply in space, and illustrates the need for changes in the way we approach and articulate questions of both debt and the body.

The range of topics, methods, and geographies in this issue illustrate the theoretical and practical application of geospatial technologies in the social sciences. As an editorial team, we decided to supplement these articles with a collection of maps produced by Humboldt State University students. These maps illustrate archeological sites, regional geographies, terrain and landcover, and artistic expression. Our aim in curating these maps, interlaced within the articles, is to merge the analytical and visual power of geospatial technologies within the social science research.

Jeremy McFarland is an alumnus of Humboldt State University, who earned a Bachelor's of Arts in Anthropology with minors in Geospatial Analysis and Scientific Diving. His passions are in cartography, marine sciences, and archaeology. His current research focuses on visualization of complex datasets, particularly ways to map and visualize the terrain and the environment in the Maya landscape. He is a Research Associate of the HSU Cultural Resource Facility, the GIS Program Manager for the Dos Hombres to Gran Cacao Archaeological Project in Belize, and contributes as a Scientific Diver to marine research along the Pacific Northwest Coast.

JEREMY MCFARLAND

The Earth's ocean ties all people together in more ways than one. For centuries, people have been drawn to the ocean for its vast openness and array of resources. Maritime heritage is the protection and preservation of humankind's past and century old stories of cultures' use of the ocean. By understanding individual connections to the ocean, more may be inspired to care for it. This map was developed to visualize the unique transition between land and sea, and capture the historic connection of this seascape town.



"Perched on the bluff overlooking the river and the ocean, the town of Mendocino is not only classically picturesque, but it is also one of the best examples of a vibrant historic landscape where people carry on everyday lives amidst the delightful and enduring legacy of the 19th century."

– Marianne Hurley, Architectural Historian, California State Parks

Points of Interest in Mendocino, CA

"Temple of Kwan Tai" CA HABS CAL: 23-MENCI,13-1

"Ford House Museum" CA HABS CAL: 23-MENCI, 5-1

"Presbyterian Church" CA HABS CAL: 23-MENCI, 21-1

**Historic Landmarks

c.1859: Mendocino Presbyterian Church**

c.1866: Mendocino Masonic Hall*

c.1854: Ford House**

c.1852-1890: Mendocino and Headlands Historic District**

c. 1854-1883: Temple of Kwan Tai**

c. 1869-1879: Mendocino Harbor and Lumber Chutes*

Meters
100
200
800
400
Feet

Cartographer: Jeremy McFarland
Map Data: NOAA, USGS, EarthExplorer
Photos: [Public Domain] via Wikimedia Commons

Madurapperuma, Buddhika, Jess Barger, Melissa Collin, Christine Emerson, Sean Fleming, Brian Murphy. 2019. "A Geospatial Recipe for Identifying Social Values and Fragmentation Issues of the Friends of the Dunes Land Trust." *Humboldt Journal of Social Relations* 41: 6–19.

A Geospatial Recipe for Identifying Social Values and Fragmentation Issues of the Friends of the Dunes Land Trust

Buddhika Madurapperuma[a], Jess Barger[b], Melissa Collin[a], Christine Emerson[a], Sean Fleming[a], Brian Murphy[a]

Abstract

The beach and coastal sand dunes comprise a dynamic and fragile ecosystem that provides a bounty of ecological services. These lands provide protection from coastal erosion and sea level rise, and are home to a rich biodiversity of plant and animal species in addition to their recreational value. The Humboldt Coastal Nature Center and the surrounding coastal dunes (HCNC) are managed as a land trust by Friends of the Dunes (FOD). FOD prioritize the restoration of dune habitats and encourages public involvement through community supported education and stewardship programs, guided nature tours, and naturalist training programs. The faculty, students, and staff of Humboldt State University regularly collaborate with FOD for research and volunteer programs. For example, mapping of the coastal dune habitats was performed in 2016, 2017 and 2018 by students from the intermediate remote sensing class and produced results addressing research gaps on social trails, dune movement, sea level rise, and invasive species distribution. This paper examines the natural and anthropocentric changes to the dune habitat from a geospatial perspective and identifies the social values of visitors to the dunes using HCNC visitor records. A small Unmanned Aerial Vehicle (sUAV) was used to acquire high-resolution imagery and then an orthomosaic image with 14 cm spatial resolution was created using the Structure from Motion (SfM) technique within the software Agisoft PhotoScan. sUAV imagery and existing maps were used to digitize social trails and distinguish them from official trails. Coastline change and dune movement were determined using UAV imagery, NAIP satellite imagery, and lidar data. Visitor records of the HCNC were analysed using word clouds and line charts. The results showed that many of the social trails emerged from the neighborhoods southeast of the FOD land trust. As an observation, some directional signs for public access trails pointed out from the trail and may have caused confusion to visitors and misguided them into creating social trails. The social trails have disturbed nesting colonies of bees and led to trampling of dune mat habitats and rare plant communities. A word cloud created from visitor logs depicted that visitors had wonderful experiences at the coastal dunes and beach and highly support the conservation efforts underway. In conclusion, we believe these findings can be used as baseline information to help inform management techniques in order to better fit the region of interest and support the mission of the Friends of the Dunes land trust.

Keywords

Coastal sand dunes, sUAV imagery, social trails, dune movement, visitor records

The coastal dunes of Humboldt Bay are a dynamic and constantly changing environment that provide ecological benefits for living communities and act as a protective barrier from coastal inundation, bolstering our tsunami defenses. From information shared between land managers, we know that recreational trails are being created by human visitors, and that this is causing habitat fragmentation for other species (Bradford and McIntyre 2007). What we do not know is the degree of human-induced impacts on the ecosystem and the resulting effects on native plant and animal populations. Consequently, our research looks to address the potential impacts of habitat fragmentation created by recreational trails and their effects on animal and plant populations. The objective of this research is to create a lens through which to view threats to native plants and wildlife in relation to anthropocentric environmental change, with the focus of the case study being on which ways the dune habitats and its biotic communities may be affected by members of the public. Our research addresses a major gap in current scientific literature and will contribute theoretically, empirically, and analytically to the ongoing debates in the fields of natural resource science, environmental protection and management, environmental education and interpretation, and social relations.

History of the Friends of the Dunes Land Trust

Friends of the Dunes (FOD) manages approximately 130-acres of coastal dunes on Humboldt Bay's North Spit as a land trust (Fig. 1). As land owned by a non-profit, the Friends of the Dunes land trust (FOD land trust) is considered privately owned, and is managed to benefit wildlife as well as the public. Currently, the trail system and adjacent Humboldt Coastal Nature Center (HCNC) are regularly used by neighbors, community members, and tourists year round. Prior to the purchase made in 2007, the "Stamps Property" was owned by a retired couple that shared coastal access with the community of Manila, which allowed many social trails to be created. Through access from the Stamps' home and neighboring dune properties, a network of user-created routes (UCRs) have existed on the property for decades as seen through aerial photos (Rochefort and Swinney 2000; Madurapperuma et al. 2018). UCR's are simply trails that become established by the public when they deviate from designated trails set up by the landowner or public agency. There are many issues surrounding the user-created and unregulated trails, particularly the matters of public safety, habitat degradation, spreading of invasive species, and impacts to wildlife (Leung 2010; Moreno-Casasola 1986). As a novel approach, sUAV imagery provides better spatial and temporal resolution, which can be utilized to monitor disturbances such as social trails, distribution of invasive species, and habitat fragmentation (Lamping et al. 2018).

Due to a combination of visitors and locals that are determined to walk UCRs that they created and enjoy, FOD inherited a suite of issues and responsibilities when they purchased the property. UCRs cause a multitude of problems for landowners and the public; they spread invasive plant seeds, fragment wildlife habitat, and create more area that managers must monitor for safety concerns. Creation of a formal trails plan began in 2007 when the property was purchased, in order to begin to attempt mitigating the effects the UCR's had already created, such as loss of native bee habitat and invasive species spread. During the creation of this plan, the issues facing

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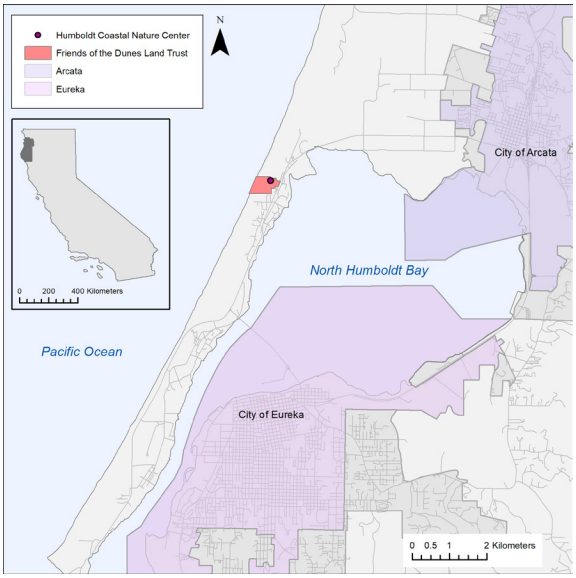

Figure 1. Locator map of the Friends of the Dune Land Trust and the Humboldt Coastal Nature Center in relation to the cities of Arcata and Eureka. Data from Humboldt County GIS data portal.

the dunes, as well as the needs of the community, were taken into consideration. Due to a high number of parallel and equivalent UCRs (i.e. trails that are relatively close together and provide similar access to the same area of the beach or dunes) that fragmented the unique ecosystem of coastal grasslands and dune-mat, closure of some UCRs was included into the plan. This induced controversy in the forms of public scrutiny and criticism. Many complaints stemmed from resistance to the idea of closing "historic trails" that the public previously accessed freely. Many local citizens had been using these areas for decades, considered the routes a part of the natural habitat, and were not willing to give up what many felt was their right to walk in the area that suited them most.

Due to the public outcry, many UCRs set for removal have remained untouched by FOD staff and volunteers for the past 12 years. Signs are placed at junctions of designated trails and UCRs to urge users to stay on the designated trails; however, these signs are ignored, removed, and frequently found broken by visitors. A great deal of time and effort goes into putting up these signs, as well as educating trail users about habitat fragmentation and the dune plant and animal species it affects. Friends of the Dunes organizes monthly walks on various dune properties in the area in the hopes that they can help to protect the dunes through education, as opposed to signs.

This is not an issue specific to FOD; balancing the needs of the environment with those of the public is a problem facing land managers everywhere (Coppes and Braunisch 2013; Korpilo et al. 2018; Walden-Schreiner et al. 2018). Locally, there is an ongoing debate between managers of coastal dunes and the public concerning the protection of these habitats and recreation needs. Members of the public are reluctant to see that UCRs are impacting the environment, and therefore take issue with FOD's desire to consolidate trails and provide more habitats, specifically for endangered coastal grasslands and dune-mat (Friends of the Dunes 2010). Part of this debate is a lack of quantifiable evidence that UCRs are degrading or taking away habitat, as most of the current evidence is based on logical deductions about the needs of endangered plant and sensitive animal species. If quantified impacts to the local environment could be determined, it would be a great tool for local land managers who have hit a wall with local government and citizens over the protection of the dunes.

Ecological and Social Values of the Dunes

Coastal dune ecosystems provide a wide ecological niche to house rich biodiversity unique to this ecosystem. For example, wild flora of the dune habitats support over 40 bee species as foraging and nesting grounds. Many of these species are ground-nesting, solitary bees that build

tunnels under the sand. This requires undisturbed areas where their offspring can spend the majority of the year developing safely (Friends of the Dunes 2019). The dune mat community provides micro-habitat conditions to grow rare and endangered plants, such as the Humboldt Bay wallflower (*Erysimum menziesii eurekensii*) and the Beach layia (*Layia carnosa*) (Friends of the Dunes 2015). These plants require open habitat where they can be exposed to low levels of sand movement. Due to their short and succulent nature and the lack of large animals in the dunes, many of the species do not survive if they experience any trampling (Friends of the Dunes 2017). The major threats for the endangered plants were reported as invasive species (i.e. European beach grass, rattlesnake grass, and yellow Bush) and trampling due to social trails (Friends of the Dunes 2015; Cortenbach et al. 2017; Julian 2012; Madurapperuma et al. 2018; Pickart and Patrick 2019).

Landowners with trail systems are responsible for designating, maintaining, and monitoring the impact that trails have on the environment, especially to listed species. Anecdotal evidence by FOD employees and volunteers show that endangered species are often found destroyed by human and domestic dog footprints. Additionally, UCR's provide access to remote areas which encourages illegal or potentially dangerous activities. It is not uncommon to find hypodermic needles, broken glass, and biologically dangerous items in remote areas of the dunes (J. Barger, personal communication, February 20, 2019). Due to limited resources, FOD is only able to monitor the designated trails on the property. The purpose of the FOD land trust is to provide places where members of the public can experience these unique habitats safely, but current conditions put the habitat at jeopardy, and potentially the visitors of the dunes as well (J. Barger, personal communication, February 20, 2019).

METHODS

This study outlines the mixed-methodology of using geospatial and social science qualitative methods (Rindfuss et al. 1998) to portray the land and ecological change in the FOD. Through the reconnaissance survey and panel discussion with the FOD staff, we located the majority of large-scale UCRs in the southern portion of the FOD. Using this information, two mission plans were developed and executed to take high resolution aerial imagery. Images were collected using a DJI Mavic Pro small Unmanned Aerial Vehicle (sUAV) for a 31 acre plot of the southern dunes at a height of about 80 meters (Madurapperuma et al. 2018).

High-resolution data is useful in gathering fine scale characteristics, such as slope, aspect, and digital elevation models. NAIP imagery provides high resolution images within 1 meter spatial resolution throughout the United States every 3–5 years. Using the collected aerial images, an orthomosaic image was created using the Structure from Motion (SfM) technique in the Agisoft PhotoScan software. A digital elevation model (DEM) with a resolution of roughly 14 centimeters was also created in Agisoft with the aerial images using dense-point cloud data to show terrain characteristics and dune movements. Data available to the public for download from federally funded programs, such as NAIP imagery, between 2004 and 2014 from U.S. Department of Agriculture's (USDA) Geospatial Data Gateway and lidar imagery between 2010 and 2012 from National Oceanic and Atmospheric Administration's (NOAA) were used to detect coastline changes using screen digitizing (Kenas et al., 2016). UCRs and trails were digitized and categorized based manually, using trails maps from the FOD and

the orthomosaic for reference. The images were also utilized to identify changes in dune physical characteristics that could be linked to human activities during the peak visitor season.

The social data were gathered from the visitor log at the HCNC from 2011 to 2017. This included comments, where they were visiting from, and the date that they visited. In addition to HCNC visitor logs, clicker counts of the number of visitors to HCNC were documented. The data was analyzed using word clouds and line graphs.

The high resolution geospatial data was used to generate a visualization of the UCRs and to delineate invasive species habitats. The historical visitor records data were plotted to see the frequency of human activities throughout the year. Knowing when the peak time of visitor arrival occurs is useful in determining the best time to collect geospatial data again for better understanding on how human activities impact for fragmentation i.e. UCRs.

RESULTS

The results of this study fall within two broad themes: geospatial and social dimensions. Geospatial analysis was conducted by mapping the social trails and coastline changes in the dune ecosystem using high resolution images and lidar data. The social values of the dunes were graphically represented using the visitor records data. By coupling geospatial and social science data in this study, we determined useful finds regarding the relationships between anthropogenic disturbances and how visitor peak times are associated with ecological fragmentation.

Ecological and Social Values

It's estimated that for every meter of trail being monitored and maintained, there are almost two meters of undocumented, unmonitored trails. This means that the impact to the dune habitat through fragmentation and habitat loss is three times as what was anticipated in the FOD Trail Plan.

Remote sensing imagery is one of the newest and most cost-effective tools in a land manager's toolbox. The varying and ever-changing topography of the dunes causes challenges for mapping and maintaining an inventory of the social trails and presence of invasive species. During World War II, the United States Coast Guard patrolled the north spit coast of Humboldt Bay; however, recognition of these social trails from aerial imagery was unsuccessful (Friends of the Dunes 2010). Complicating this task further is the limitation of inadequate staffing and funding for monitoring projects. A multi-scale study on dune habitats was carried out by a group of undergraduate students at Humboldt State University, which identified social trails from sUAV imagery through the digitization social trails visible in the imagery (Cortenbach et al. 2017; Lamping et al. 2018). The total length of trails given in Fig. 2 was 911 m. Of the unmonitored trails, estimated length for minimal use was 317 m, moderate use was 159 m, and heavy use was 168 m. The invasive *Briza maxima*, with proximity to sea shore and the study area, was mapped using *in-situ* data collection.

During the peak visitor season in July and August, a large number of people visit the dunes from many regions. A noticeable amount of social trails have arisen due to off-trail use by visitors when accessing sites of interest and when attempting to take shortcuts. This leads to significant disturbance of endangered herbaceous communities and high risk of habitat loss from the increased fragmentation of natural areas. Habitat fragmentation caused by UCRs increases spatial isolation and could eventually lead to the spread of invasive species and reduction of native flora and fauna. These changes disrupt the

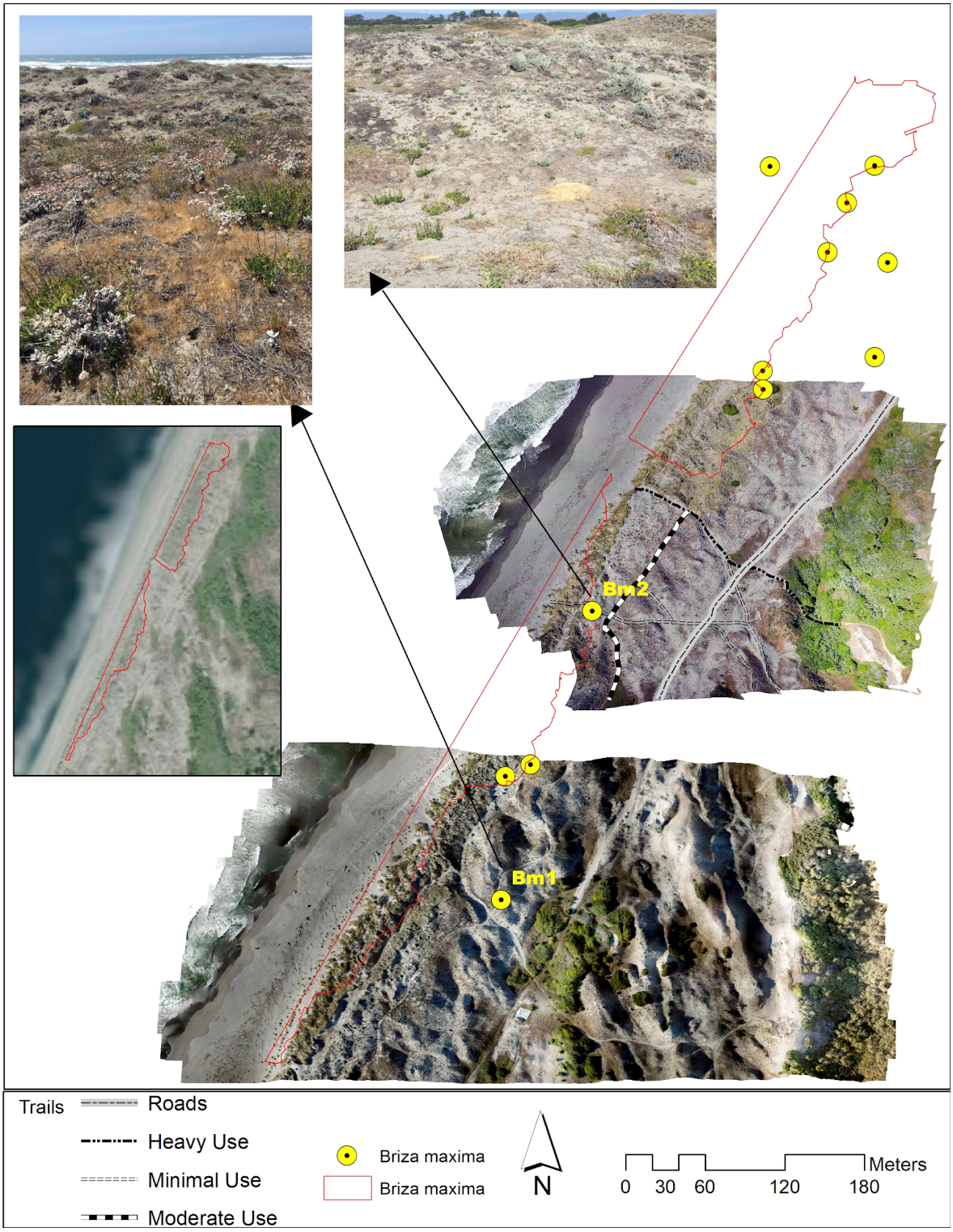

Figure 2. Social trails identified using sUAV imagery taken at the Friends of the Dunes (FOD) in 2017 (above image) and the southern FOD in 2018 showing dynamic sand dune habitats and prominent user-created rtoutes (below image). *Briza maxima*, annual invasive grass is shown by red polygon and dominant locations (yellow circle). The species occurrence at two sites (Bm1 and Bm 2) is displayed with photos.

essential spatial component necessary for genetic variation and could alter essential processes, ultimately leading to the risk of local extinction. Reduced genetic variation could also potentially hinder a species' ability to adapt to environmental changes (López-Pujol et al. 2003). For example, bee nests are highly sensitive to disturbance. Many of the bee species nests are just below the surface of the soil crust, making them extremely vulnerable to trampling. Other species, such as the silver bee nest in blown out areas, in open sand, or near the base of vegetated dunes. These kinds of nesting locations are often used as parts of UCRs because the sparse vegetation and gentler slopes make these areas easier for people to walk through.

Dune Movement

Coastal sand dunes are constantly shifting due to coastal erosion and the continual movement of the dunes by the wind (Mitasova 2005; Mull and Ruggiero 2014, Labuz 2015). The foredunes, which in our study site are the dunes west of the Waterline Trail, are dominated by dune mat vegetation or European beachgrass (Madurapperuma et al. 2018). These foredunes have only localized areas of sand movement. The dunes move slowly through small pockets or "tongues" of sand, especially during the summer months. Additionally, the large areas of sand that were shown to have significant movements are also expected to be that of a specific microhabitat—a moving sand sheet. Not only is dune movement is important for nutrient cycling, but it provides a niche for unique specialist species, and helps facilitate a diverse dynamic ecological community (Moreno-Casasola 1986). During the summer, the sand is dry and very susceptible to being moved by the wind (Rader et al. 2018, Pickart and Patrick 2019, Hapke et al. 2006, Hapke et al. 2009). The winds on this portion of the coast blow primarily from the northwest in the summertime. This wind pattern causes the formation of parabolic dunes, the type of dunes seen on the spits of Humboldt Bay (Moffat and Nichol 2013; Pickart and Patrick 2019; Hapke et al. 2006). Within the local dune ecosystem, very large unvegetated parabolic dunes, known as moving dunes, are slow to become colonized by plant species, and slowly move toward the southeast during the summer (Friends of the Dunes 2017).

Remote-sensing techniques are an important way to measure dune movement and/or expansion through the use of high resolution images. For example, SUAV imagery provides better sampling efficiency and data quality, which is useful in capturing the micro-topographical variation of dune ecosystems (Madurapperuma et al. 2018). According to the 2018 Lamping et al. study on dune movement, the largest amount of change can be seen on the northeastern facing slopes that are not directly exposed to wind from the ocean.

Kenas et al. (2016) used NAIP imagery and lidar data to measure dune movement at the Male'l Dunes and found slight dune movement and expansion towards the east between 2004 and 2014 (Fig. 3).

Social Values

Humboldt Bay beaches and dunes provide high amounts of social and recreational value as areas for hiking, walking, photography, and general recreation. The FOD land trust is frequently visited by not only locals, but tourists from all over the world (J. Barger, personal communication, February 20, 2019). Visitors' personal experiences, as well as their perceptions of the FOD land

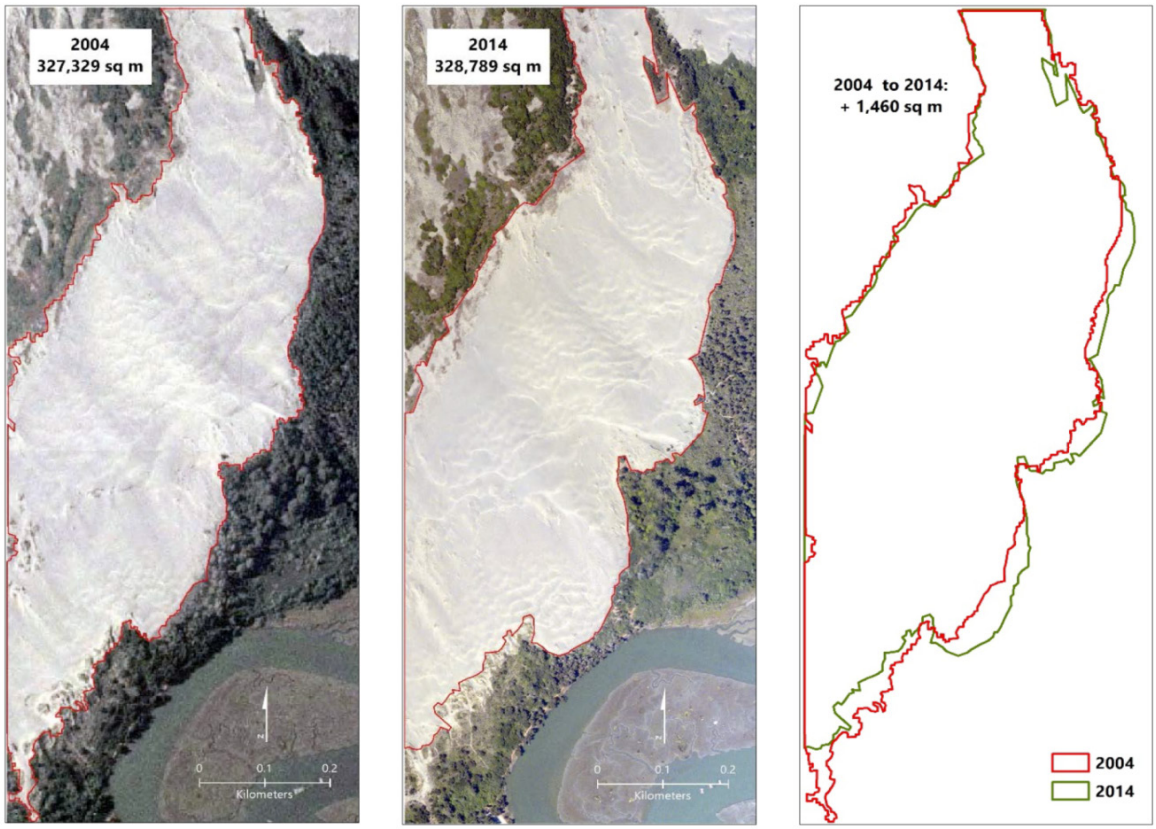

Figure 3. Coastal shoreline changes of Ma-le'l Dunes in Humboldt County between 2004 and 2014 (Left 2004 NAIP imagery and digitized shapefile, middle 2014 NAIP imagery and digitized shapefile, right comparison of 2004 and 2014 digitized shapefile) (Source: Kenas et al. 2016).

word cloud (Fig. 4). The frequency of words is represented by font size, with the most frequent words being the largest. The majority of visitors had great experiences at the FOD land trust based upon recreational value of the unique habitat, walking trails, and fun activities, such as restoration. The word cloud depicts visitor's satisfaction and their attraction to the FOD land trust. Visitors left reviews and comments with frequently used words such as love, cool, nice, great, beautiful, amazing, gorgeous, wonderful, awesome and fabulous etc.

The visitor records from HCNC were accumulated monthly and plotted from 2011 to 2016 (Fig. 5). The average monthly visitor records for the dunes was 125 over 6 years. 2015 had the largest number of HCNC visitors, with an average of 170 visitors per month. The visitor season is observed as July and August with an average of 214 and 178 visitors respectively.

Visitor records that were obtained from the clicker counts were plotted from 2012 to 2017 (Fig. 6). A few months of visitor records were missed in 2012. An average of 604 people per month visited the dunes from 2013 to 2017. The largest number of visitors (with average monthly

Figure 4. Word cloud of visitor comments from the FOD land trust visitor logs. Larger words indicate more frequent occurrence in the comment section of the visitor logs.

visitors) visited the HCNC in 2013, with peaks in April and October. Overall, a large number of visitors were observed in July and August (with an average of 861 and 747 respectively) at the dunes.

The visitor records from clicker counts indicate a large, consistent usage over five consecutive years of the HCNC with close to double the number of visitors during the summer seasons. Additional beach usage likely occurred, but was not documented, from those who visited outside of HCNC hours, visited using a different entrance, or were missed during the clicker count.

DISCUSSION

This study involved both a geospatial and social science lens in order to analyze the continuous human and natural impacts on the Humboldt Bay coastal dune ecosystem. The research conducted provides substantive information which could be used by decision makers for coastal habitat management.

High resolution aerial imagery is useful for delineating social trails and mapping invasive species habitats (Cortenbach et al. 2017; Madurapperuma et al. 2018; Lamping et al. 2018), which is crucial information for dune managers to implement the best management plans to conserve dune habitats. The ability to recognize trails from medium resolution images (i.e. Landsat) is not feasible; however, orthomosaic sUAV imagery overcome the limitation of recognizing social trails through open sand and sparse dune mat vegetation. Compared to Landsat imagery, sUAV imagery has more advantages: (i) high spatial resolution (~14 cm), (ii) high temporal resolution, and (iii) associate with elevation data which can create DEM.

Invasive species became dominant at Humboldt coastal dune areas, and we mapped *Briza maxima* colonization along the foredune of FOD (Fig. 2). Transgressive grasses and forbs, such as *Ammophila arenaria* and *Lupinus arboreus*, encroach towards dunefield due to wind blowout (Pickarta and Patrick 2019; Madurapperuma 2018). As Fig. 2 showed, the beach pine forest

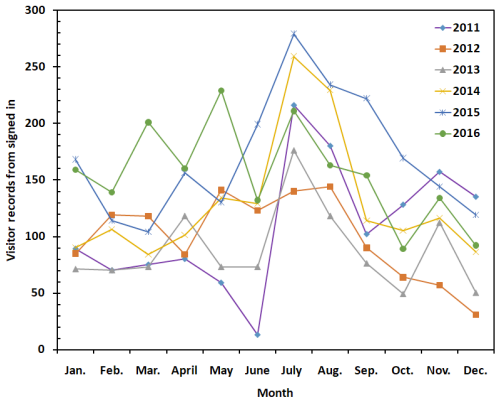

Figure 5. Visitor records at Friends of the Dunes from 2011 to 2016.

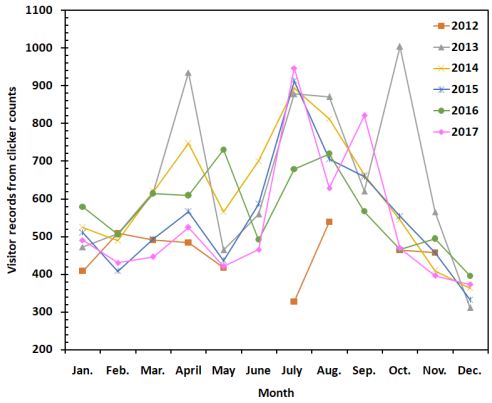

Figure 6. Visitor records at Friends of the Dunes from clicker counts from 2012 to 2017.

was scattered around central and far-east dune which permits less barrier for wind blowout. Lamping et al. (2018) and Madurapperuma et al. (2018) mapped invasive species distribution in these areas using SUAV imagery and supervised classification techniques. The dune habitat restoration was employed on the North Spit of Humboldt Bay by manual removal of exotic species (i.e. *Lupinus arboreus*, *Vulpia bromoides*, and *Holcus lanatus*) through volunteer programs resulting in re-colonization by native species (Pickart et al. 1998).

According to Kenas et al. (2016), findings on dune movement in the Malel'l dunes between 2010 to 2012 reported to be 0.5 m to 1.0 m with an elevation gain of six to seven centimeters. Similarly, Hapke et al., (2009) reported 0.3 m–0.5 m shoreline change in Northern California. In particular, Eureka attributed long-term shoreline change patterns due to variations in waves and currents (Hapke et al. 2006; 2009). The geomorphology of the Northern California coastline has contributed such coast line changes via cliff formation, crenulated headlands and embayments (Hapke et al. 2009).

A participatory GIS (PGIS) approach would be an ideal scenario to collaborate with the local neighboring community for restoration programs to control invasive species, and to make an awareness program on UCRs and their impact on native and invasive flora. Participatory GIS has the ability to inform land managers, environmental educators, and environmental interpreters on aspects of the ecosystem being studied in ways that are otherwise impossible. By incorporating the community into the process of conservation, they receive power over how the land they interact with is represented into data which will, in turn, be applied to how it is managed (Tsai 2013). Public PGIS can redistribute power to the visitors because they can depict their subjective view of the dunes, and how management affects their experiences (Tsai 2013). However, while PGIS can greatly increase the amount of data, representation is still limited by technological and social obstacles (Elwood 2008).

Many non-profit organizations, such as FOD, have limited staff and funding, making cost and time-effective techniques invaluable. From a land manager and dune ecology perspective, aerial imagery is an incredible time-saving resource that can allow managers to visually evaluate an environment that has topographical barriers, such as high dunes, some of which are forested. Additionally, it allows managers to capture changes in sand movement that can otherwise

only be measured using expensive lidar experiments that require replicable surveys, and are not always possible in the ever-changing terrain, such as a moving sand sheet.

When the cause of the sand movement is UCRs, the implications of PGIS are not only ecological, but social. Many members of the public need some sort of tangible effect of their fragmentation to understand their impact, and cause a change in their behavior. The results of this research can be used to demonstrate to the public how many acres a UCR fragments, and how many square feet of dune mat vegetation are lost, etc., which can be used in environmental education and interpretation programs. This data could be incorporated into a web page, facilitating the public with the data that PGIS collects (Tang 2016). A mobile app could also increase the amount of educational material the FOD visitors could receive without building new infrastructure, such as signs (Lorenzi 2014). Using PGIS in the form of a mobile app could allow visitors to generate data that has been spatially located and time stamped.

As visitor records portray (Figs. 5 and 6), during the summer or tourist season, there is a possibility that UCRs would be reinforced or widened by unfamiliar tourists. The sUAV imagery can monitor, during visitors peak times, social trails, and can be coupled with recruiting more volunteers for patrolling and conducting awareness programs to mitigate the human impact on dune habitats. In addition, waypoints could be incorporated into an app in order to ease visitors into reorienting themselves if they get lost. Waypoint systems can function without the use of network access, making them a valuable tool for hikers who experience loss of cell signal or GPS failure (Lorenzi 2014). This assisted navigation applied at the FOD land trust could redirect visitors off of UCRs and to the designated trails. Alternatively, during non-tourist season, it could be predicted that new social trails would be created by locals that have a higher level of ownership for the area, and are more likely to "explore" in off-trail areas, creating UCRs in the process.

This research opens the door into studying human behavior in the context of natural resource ownership by evaluating the effect of different kinds of use on a habitat. Dunes are a particularly responsive habitat; it only takes a few visitors to walk in the same path to establish a path through the vegetation. Future applications of this research could help determine in which months to focus education about trails, and to quickly determine which UCRs are becoming most established or most detrimental.

While land managers will likely continue to face challenges surrounding public access and trail maintenance, the increased integrated use of GIS technology and land trust organizations can aid in developing more efficient and effective education and stewardship strategies for combating habitat fragmentation and degradation created by UCRs.

CONCLUSIONS

This study presents an overview and methodology on the use of geospatial technology, such as sUAVs, to monitor changes in a coastal dune environment. Because this type of analysis can be used to inform management and policy decisions, it has implications in the fields of natural resources, ecological restoration, environmental education, and environmental interpretation. Geospatial analysis and the use of remote sensing allow for improved information gathering because of the high spatial and temporal

resolution that sUAV data provides. As shown in this study, sUAVs are extremely useful in generating valuable geospatial data, such as social trail identification, with high accuracy and relatively low cost. This valuable data can be used to monitor the most current state of the dunes and make models and predictions of future land use/cover changes. Future use of PGIS could also play an integral role in collecting data and incorporating the visitors into the conservation process. Understanding where social trails are emerging and being able to map the extent of invasive species is crucial for the FOD land trust in order to implement best land management practices and meet their goals of ecological restoration of native plant habitats, controlling invasive plant populations, and conservation and preservation of coastal land. Meeting these goals is important because of the high value the public has assigned to these areas, as evidenced by the visitor records charts and word cloud presented in this study.

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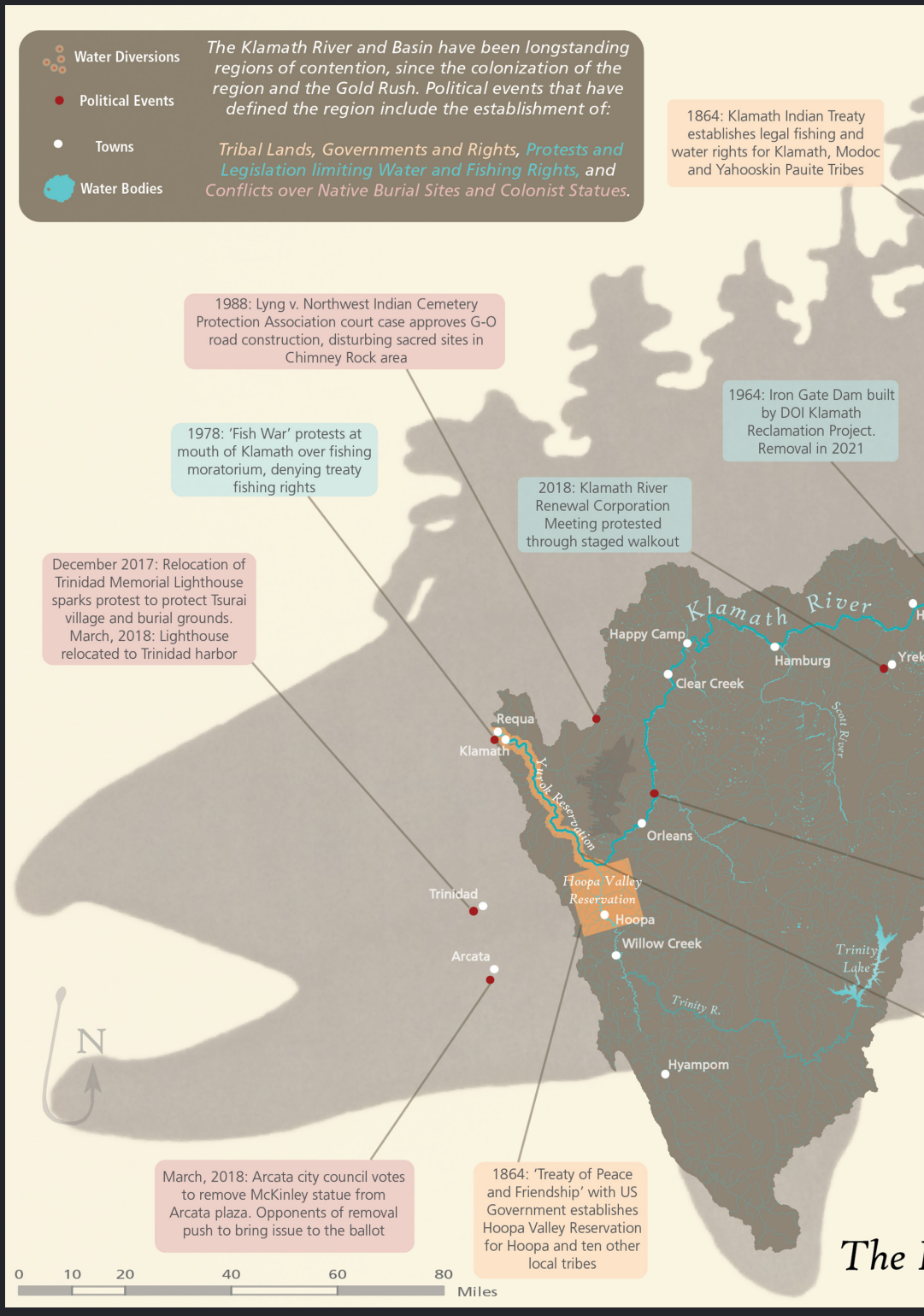
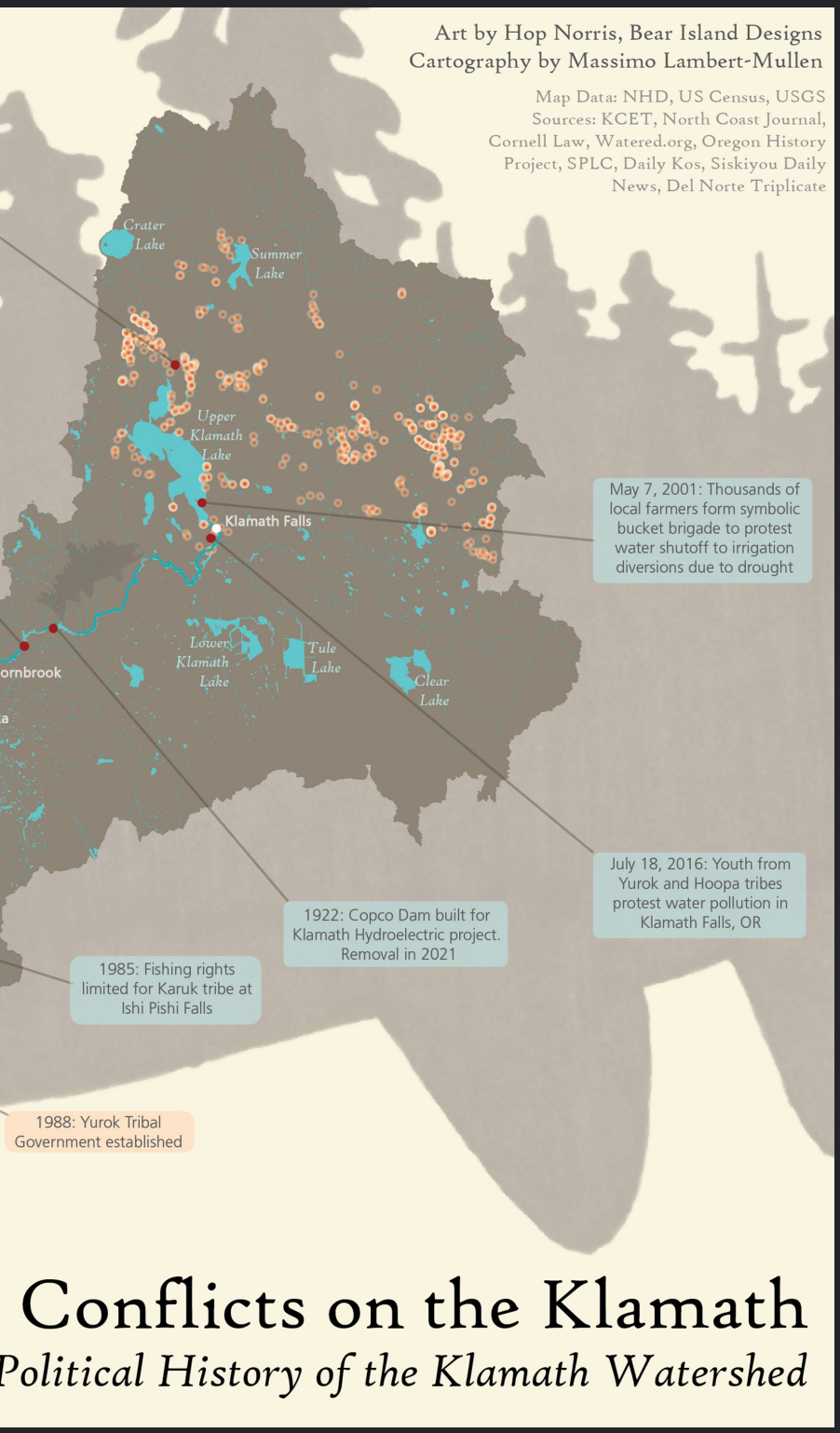
Massimo Lambert-Mullen is an urban farmer, activist, and geographer who recently graduated from Humboldt State University with a Bachelor's of Arts in Geography, and has been living in the San Francisco Bay Area. When he is not tending to vegetable gardens or installing irrigation systems, he is volunteering in local community projects and traveling.

Hop Norris is a father, husband, artist, activist, water warrior, and culture bearer. He is the owner of Bear Island Designs, where he sells beautiful custom printed clothing and apparel as well as jewelry made by his wife, Brigette, and himself.

MASSIMO LAMBERT-MULLEN



& HOP NORRIS



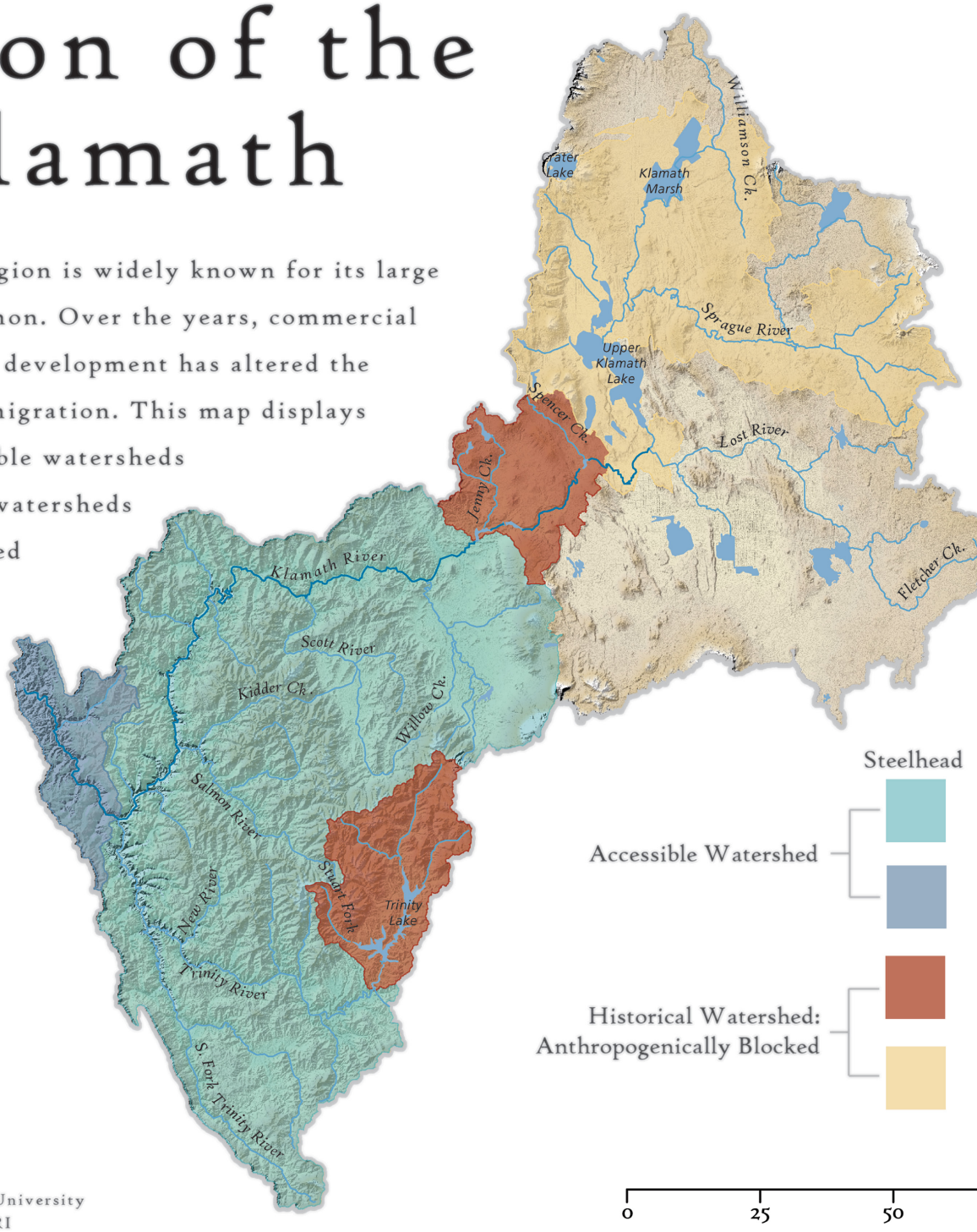
Conflicts on the Klamath is a collaboration between Massimo Lambert-Mullen, a Humboldt State University Geography alumnus, and Hop Norris, a local artist, activist, and water protector based out of Crescent City, California. The inspiration behind this infographic is the complex and rich contemporary history of the Klamath river, including the establishment of reservations and the construction of dams, roads, and monuments that disrupt the flow of salmon and disrespect sacred sites. It is a politically motivated piece that means to convey the cultural and ecological importance of salmon and criticize government and settler actions to disenfranchise local Yurok, Hoopa, and Karuk tribal members of their fishing rights. The visual effect of depicting water diversions in the Upper Klamath basin as salmon eggs conveys that salmon should be allowed to swim the full length of the river, and restore its poisoned ecology. Un-Dam the Klamath!

Melissa Collin is currently an undergraduate at Humboldt State University (HSU) majoring in Environmental Science and Management with a concentration in Geospatial Science and minoring in Ecological Restoration. This coming fall she will begin her studies with HSU's graduate program, working towards a Master's Degree in Natural Resources. She is currently working as a GIS Specialist for an environmental consulting company, and was previously an Instructional Student Assistant for the geospatial curriculum. Melissa's research interests and experience include web development, watershed modeling, land cover analysis, cartography, and coastal habitat mapping.

MELISSA COLLIN

Salmon of the Klamath

The Klamath bioregion is widely known for its large populations of salmon. Over the years, commercial fishing and human development has altered the salmon's historic migration. This map displays the current accessible watersheds and the historical watersheds that are now blocked for the 3 most prevelant salmon species: Coho, Steelhead, and Chinook.



Melissa Collin 18 |Humboldt State University
Data Sources: NOAA Fisheries, ESRI

The Klamath is a diverse bioregion widely known for its abundant population of salmon. It extends through the states of Oregon and California, and has a drainage basin of over 15,000 square miles that flows into the Klamath River. The three most prevalent species of salmon in the region (Coho, Steelhead, and Chinook) have all experienced sharp declines in populations since the mid-20th century. This is due to human activity such as commercial fishing, logging, dams, and urban development that has altered the salmon's historic migration. This map aims to visualize the various waterways and water bodies that flow throughout the basin, while showing the current accessible watersheds and the historical watersheds that have been anthropogenically blocked.

Perdue, Nicholas. 2019. "Agent-based Models in Supporting Pedestrian Transportation Planning and Design." *Humboldt Journal of Social Relations* 41: 24–41.

Agent-based Models in Supporting Pedestrian Transportation Planning and Design

Nicholas Perdue[a]

Abstract

Agent-based models offer a new approach to understanding human-urban interactions in transportation systems, allowing individual entities within a system to be characterized with cognitive and behavioral properties. This paper discussed the role of agent-based representations of pedestrian transportation systems, detailing the underlying assumptions and techniques behind different types of pedestrian models and illustrating the differences between aggregate and individual agent representations. It then turns attention to the case study and the development of a cognitive pedestrian model as a way to illustrate the spectrum of potential spatial behaviors that are enabled by material changes to the transportation network. The paper concludes with a discussion and specific frameworks for employing agent-based models to support transportation planning decisions.

Cities across the country are struggling with how to best address a network of street infrastructure that in many ways opposes shifting views of public health, urban transportation, and environmental sustainability. Many scholars advocate for a "complete street" design that enables safe access for all modes of transportation, maintaining that inclusive changes to street infrastructure can address the spatial mismatches in contemporary cities, while increasing the public safety and walkability of neighborhoods (Ewing et al. 2006; Schlossberg 2013). The design of walkable neighborhoods and pedestrian-oriented spaces are often portrayed as simple, solution-based approaches to redevelopment that can address myriad structural and social issues in the city (Speck 2012), and scholars emphasize deeper engagements between street infrastructure and human-scale pedestrian behaviors can form a strong theoretical foundation for more sustainable urban practices (Kenworthy 2006). As the public becomes increasingly aware of walkability as a measure of urban health, scholars and practitioners are beginning to focus more attention on both the structural elements of pedestrian-oriented design as well as the human experiences in practices of walking.

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Despite the need for pedestrian-oriented redevelopment, transforming existing street infrastructure is not a straightforward process, and the human responses to such changes are complex, dynamic, and plural. Modernist approaches to planning and design have embedded a set of automobile-oriented values into our collective urban imagination, bracketing our concept of streets and rendering alternative configurations and uses difficult to imagine (Forsyth and Southworth 2008). These embedded values often lead to confusions about the impacts of proposed changes among a variety of local stakeholders; thus, many redevelopment projects proposing to transform existing street infrastructure are met by the public with a great deal of confusion, often interrupting, delaying, or fostering resentment towards the proposed changes.

The paper will first discuss the history and context of agent-based models in pedestrian and human movement studies, with a particular focus on how different goal-oriented modeling frameworks have been implemented in the urban context and how these illustrate different types of movement scenarios. Next, a case study of a redevelopment project in the South Willamette Street corridor of Eugene, OR, will be introduced, highlighting both the need for changes to street infrastructure as well as alternative configurations to meet this need. Next, an agent-based model design is described using the ODD protocol (Grimm et al. 2010) that incorporates data-driven cognitive capabilities in pedestrian agents, interacting in a simulated environments matching the redevelopment proposals for South Willamette Street. The results of the model simulations illustrate the need for behavioral approaches to agent design, highlighting how the concept of individual cognitive capabilities can be incorporated into computational representations of transportation systems. Additionally, the results show how official assessments of redevelopment scenarios may be seriously limited in understanding the human impacts of changes in the built environment. The paper concludes with an extended discussion about agent-based modeling frameworks for supporting transportation planning and best practices for representing the individual spatial behaviors of pedestrians.

AGENT-BASED MODELS IN PEDESTRIAN STUDIES

Many sustainable transportation scholars advocate for the redesigning of city streets as a primary way to address issues from the local to the global scale, proposing that pedestrian-friendly configurations of street infrastructure can have a positive impact on issues ranging from citizen health to climate change (Forsyth and Southworth 2008; Speck 2012; Southworth 2014). Though pedestrian movement is a complex and difficult behavior to model (Whyte 1988), understanding how people move through space has important implications in practices of architecture, urban design, emergency management, and public safety. An agent-based modeling approach to investigate pedestrian movement often provides more flexibility, usability, and behavioral realism than traditional statistical or network optimization models (Torrens 2003). One unique benefit of an agent-based modeling platforms is the ability to understand how system-wide patterns emerge from a collection of individual behaviors and interactions, often producing results and insights that would be difficult to come by from the collection of the individual parts (Manson 2001; Bennett and McGinnis 2006).

Despite the ability to represent the heterogeneous behaviors of individuals, agent-based models are rarely employed in analysis and discussions about everyday individual pedestrian practice. This, in la is due in large part not to

exclusion by urban and transportation planners, but rather because the predominant way to represent pedestrian agents is rather narrow and limited. Many agent-based pedestrian models parameterize, or define agent behaviors, in collective rather than individualistic terms (Raubal 2001; Helbing et al. 2005; Bitgood and Dukes 2006; Torrens 2012). While collective representation may be best suited for planning issues at regional scales (Ligtenberg et al. 2004), aggregating individuals in pedestrian modeling often fails to capture the individual social motivations and cognitive processes of pedestrian behaviors. Thus, the use of generalizable agents is an appropriate representation for just two specific types of pedestrian behaviors: wayfinding models and evacuation models.

Pedestrian wayfinding models (see e.g., Raubal and Worboys 1999; Turner and Penn 2002; Antonini et al. 2006) typically use a stimuli-response framework to represent pedestrian movement, creating a set of causes and effects within the environment based on agent perceptual and physiological abilities. For example, an agent within the model environment perceives an environmental feature (e.g. a landmark) and responds with a specific behavior (e.g. turn right) in order to meet a defined goal. This approach focuses on the optimization of energy and spatially dependent variables as the catalyst for agent movement across the model landscape. In other words, agent perception of the environmental affords the planning and execution of rational, goal-driven actions (Torrens 2010). Portugali (2011) argues this approach to modeling pedestrian movement, while productive in certain scenarios, embeds agents with unrealistic motivations and abilities that lead to uniform and often inflexible representations of human behavior. While models with this design have been quite effective in representing pedestrian behavior in relatively static and single-purpose spaces, such as navigation through an airport terminal (Raubal 2001) or a shopping mall (Bitgood and Dukes 2006), they are limited in capturing broader and dynamic everyday pedestrian activities by assuming all agents to be rational, goal-oriented, and equal in abilities such as locating, encoding, and using salient environmental features in decision-making.

A second common type of pedestrian modeling using group-defined behaviors is extreme event or scenario-based models, such as emergency evacuation from a building or crowd flows at a festival (see e.g., Batty et al. 1998; Helbing et al. 2001; Shao and Terzopoulos 2005). Many scenario-based models are driven by agents perceiving and mimicking the movements of other agents, resulting in a sort of flocking behavior that creates an aggregated flow of people across space. This type of collective movement is typically referred to as a physics design (Helbing et al. 2005) in which individuals are treated as outwardly or physically reactive to environmental stimuli. As a result, computational resources focus primarily on physiological aspects of movement, such as steering, collision avoidance, and soft-body dynamics (Torrens 2012), producing realistic-looking but not necessarily realistic-behaving gamified pedestrian agents. Typically, these models represent agents homogenously in order to understand how crowds may react in certain situations or in response to different aspects of the built environment.

Homogenous agent design, however, limits the range of potential behavioral outputs that may prove more insightful both in understanding individual agency as well as the complexities of the whole system (Johansson and Kretz 2012). In moving towards expanding the role of agent-based modeling in support of urban and transportation planning, this paper advocates

for increased attention in representing humans as more than goal-oriented, rational, and reactive entities. To understand pedestrians beyond the limits of discrete and place-specific environments, we must work towards deeper representational frameworks that embody individual abilities and agencies rather than the collective representations common in many human-movement models. To explore this potential, I turn now to a case study of the South Willamette Street corridor in Eugene, Oregon, which is currently in the process of redevelopment with a particular focus on complete-street design to creates pedestrian friendly spaces and a walkable neighborhood.

STUDY AREA AND RESEARCH CONTEXT

South Willamette Street is typical of many streets in cities across the country—a car dominated arterial street intersecting a medium-density neighborhood with multiple modes of transportation competing in a limited space. In December 2013, the city of Eugene proposed the South Willamette Street Improvement Plan to improve an eight-block stretch of transportation infrastructure was in need of repair (Figure 1). The current configuration of a four-lane roadway with numerous driveways, obstructed and inaccessible sidewalks, and little bicycle or public transit facilities creates a relatively congested, disjointed, and, many argue, unsafe environment for pedestrian travel:

> "South Willamette Street is a multimodal corridor with a mixture of facilities to serve automobiles, bicycle, pedestrian, transit, and freight users. The challenge of providing mobility and accessibility to all users is managing various conflicts that arise, such as bikes and automobiles at driveways and turning trucks blocking travel lanes" (City of Eugene 2014).

In addition to addressing issues of multimodal interaction, redevelopment of South Willamette Street must meet the overlapping guidelines put in place by multiple agencies over the past two decades, including the Eugene Arterial and Collector Street Plan, the Eugene-Springfield Transportation Plan, and the Eugene Pedestrian and Bicycle Master Plan, resulting in a relatively unclear long-term vision for the space. Recognizing the need for redevelopment but without a clear framework of how to design, implement, and evaluate the impacts of the proposed changes on the transportation system in this short corridor, the city enlisted a private environmental consulting firm to assess the potential impacts of street improvement under a "triple-bottom-line approach to sustainability, providing for consideration of people, the planet, and prosperity" (City of Eugene 2014: V). Subsequent analysis proved inconclusive and city officials entered public meetings with a collection of alternative concepts for South Willamette Street and little insight into how the proposed changes may impact, among other things, pedestrian behavior. In order to better understand how pedestrians may be impacted by structural changes in the built environment, and specifically the impacts of each of the six conceptual alternatives, this paper introduces the design and analysis of an agent-based model to evaluate the relationship between redevelopment and everyday pedestrian behaviors.

METHODS

The purpose of the pedestrian and redevelopment (PAR) model is to represent a simple multi-agent pedestrian model street network to explore the effects of different municipal redevelopment plans in a simulated urban environment. Specifically, the PAR model explores the how six different conceptual alternatives

Figure 1. The South Willamette Street corridor, highlighting proposed changes between 24th and 32nd Ave. Pictures indicate the current state of the street infrastructure. Map: City of Eugene 2014. Photos: Julie Stringham 2016.

of the South Willamette Street corridor will impact a population of realistic pedestrian agents. The population of the PAR model is filled with agents who are parameterized with artificial different levels of spatial cognition, parameterized with data generated from a set of psychometric test. As cognitive variables are intangible constructs, they are difficult to directly measure. As such, psychometric test are commonly used to measure an individual's cognitive capabilities and preferences, strengths and weaknesses, and overall task completion strategies (Hegarty and Waller 2005).

This study uses five distinct cognitive variable sto construct the agent spatial intelligence: spatial memory, non-metric location coding, metric

location coding, path integration, and spatial reference frame. Spatial memory is an agent's ability to remember the location of objects while moving through the environment (McNamara 2002) and is measured with a 15-question sense of direction psychometric test (Hegarty et al. 2002). The cognitive variable non-metric location coding is the agent's ability to use the egocentric, first person perspective to perform a piecemeal updating of the environmental frame of reference (Wang and Brockmole 2003) and is measured with a 14-question self-location psychometric test (Lobben 2004). The cognitive variable metric location coding is the agent's ability to use the allocentric perspective to perform global updating of the environmental frame of reference (Holden and Newcombe 2013) and is measured with a 12-question environmental perspective psychometric test (Lobben 2007). The cognitive variable path integration is the agent's ability to maintain a sense of place recognition and direction of movement within an environment to create efficient routes (Loomis et al. 1999) and is measured with a 65-question spatial engagement survey (Cherney and Voyer 2010). The cognitive variable spatial reference frame is an agent's ability to use move between an egocentric and an allocentric perspective when conceptualizing the environment (Taylor and Brunyé 2013) and is measured with a route-planning test (Lobben 2004).

The suite of cognitive test was administered to 42 participants in July 2015. Rather than using the direct scores to parameterize the agents in the model environment, participant data is reduced with a principal component analysis to find a new set of desirable variables that efficiently represent the information in the original participant dataset. The principal component analysis reduces the individual cognitive properties of the 42 participants down to 4 primary groups based on performance across the 5 psychometric tests.

Group 1 (54%) exhibits high scores in the spatial memory and metric location coding tests, indicating a strong ability to remember the location of objects in the environment and use an allocentric or top-down perspective. Group 1 is classified as *purposeful walkers* to represent objective-driven pedestrians in the model environment. Group 2 (26%) exhibits high scores in non-metric location coding and spatial reference frame, indicating a strong ability to use an egocentric or first person perspective. Group 2 is classified as *social walkers* to represent more-than objective-driven pedestrians. Group 3 (13%) exhibits strong performance in across all tests and is classified as *experiential walkers* to represent individuals who shift between objective-driven and more-than objective driven practices. Group 4 (7%) exhibits low scores across all tests as is classified as *wanderer walkers* to represent random pedestrian behaviors. Each pedestrian type uses a different submodel to direct individual movement in the model environment.

It should be noted the classification of agent types from cognitive data for this particular set of simulations is not to say participants classified a certain way will exhibit the associated capabilities, strategies, and behaviors during all pedestrian activities. Rather, cognitive performance at any given time relies on a multitude of factors, many of which are immeasurable with psychometric test. Rather the data indicates that during this discrete set of test, participants exhibited a set of cognitive capabilities across multiple measures, which can be classified into pedestrian types for the purpose of coding the model and making a more meaningful representation of a heterogeneous population within the model environment.

During model setup, agents are assigned one of the 4 pedestrian types based on the proportion of variance for each principal component. The cognitive capabilities of the agents for each

of the 5 cognitive variables are assigned using a random value within one standard deviation of the mean for each pedestrian type, allowing the population of the model environment to scale up from the number of participants while maintaining realistic human cognitive capabilities in the agents.

The PAR model environment is a horizontally oriented five-block by three-block urban streetscape populated with cognitive pedestrian agents, private automobiles, and bicycles. Automobiles and bicycles travel along the gridded road network at various rates of speed, stopping at traffic signals and operating unaware of the pedestrian agents. The spatial resolution of the PAR model is 1 pixel = 20 feet and the temporal resolution is 1 time step = 2 seconds. Each simulation runs for a total of 2500 steps. Grid cells are classified as street, sidewalk, crosswalk, or development, based on the spatial configurations of the various conceptual alternatives for redevelopment, and remain constant over the course of each simulation.

Process Overview and Scheduling

The PAR model measures how each agent moves through the environment and interacts with the different features of proposed redevelopment. Different rule-based spatial movement submodels for each pedestrian type drive this human-urban interaction and the model directly measures how the agents respond to structural change in the built environment. The model environment can be altered with four parameters highlighted by qualitatively coding the six conceptual alternatives for street redevelopment outlined in the proposed South Willamette Street Improvement Plan.

The South Willamette Street Improvement Plan is a redevelopment strategy to improve the eight-block stretch of transportation infrastructure in Eugene, Oregon. In November 2012, six conceptual alternative configurations (Figure 2) of South Willamette Street was introduced to the public to create a strategy by the second meeting to evaluate each of the alternative designs. During the second meeting, both the Eugene City Manager and the Transportation Community Resource Group endorsed a formal screening criterion to quantitatively evaluate the alternative concepts, focusing on social, environmental, and economic impacts of redevelopment.

The formal screening criteria calculated scores from the six conceptual alternatives on 23 different measures across eight categories—*Access and Mobility, Safety and Health, Social Equity, Economic Benefit, Cost Effectiveness, Climate and Energy, Ecological Function, and Community Context*; 18 of the identified measures received a score as part of the formal assessment (Table 1). The formal assessment used a quantitative assessment, coding values of -1 to indicate negative changes, 0 to indicate no change, and +1 to indicate positive change. The sums of scores across all 18 measures create an index to evaluate the impact of each alternative concept.

The primary concern with this assessment is the assumption all variables have equal impact on the system as a whole. Rather than follow assumptions of linearity and accept that all inputs have equal weight on the final output, the PAR model allows for a more in-depth and nuanced exploration into the various combinations as well as the nonlinear processes that may indicate the relative strength of different variables; how unique combinations or arrangements of redevelopment practices could produce unexpected outcomes to the pedestrian agents in the model. The model environment is parameterized by qualitatively coding the 18 established measures into four categories that reflect the type of structural change—dimensional changes,

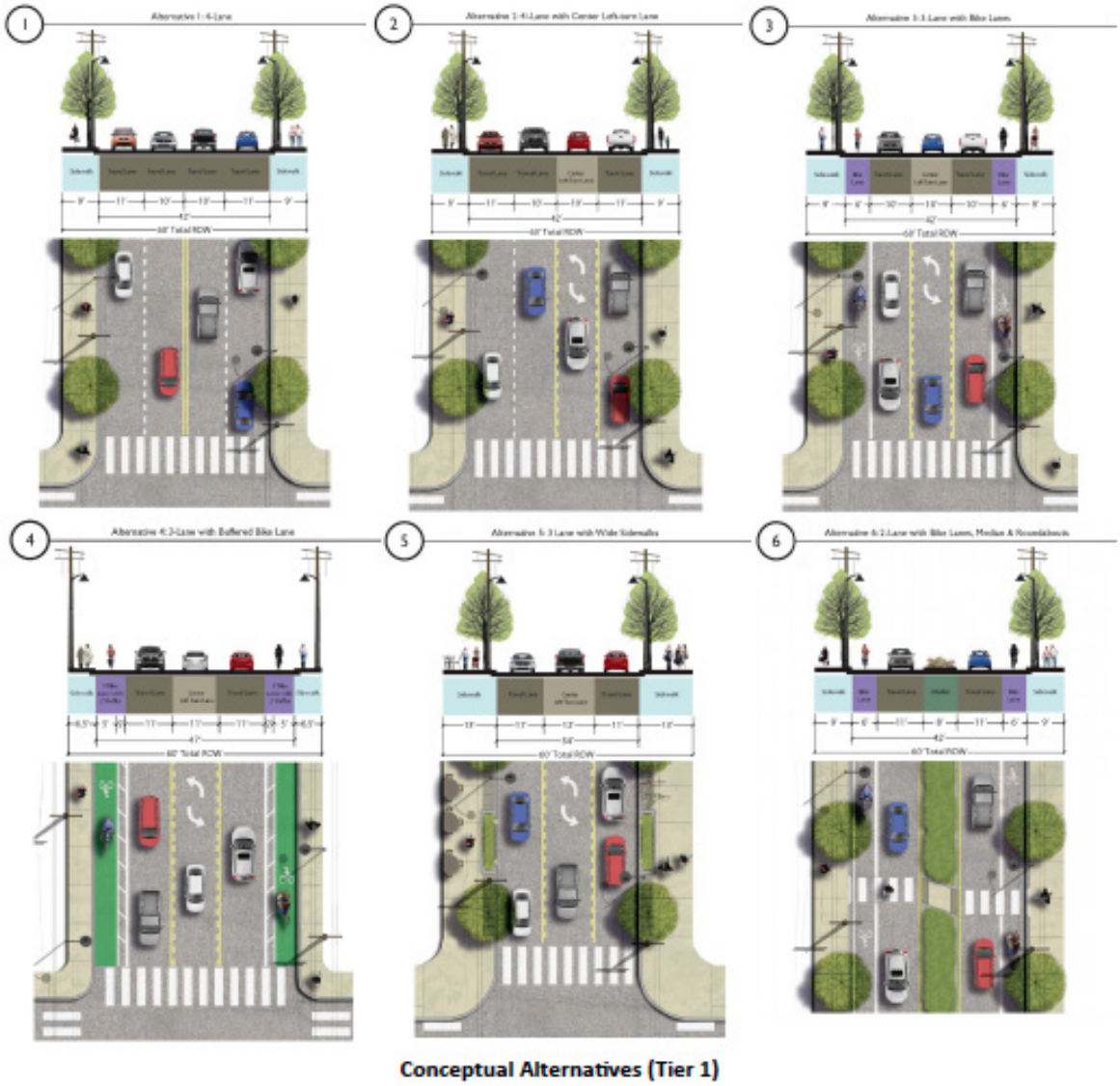

Figure 2. The six alternative concepts proposed by the city of Eugene to redevelopment South Willamette Street between the 24th and 32nd Streets. Source: City of Eugene 2014.

public safety improvement, economic benefit, and community support. Classification of each of the six alternative concepts creates a set of environmental values that are coded directly into the PAR model environment based on the scores from the official assessment across the four coded categories, creating six model environments based on municipal plans. In additional to the six alternative concepts, a parameter sweep is run by iteratively changing each variable by .1 while keeping all other variables constant in order to understand how the pedestrian agents respond to each environmental parameter

A different movement submodel drives the behaviors for each agent type in the PAR model. *Purposeful walkers* use a wayfinding submodel in which each agent perceives discrete environmental features, such as a landmark or a specified

Table 1. Qualitative coding of the 18 measure assessment performed by the City of Eugene. Green indicates dimensional variables, yellow public improvement safety variables, blue economic benefit variables, and pink community support variables.

Design Concept		1	2	3	4	5	6
Access and Mobility	Neighborhood connectivity			1	1		1
	Motor vehicle travel time			-1	-1	-1	-1
	Active mode travel time			1	1		1
Safety and Health	Safety			1	1	1	1
	Security			1	1	1	1
	Emergency response			-1	-1	-1	-1
Social Equity	Equity			1	1	1	1
	Economic access			1	1	1	1
Economic Benefit	Freight mobility			-1	-1	-1	-1
	Walkable/bikeable			1	1	1	1
	Business vitality		1				-1
Cost Effectiveness	Fundability	1			-1	-1	-1
	Assett management	1	1	1	1	1	1
	Project benefits	1	1	1	1	1	1
Climate and Energy	Pedestrian facilities				-1	1	
	Bicycle facilities			1	1		1
	Transit facilities					1	
Community Context	Community vision				-1	1	
Total		3	3	7	4	6	5

intersection, and responds with a behavior to meet a goal (see e.g., Raubal 2001; Turner and Penn 2002; Antonini et al. 2006). The wayfinding submodel represents individuals engaging in directed, purposeful walks between two points in the environment. *Social walkers* use an entity-interaction submodel in which local interactions with other *social walkers* is reinforced, causing small groupings of agents over time (Vicsek et al. 2008). The entity-interaction submodel represents individuals moving through the environment with intentions of being social with other individuals, rather than navigating to a specific location. *Experiential walkers* uses a localized search submodel (O'Sullivan and Unwin 2010) in which interactions with particular environmental features creates a positive feedback for the agents, motivating them to visit the location again during the model run. The localized search model represents individuals moving through and learning about desirable places in the environment to revisit for non goal-driven reasons, but rather because they are enjoyable or beneficial for whatever reason. *Wanderer walkers* use a random walk in which movement is not guided by anything but random decision-making, representing individuals who simply walk through the environment.

RESULTS AND DISCUSSION

Part 1: Representing Human Pedestrians

Due to the complexity and difficulty of modeling human movement, many computational pedestrian models strip away elements of individual agency, favoring the representation of human agents as responsive or reactive to external environmental variables. The PAR model uses a data-driven approach to code cognitive variables as means to represent individual agency in the model, aiming to achieve a deeper and more complete representation of human capabilities (O'Sullivan 2008). Parker et al. (2003) state, "the term cognition ranges in applicability to situations ranging from relatively simple stimulus-responses decision making to the point where actors are proactive, take initiative, and have larger intentions" (317). In the PAR model, cognition is conceived of as a high-level function, which guides the classification of the pedestrian type submodels and the individual level interactions between environmental features and agents. Model simulations under baseline conditions revel how the different data-driven pedestrian types respond and interact with different environmental variables through the course of pedestrian movement (Figure 3).

Incorporating a range of pedestrian cognitive capabilities into an agent-based modeling frameworks echoes the theoretical approaches of behavioral geographers, who argue that understanding different types of human decision-making processes and observable spatial movements in the environment is best known from the study of individual differences in the internal or cognitive processes (Golledge and Stimson 1997). Mark et al. (1999) provides a framework to understand how individuals perceive, cognitively transform, encode, and articulate the perceived external world. The first step in this theory of spatial knowledge acquisition

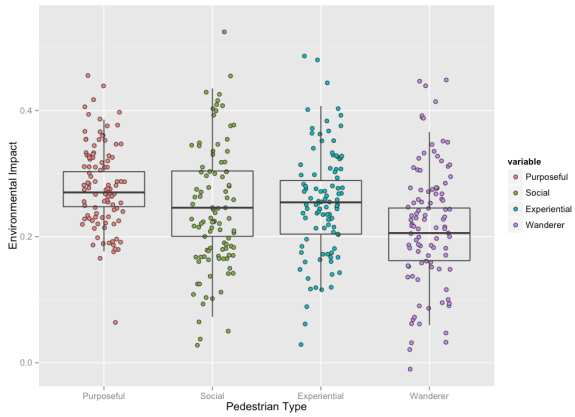

Figure 3. Impact of baseline environmental conditions across four walker types.

is the sensory perception (sight, sound, touch, etc.) of the external environmental by an individual (this is the stage in which the majority of pedestrian models stop). The external perception of the world is then internally transformed into a mental representation of the environment. The quality, extent, and completeness of the transformation from external to internal varies from person to person based on a multitude of cognitive, sociocultural, biophysical, and spatiotemporal factors. The mental representation, or individually constructed knowledge of the environment, is then used in a decision-making process. Knowledge use again varies dramatically from person to person, ranging from subversive to goal-oriented motivations. Finally, spatial knowledge is articulated and communicated either through language, movement, or another type of spatial behavior. This framework provides a clear way to define the cognitive capabilities of each agent type in the model environment (Table 2).

An agent-based modeling platform provides the opportunity to explicitly model cognitive processes and to orient pedestrian representations towards more human-centered approaches. As opposed to generalizable representations of pedestrians, agent-based models allow for the investigation of pedestrian practices based on a

Table 2. Pedestrian types classified in a spatial knowledge acquisition framework.

Agent	Perception	Mental Representation	Knowledge Use	Communication
Purposeful	Vision	Rational	Optimization	Wayfinding Walk
Social	Vision	More-than-rational	Attraction and repulsion	Entity-interaction
Experiential	Vision	Cognitive map	Self constructed	Localized Search
Wanderer	Vision	Ephemeral	Impetuous	Random Walk

multitude of motivations, capabilities, emotional states, and past experiences. In this sense, agent-based modeling can help address the 'wicked' problem of transportation planning and, more specific to pedestrianism, of how to balance the technical and human components of a system.

Modeling pedestrian behavior from a human-centered perspective provides an entry point to understand and analyze the relationship between the conceptualized spaces of scientist, planners, and architects and the lived spaces or users and inhabitants (Lefebvre 1991). A human-centered approach is to embrace the individuality of the human subject, endowing the individual with agency as a way to link human and artificial representations in an analytical framework. Heterogeneous agent representations embrace the concepts of individual differences in cognitive capabilities and the myriad of social motivations inherent to human-centered planning practices. Alternatively, reducing human agency to the most technical and generalizable of terms, as is the case with the majority of pedestrian agent-based models, embraces a configurational planning approach (Sepe 2010) that focuses on the structural aspects of the environment, which, in most cases, is likely better represented by the more traditional statistical, site-suitability, or linear models. With elements such as memory, cognition, adaptation, mental maps, and changing motivations, human elements of everyday pedestrianism can easily be incorporated into an agent-based modeling framework.

Part 2: Impacts of Redevelopment on Pedestrians

In addition to illustrating differences in agent behavior, the PAR model is also able to explore the human impacts of different structural elements. The city identified 18 separate measures which were critical to evaluate to understand the impacts of the redevelopment, which, for the purpose of this analysis, were reduced to four primary categories that reflect the type of structural change: dimensional changes, public safety improvement, economic benefit, and community support. Dimensional changes include the variables of neighborhood connectivity, motor vehicle travel time, active mode travel time, and walkable/ bikeable business district. The defining feature of this classification is the effect of the change in configuration or dimensions of the material environment on different modes of movement. The results from the model indicate that iterative changes to the dimensions or configurations to the material environment has a positive impact on *purposeful walkers*, but has little to no effect on other types of pedestrian practices (Figure 4).

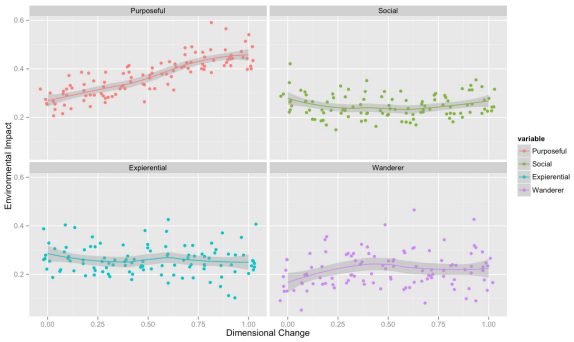

Figure 4. Impacts of dimensional changes on different pedestrian types.

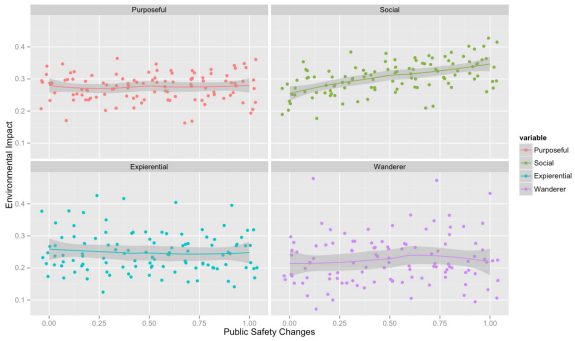

Figure 5. Impacts of public safety changes on different pedestrian types.

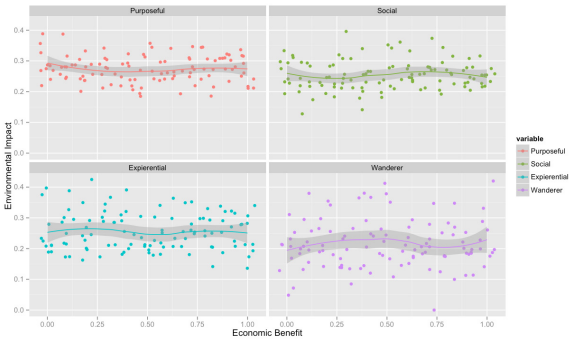

Figure 6. Impacts of economic benefit changes on different pedestrian types.

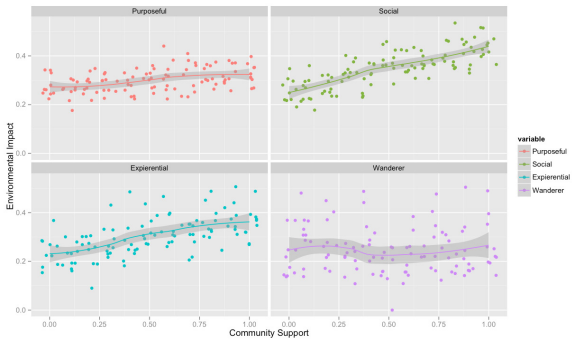

Figure 7. Impacts of community support changes on different pedestrian types.

The category 'public safety' improvements include the variables safety, security, and emergency response. Safety and security indicate the speed and proximity of private automobiles on the road network, whereas emergency response refers to the interactions of emergency service vehicles with other entities in the network. The results from the model indicate that iterative changes to the safety of the environment has a small positive impact on *social walkers*, but has little to no effect on other types of pedestrian practices (Figure 5).

The category 'economic benefits' includes the variables freight mobility, business vitality, fundability, asset management, and project benefits. These variables measure both the business related impacts as well as the financial burden on the city of redevelopment. The results from the model indicate that iterative changes to economic benefits, as measured by the official assessment, have little to no effect on any of the pedestrian types (Figure 6).

The category 'community support' includes the variables equality, economic access, pedestrian facilities, bicycle facilities, transit facilities, and community vision. These variables measure the ways in which redevelopment supports community goals and provides facilities and access across a wide range of citizens and individual practices. The results from the model indicate

Table 3. Weighting table for all variables and pedestrian types.

	Purposeful	Social	Experiential	Wanderer
Dimensional	3.3215	-0.01435	-0.6428	0.6251
Safety	0.259	3.4821	-0.3378	0.2984
Economic	-0.3202	0.3535	-0.1809	0.08159
Community	2.7184	3.1685	2.3398	-0.07749

that iterative changes to community support have a positive impact on *social walkers* and *experiential walkers*, a small positive impact on *purposeful walkers*, and little to no effect on *wanderer walkers* (Figure 7).

The analysis of this model most clearly reveals that the original assessment by the city of Eugene assumes all citizens will respond equally to changes, and the binary metrics used to evaluate the six conceptual alternatives in the official assessment misrepresents the impacts of each redevelopment variable on pedestrians. To correct this assumption, this paper uses a linear regression analysis between each redevelopment variable and each pedestrian type to create a weighting chart for a more detailed and refined assessment of the different conceptual alternatives (Table 3).

The weighting table is combined with the formal assessment by the city of Eugene and the distribution of people from the principal component analysis of pedestrian types to evaluate the impact of each redevelopment on a heterogeneous population of pedestrian citizens. With this approach, the impact of each conceptual alternative is measured in human-centered terms, giving considerably more attention to the range of pedestrian practices and being inclusive of individual differences within the population (Table 4).

The results of the model find two important considerations not calculated in the official assessment of South Willamette Street. First, not all variables are equal when considering the range of pedestrian practices within the redevelopment space; the variables of community support and dimensional changes have a much more significant influence on pedestrians in the system than the variables of public safety and economic benefit. The model analysis also reveals that in the redevelopment of pedestrian spaces, design practices focusing on network connectivity, non-automobile facilities, and inclusive or evenly distributed development are essential changes. Often the issues of public safety and business

Figure 8. Example of economic benefit and public safety being linked in opposition to redevelopment. Photo by Author.

Table 4. Human-centered assessment of alternative redevelopment concepts. Green indicates dimensional variables, yellow public improvement safety variables, blue economic benefit variables, and pink community support variables.

Alternative		1	2	3	4	5	6
Access and Mobility	Neighborhood connectivity			1.770	1.770		1.770
	Motor vehicle travel time			-1.872	-1.872	-1.872	-1.872
	Active mode travel time			1.770	1.770		1.770
Safety and Health	Safety			0.854	0.854	0.854	0.854
	Security			0.854	0.854	0.854	0.854
	Emergency response			-0.570	-0.570	-0.570	-0.570
Social Equity	Equity			2.614	2.614	2.614	2.614
	Economic access			2.614	2.614	2.614	2.614
Economic Benefit	Freight mobility			-0.248	-0.248	-0.248	-0.248
	Walkable/bikeable			1.770	1.770	1.770	1.770
	Business vitality		0.313				-0.248
Cost Effectiveness	Fundability	0.313			-0.248	-0.248	-0.248
	Assett management	0.313	0.313	0.313	0.313	0.313	0.313
	Project benefits	0.313	0.313	0.313	0.313	0.313	0.313
Climate and Energy	Pedestrian facilities				-0.367	2.614	
	Bicycle facilities			2.614	2.614		2.614
	Transit facilities					2.614	
Community Context	Community vision				-0.367	2.614	
Total		**0.939**	**0.939**	**12.795**	**11.813**	**14.234**	**12.300**

vitality are linked together and serve as the main focus of discussion, both in arguments supporting and opposing larger redevelopment projects. The analysis shows arguments within this framing likely fail to capture the actual impacts on pedestrian movement within redevelopment spaces (Figure 8).

Additionally, the new assessment illustrates the impact of each conceptual alternative on pedestrians are not even across all types of walkers, and assumptions of homogenous or uniform impacts from the identified redevelopment variables neglects many of the individual and human-centered elements of pedestrian practices. The results from the official assessment of the conceptual alternatives ranked option three highest, and the redevelopment of South Willamette Street to meet these specifications is set to begin in Summer 2016. While there are multiple variables and modes of transportation to consider when evaluating the redevelopment of South Willamette Street as a whole, the results from this analysis ranks option five as the highest (Figure 9).

This analysis does not suggest option five is superior to option three, nor is it meant to predict how a broader sense of walkability will change from these different structural arrangements. Rather, the analysis of the PAR model shows the strengths and weaknesses of the

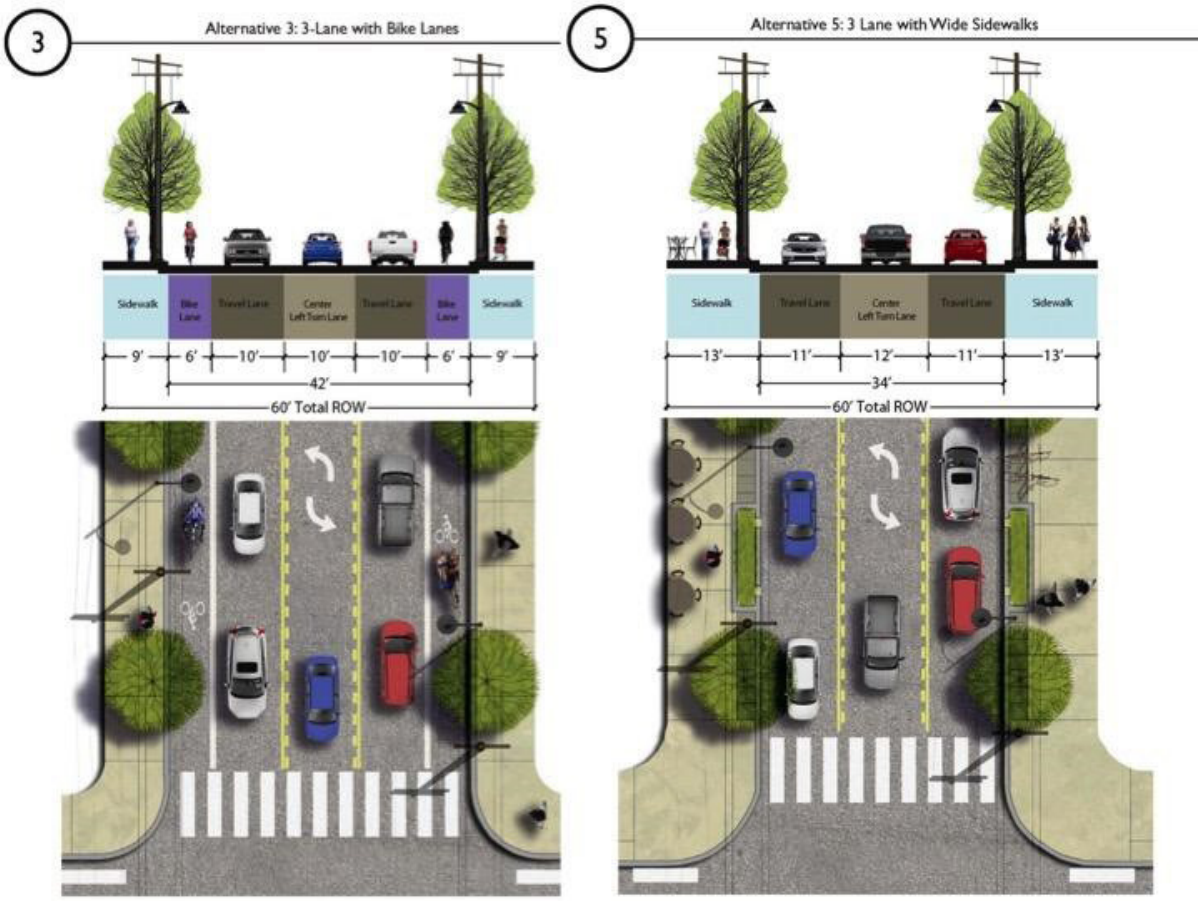

Figure 9. Side by side comparison of alternative concept three and five for the redevelopment of South Willamette Street. Source: City of Eugene 2014.

alternative concepts in a more nuanced and thoughtful way, disrupting assumptions about the impact of different environmental variables on a representative population of individual pedestrians and providing clues pertaining to the most important variables to consider when designing pedestrian-friendly spaces in multimodal corridors. While options three and five appear quite similar, small differences between the two provide clues into features most desirable to pedestrians.

First, the sidewalk dimensions of option five create more space for multiple types of pedestrian practices and accommodate features such as sidewalk furniture, public art, and social spaces. Option five also provides more room in the road network, creating more space for cars to operate. Option three does have bike lanes where five does not, creating both a buffer for pedestrians and access for another mode of transportation. Both alternatives illustrate the difficulties in supporting multiple modes of transportation within 60 feet of right of way, and regardless of the configuration certain modes will be privileged while others disadvantaged. The PAR model serves to remind us how a human-centered evaluation of such projects provides can highlight specific features that are pedestrian friendly and illustrate how the range of pedestrian experiences respond to different environmental features.

CONCLUSION

Literatures on the everyday experiences of walking in the city (see e.g. Lynch 1960; Jacobs 1961; Whyte 1988; Solnit 2000) all place a heavy emphasis on the more subjective variables in understanding pedestrian practices. Many existing pedestrian models are embedded with reductive ontologies (O'Sullivan and Hakley 2000), framing the pedestrian as a rational transportation unit optimizing resources or reacting to other agents across the model environment. While wayfinding and evacuation approaches to pedestrian movement have proven effective for discrete purpose or event-based phenomena, other aspects of pedestrian movement such as communication with other agents, cognition and emotion, uneven internal representation of perceived spaces, and multiple agent motivations need to be incorporated into the agent-based framework to understand more everyday human pedestrian behaviors.

Despite the communication barriers embedded in process-driven analysis, agent-based modeling remains a powerful and innovative way to understand the relationships between changing spaces and individual behaviors, serving to highlight many unexpected facets of both individuals and the system in which they are embedded. The PAR model described in this paper incorporates a data-driven representation of cognition into agents as a way to explore the implications of different types of redevelopment and design on realistic pedestrian types. The results indicate the design variables of dimensional changes and community support has a stronger influence on a heterogeneous population of pedestrians than the design variables of public safety and economic benefits classifications. The model also introduces a weighted interaction scheme highlighting flaws in the official assessment administered by the city of Eugene. In doing so, the PAR model provides insight that would be hard or impossible to obtain with traditional statistical models.

Due to the immense potential of agent-based models to shed light on pressing issues in land-use, urban growth, and especially transportation planning practices, it is critically important that research on agent-based models, both from modelers and from planners, continues to focus not only on design and evaluation metrics, but on the discursive dimensions of the knowledge produced by models and the role of that knowledge in policy debates. This is especially true for pedestrian modeling applications, as pedestrian-oriented development has great potential to radically transform urban transportation spaces and address pressing global issues with localized sustainable practices. In the context of increasingly urgent social and environmental issues, there is a pressing need to understand how people move through everyday spaces, how various human subjectivities play into pedestrian decision-making, and how to best design and communicate model results to support municipal planning and development.

Agent-based models provide a relatively new scientific tool to integrate human-centered and configurational approaches to urban and transportation planning. A computational approach to represent human-centered and everyday pedestrian behaviors has significant methodological contributions in the field of planning and elicits strong insight to address many community-based goals of livability, safety, and environmental sustainability. Thoughtful pedestrian representations in agent-based models aligns with emerging municipal goals of data-driven smart city design initiatives (Townsend 2013), while drawing linkages between individual representations of space and the concrete elements of the city, informing a deeper understanding of

pedestrian behaviors and transportation choices. Additionally, an agent-based modeling approach allows for different design variables, infrastructure configurations, and social conditions to be systematically simulated in a model environment, fostering a broader understanding of how real-world behaviors are influenced by material changes in the environment. While there are still many issues in design protocols, validation techniques, and communication frameworks that require continued attention, agent-based modeling can serve as a powerful and low-cost computational platform to learn about urban and transportation systems in supporting planning practices.

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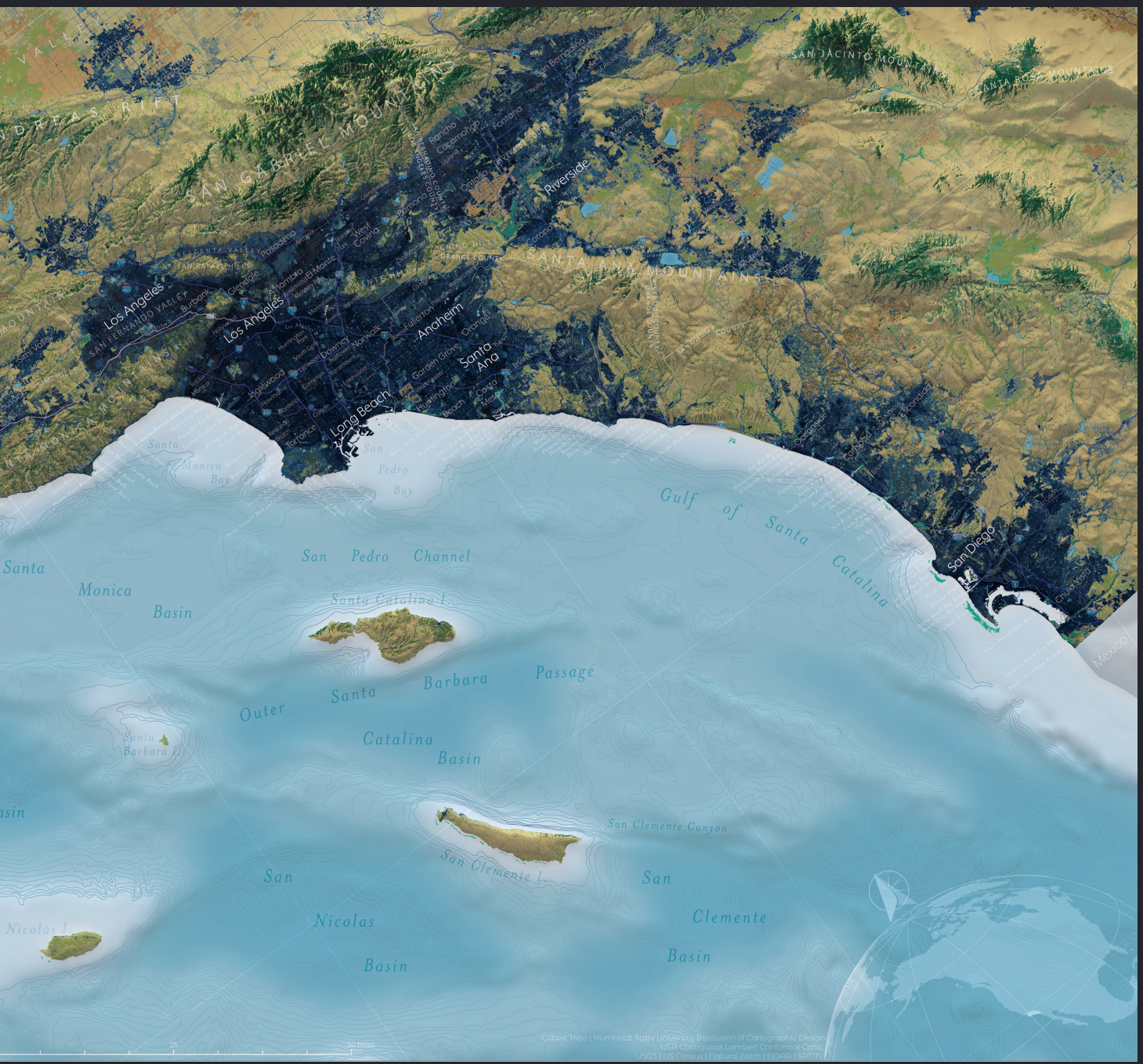
GILBERT TREJO

The purpose of this map was to create a landscape view of my home region of Southern California that adequately displayed the complexity of it's natural and man-made terrain. One of the challenges I faced was the amount of labeling in the greater Los Angeles (LA) area. I decided to not include any city borders because moving around LA feels more like moving across various neighborhoods and regions than crossing from one city to another. Slanting the text provided more space without making it too difficult to read. The orientation creates a more interesting layout than the usual north-up orientation, and allowed me to better restrict the map extent to the coast and inland cities. It did introduce a bathymetry challenge, as I had to include the islands and ocean in a way that suited the complexity of the land. I created a hillshade for the ocean floor to give it motion and shape; contour lines were filled with a deepening blue scale and blended together to provide depth. Other details include the shading used to subtly display elevation, the density of developed area, and vegetation and canopy density.



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Mapping Maya Hinterlands: LiDAR Derived Visualization to Identify Small Scale Features in Northwestern Belize

Jeremy McFarland[a], Marisol Cortes-Rincon[a]

Abstract

This paper discusses the processes and methods of relief visualization of LiDAR-derived digital elevation models (DEM's) and classification of secondary data to identify archaeological remains on the ancient Maya landscape in northwestern Belize. The basis of the research explores various Geographic Information Systems (GIS) and cartographic techniques to visualize topographical relief. Graphic terrain maps assist archaeologists with predictive settlement patterns. The Relief Visualization Toolbox (RVT 1.3) aids to visualize raster DEM datasets in the predictive identification and interpretation of small-scale archaeological features. This dataset and methodology can be utilized to answer questions of population estimates, mobility costs, and effectiveness of ancient technological agricultural systems.

Keywords

Maya settlement patterns, Maya hinterlands, geospatial studies, LiDAR

The Maya landscape of the Classical period (250-900 CE) was both geographically expansive and diverse. The Maya culture was not cohesive in expression, nor unified under a single King; the Maya polities settled and constructed their landscape in multiple forms, consequentially preventing a single model to characterize them (Chase et al. 2011). A landscape perspective—the study of the interrelationship between human culture and the environment—has been a growing interest between various fields of research. The term landscape is usually defined in a broad and ubiquitous manner, explaining little of the concept and use of the term in a subjective physical, social, and cultural dimension. In this

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paradigm of archaeology, a landscape can best be understood "by what it *does* than what it is." (Whittlesey 1997). Anschuetz et. al. (2001:160-161), provides four interrelated principles to help clarify the landscape paradigm:

1. "Landscapes are not synonymous with natural environments;" they are a conceptual perception constructed and organized by the human experience with the external world.
2. "Landscapes are worlds of cultural product," representing a culture in space and time composed of the daily activities, beliefs, and values which perpetuate meaning to the environment.
3. "Landscapes are the arena for all of a community's activities;" containing the resources to sustain human populations and organize perception and action of a society, thus an area of use and the empty spaces in-between are interconnected within the environment.
4. "Landscapes are dynamic constructions," ever-changing with generations of community perception of space and arrangement in time.

The study of rural settlement patterns of the ancient Maya has been an area of difficulty considering the corpus and diversity of polities. In the past, typical mapping strategies in the Maya Lowlands involved regular pedestrian survey intervals using a mixed block transect documenting settlement within a set distance from either side of a baseline between major sites. These transects have involved narrow swaths collecting spatial data with various forms of mapping from tape and compass, Global Positioning System (GPS) units, and/or a total station; more expansive survey coverage has been too expensive and laborious to be possible (Robichaux 1995; Lohse 2001; Hageman 2004; Cortes-Rincon 2013; Chase et al. 2014).

Understanding settlement patterns of ancient cultures in response to the landscape has long-been the goal of archaeologists. With the drastic advancement of technology during the 21st-century, full-coverage mapping of broad areas has not been addressed until the advent of Geographic Information Systems (GIS) and remote sensing techniques, such as Light Detection and Ranging (LiDAR). GIS encompasses a series of specialized technological based programs used to create, analyze, and display geospatial data. Remote sensing is the art and science of collecting ground-based data using remote sensors mounted on airplanes or satellites. In the past decade, these technologies have become ever-more accessible to a wide range of disciplines. Mayan archaeologists have entered new domains of studying settlement spaces with the use of GIS and LiDAR by enhancing visualization of structures and mapping Maya sites' organization (Kvamme 2003; Masson 2014; Willisa et al. 2017; Ringle 2017). These tools have provided data valuable to understanding the Earth's surface and it's changing landscape.

Archaeologists today use LiDAR data to enhance three central themes of archaeological practice and methodology: (1) to efficiently map, document, and manage known and unknown disappearing ancient sites and landscapes; (2) to understand environmental formation processes in diverse landscapes; and (3) to provide more efficient modes of cultural heritage management for preservation and accessibility to researchers and the public (Hritz 2014; Schwerin et al. 2016).

These methods help gain a deeper understanding of Maya polities' settlement patterns, interaction, and development, and their influence and exploitation of natural resources.

Initial applications of LiDAR in Mesoamerica have been carried out extensively as part of the Caracol Archaeological Project to reconstruct and characterize settlement patterns in Belize (Chase et al. 2010, 2014). The majority of the LiDAR surveys in the Maya region have been focused on large city-centers including Caracol, Mayapan, Tikal, El Mirador, and many other elite sites. These studies have included a small section around the sites; however, the research has largely ignored the hinterlands—the area lying beyond what is known or explored. This has created a clear gap in estimations of population size, spatial distribution, and further understanding relationships between regional centers and their supporting peripheral sites. LiDAR has provided an invaluable approach to map ruins, which are widely distributed and densely covered by Belize's diverse environment, but have lacked applications to the Maya hinterlands. This data acquisition process needs to be addressed in the regional study.

A long-term multidisciplinary research collaborative, in the Orange Walk District of northwestern Belize, has been operating under the auspices of the Programme for Belize Archaeological Project (PfBAP), under the direction of Dr. Fred Valdez Jr., since 1992. PfBAP has been an umbrella for a variety of sub-projects, which have ushered the continuation and success of archaeological research in the region (Valdez 2007). This research is set in the Rio Bravo Conservation Area – a continuation of the Yucatan Platform – underlain by limestone and marl deposits. The principal topography consists of a series of escarpments aligned southwest- northeast guiding three low lying drainages of the Rio Bravo, Booth River, and New River systems. Ecosystems range

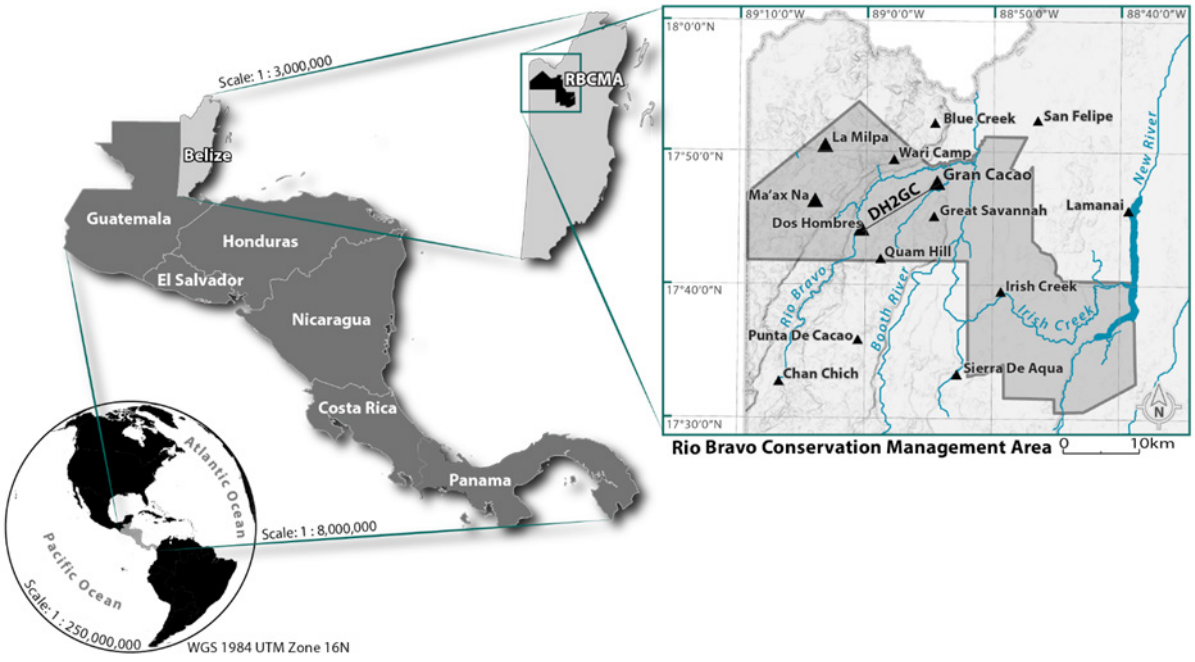


Figure 1. Location of DH2GC in the Rio Bravo Conservation Management Area, Belize, Central America.

from a complex mosaic of vegetation types, but is classified primarily as lowland broad-leaved moist forest.

The Dos Hombres to Gran Cacao Archaeology Project (DH2GC) has been conducting research on the Maya hinterlands, under the auspices of PfBAP, since 2009. DH2GC is a 12-km transect between two Maya city-centers: Dos Hombres and Gran Cacao. In 2016, an interdisciplinary grant allowed PfBAP researchers to acquire LiDAR for part of their research areas. LiDAR has allowed for this project to expand into new unknown reaches of the Maya Lowlands and has extended the DH2GC project to connect with other unknown site centers. For this paper, the authors have focused on the hinterlands near the center of Dos Hombres (Figure 1).

What is LiDAR?

LiDAR is a remote sensing technique, also known as airborne laser scanning (ALS), which has become a leading tool for generating three-dimensional datasets of the Earth's surface and it's land cover characteristics. Airborne LiDAR sensors deliver light in the form of pulsed laser to measure variable time and distance of multiple pulse returns from the Earth's surface. Additionally, these sensors apply an arbitrary scaled measure of intensity of light return to aid with feature detection (Fernandez-Diaz et al. 2016). This provides advantages when studying in tropical rainforests due to the dense vegetation and canopy cover that can conceal culturally modified landscapes from traditional survey methods and/or aerial imagery.

LiDAR data is represented in three main forms: a point-cloud, a Digital Elevation Model (DEM), and/or a triangulated irregular network (TIN). Each form of representation can hold information for a variety of purposes. For example, a point cloud can produce a DEM (bare earth) or a digital surface model (canopy), which can be used for surface, vegetation, or structural analysis. For this research, a high-resolution (0.5-meters) DEM was extracted from the LiDAR point-cloud to provide a base layer for multiple types of visualization manipulation using different algorithmic techniques.

In the interest of maintaining the original integrity of the data along with unfamiliarity with fundamental software techniques, visualization manipulation of DEMs has traditionally been avoided by cartographers and GIS specialists (Patterson 2006). A DEM is inherently a representation of the Earth's surface and manipulation of the data further depicts an abstract reality by portraying features more prominently than others or not at all (Gartner 2014). This abstraction can create a powerful map for use by archaeologists; however, significant studies in image-processing techniques of LiDAR data have been primarily focused in other disciplines. As archaeologists are becoming more adept with geospatial programs and gaining a deeper understanding of LiDAR methodology in archaeological research, a number of authors have published studies on new analytical techniques. This paper discusses the application of airborne LiDAR and specific visualization techniques of DEMs, to assist Mayan archaeologists with identifying, interpreting, and mapping small-scale archaeological features in Mesoamerica.

DATA AND METHODS

Data Acquisition and Post Processing

Ground-based mapping on the hinterlands near Dos Hombres has been a part of the DH2GC archaeological field school since 2009. As previously mentioned, a baseline connecting the site of Dos Hombres to Gran Cacao has been established with a grid of perpendicular lines spaced

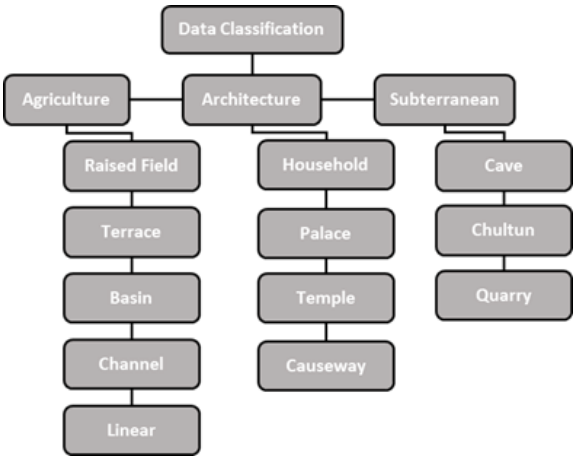


Figure 2. A Classification Scheme of Field Collected Data in the Dos Hombres Hinterlands.

every 50-meters. Students and researchers have been mapping features and household groups using a variety of techniques, such as tape and compass, GPS units and/or total station. Nomenclature of groups and features follow the grid path. For example, a household group may be assigned a grid coordinate of "N150E75", meaning this group is 150-meters north of the zero point and 75-meters east of the N150 point. Mapped landscapes primarily include agricultural, architectural, and subterranean features (Figure 2). At the HSU Archaeology Research Laboratory (ARL), students have processed data excavated from the site including lithics, ceramics, soils, and other cultural material to characterize further the Maya use of the landscape in the region.

Between June 2nd and June 4th, 2016, a total of 274.6 km^2 of LiDAR was flown by the National Center for Airborne Laser Mapping (NCALM) for a consortium of archaeologists working in northwestern Belize. The LiDAR data was collected with an Optech Titian terrain mapping system set to a pulse repetition frequency of 175 kHz and flown with a swath width of 600-meters (Table 1). The processed LiDAR data produced a DEM gridded to a 0.5-meter resolution. Full details of the data collection and processing methods for this work are discussed elsewhere (Fernandez-Diaz et al. 2016).

LiDAR DEM Visualization Methods

The methods of LiDAR DEM visualization took on a multidisciplinary approach, encompassing image processing techniques developed by a diversity of researchers in various fields. General goals were to enhance terrain topography while illuminating small localized features.

Table 1. LiDAR scanning parameters of the Blue Creek Region (Belize).

Scanner Type	Optech Titian
Platform	Piper Aircraft
Date	July 2–4, 2016
Swath Width (m)	600
Flying Height (m)	570
Percent Overlap	50
Pulse Repetition Rate (kHz)	175
Spatial Resolution of the Final Elevation Model (m)	0.5

For interpretation, we utilized a paired system where at least two researchers would agree on the outcome. First, a remote sensing analyst, who is proficient in LiDAR and various visualization methods, helped with productibility. Second, a field researcher who has ground-based knowledge saves time and effort in mapping and additional analysis.

Relief shading and topographic enhancement

Relief shading, also referred to as analytical relief shading, of DEM's has been used by archaeologists as an auxiliary tool for mapping culturally modified landscapes; however, this visualization technique poses a variety of limitations (Hesse 2010). In the case of this research, the detection of potential archaeological features depends to a large degree on the chosen illumination angles. Researchers like Zakšek et. al. (2011: 398), acknowledge this limitation and address two major drawbacks: "identifying details in deep shades and inability to properly represent linear features lying parallel to the light beam".

The first phase of LiDAR visualization involved enhancing basic relief shading with conventional cartographic terrain techniques. As an attempt to do so, we created two curvature raster's (profile and planform) extracted from the 0.5-meter DEM. Curvature is defined as the second derivative of the slope and displays the shape or curvature of a surface as either concave or convex; profile and planform address the directions in which the curvature of a landform can be calculated either parallel or perpendicular (ESRI 2016). The curvature function has been used most widely in geomorphology and cartography to enhance topographic detail and visualize high frequency information, such as change in landforms and their characteristics on medium resolution DEM's (Kennelly 2008; Štular et al. 2012). Although, the use of this function on our high-resolution DEM

Table 2. Software and settings used to generate the various visualization type.

Visualization Type	Software	Settings
A. Relief Shading/Contours	ArcMap 10.5	315° Sun azimuth, 45° Sun elevation, 1m contour
B. Principle Component Analysis (PCA)	RVT 1.3	16 directions, 35° Sun elevation
C. Slope Gradient	ArcMap 10.5	No parameters required
D. Sky-View Factor (SVF)	RVT 1.3	16 directions, 5-meter radius
E. Anisotropic Sky-View Factor	RVT 1.3	Same as SVF with 355° direction of anisotropy
F. Openness — Negative (ONEG)	RVT 1.3	32 directions, 20-meter radius (taken from SVF)
G. Openness — Positive (OPOS)	RVT 1.3	32 directions, 20-meter radius (taken from SVF)
H. Local Dominance (LD)	RVT 1.3	Min. radius 10 – Max. radius 20
I. Red Relief Image Map (RRIM)	RVT 1.3/ArcMap	LD settings with slope raster
J. RRIM/Local Dominance	RVT 1.3/ArcMap	LD settings & yellow histogram with slope raster
K. Local Dominance/OPOS	RVT 1.3/ArcMap	LD settings & yellow histogram with OPOS

to visualize and identify small-scale features had limiting results. The application of planform and profile curvature modifications to our DEM, for example, exaggerated ground return noise and thus obscured archaeological features, a limitation also emphasized by Štular et al. (2012).

DEM manipulation methods

The second phase of this research involved evaluating more nascent and complex visualization methods. The RVT 1.3 toolbox was used as a basis for this project to calculate a variety of analytical image processing techniques because of its accessibility and ease of producibility (ZRC SAZU 2010). Conducting our own literature review and personal trials identified key advantages and disadvantages for our project area. These techniques included principal component analysis of analytical relief shading from multiple directions (Devereux et al. 2008), slope gradient (Doneus and Briese 2011), sky view factor (Kokalj et al. 2011), positive and negative openness (Yokoyama et al. 2002), and local dominance (Hesse 2016) (Table 2).

Principal Component Analysis (PCA) summarizes and combines the results of several analytical relief shadings from multiple directions (Devereux et al. 2008). Relief shading in 64 directions can be used, but 16 provided best results for this research. RVT 1.3 was used to create an 8-bit image showing the first three components as an RGB image (Red-315°, Green-15°, and Blue-75° azimuth with 35° sun elevation).

Slope gradient is the first derivative of a DEM, and is defined as the maximum amount of rise (or change) in elevation (Štular et. al. 2012). It is typically displayed in a greyscale scheme where darker areas represent steeper slopes regardless of rising or falling. A disadvantage of this image is that it is hard to distinguish between positive/convex (e.g. protuberance) or negative/concave (e.g. depression) features (Kokalj et. al, 2017). This dataset was used frequently in our research because it retains a smoothed representation of ground topography with reduced noise, which is straightforward to interpret and works well when combined with other forms of visualization.

Sky View Factor (SVF) is an alternative method of relief mapping which represents the proportion of the sky observable from a point on the earth surface assuming equal (diffuse) illumination from all directions within a hemisphere (vs. direct lighting in relief shading) (Kokalj et al. 2011). Settings can be switched to specify a maximum number of search directions within a defined search radius (pixels). Certain antistrophe can be applied to the SVF to emphasize brighter directions and highlight small features in flat areas. A search direction of 8 with a radius of 10-pixels (10-meters) was used for the SVF and 355° of anisotropy for the Antistrophic SVF.

Openness is similar to SVF, in that it is also a method which uses diffuse lighting, but considers the entire sphere for illumination instead of just the celestial hemisphere (Yokoyama et. al. 2002). Openness can be calculated by determining the mean zenith angle (positive) and the mean nadir angle (negative) of all horizons (Kokalj et. al. 2017). With a search direction of 32 and a radius of 20 pixels (10-meters), two positive and negative openness grayscale images were produced.

Local Dominance (LD) is computed by calculating the dominance of an observer in each pixel in relation to the surrounding pixels with a specified height and a defined search radius (Hesse 2016). LD does not utilize the Sky View Factor, but results in a similar, if not the same, visualization as an inverse negative openness image, where high values are displayed as protuberances and low values as depressions. Unlike openness however,

a minimum radius can be specified for LD which helps reduce the abundance of small-surface noise and creates a smoother image (Kokalj et. al. 2017). It was appropriate for this research to 1) specify a minimum radius (above 10) and maximum (below 20) to highlight small prominent localized features/depressions, and 2) adjust the histogram range to isolate dominant features.

Combining multiple raster's

The final phase of this visualization process addresses the advantages of combining multiple raster's datasets to create detailed topographic images and highlight certain features. Our research primarily focuses on settlement and distribution of small localized structures in a semi-flat topography—thus an emphasis on topography and low-lying structures became an interest for this process. For example, a combination of a slope raster draped over local dominance with a yellow histogram stretch can distinguish convexities and concavities on the topography while highlighting low-lying structures. A slope raster was chosen as a base layer because of its smoothed texture and ability to display the change in slope despite size of feature. Local dominance was chosen because this type of visualization is best for highlighting protuberances and depressions in a light to dark grayscale and, when switched from yellow to black, can contrast well with the slope base-layer.

This same effect can be achieved by subtracting the Openness Positive from an inverted Openness Negative underlaid beneath a red colored slope raster—a technique coined Red Relief Image Mapping (RRIM) by Chiba et al. (2008). With the raster calculator function in ArcGIS, this simple calculation of image combination can be achieved. Combining multiple images is convenient for visualization purposes because they can easily be viewed in other image processing softwares and produce quality maps for print. It is important to note that with multiple combinations, visualizations gain a greater level of abstraction from reality.

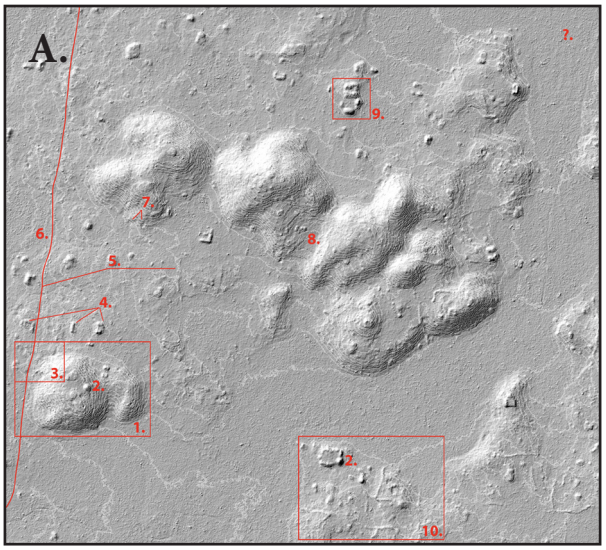
RESULTS AND DISCUSSION

Our methods of visualization have followed a long chain of steps. We started with a LiDAR-derived digital elevation model representing numerical values of elevation as rasterized pixels, manipulated these values using complex

Table 3. Assessment of visualization techniques for representing selected archaeological features in the region.

	Households	Depressions	Causeways	Terraces	Raised Fields	Linear
Relief Shading	+	-	+	o	o	-
PCA	+	+	++	+	o	+
Slope	+	+	o	+	-	+
SVF	+	++	+	++	-	++
Openness — Negative	+	-	-	-	-	+
Openness — Positive	++	++	++	+	+	++
Local Dominance	++	++	++	+	++	++

- not suitable; o *indistinct*; *+ suitable*; *++ very suitable*



1. N950 – Ceremonial Site
2. Temple/Shrine
3. Quarries
4. Households
5. Maya Road
6. Modern Logging Road
7. Water Basins
8. Sloped Terraces
9. Courtyard Group
10. Courtyard/Agriculture

? Possible Raised Fields

Figure 3. relief shading overlaid with 1-meter contours as a basic form of terrain representation. Figure (A.) displays field collected data on the hinterlands near Dos Hombres for comparison with the following maps.

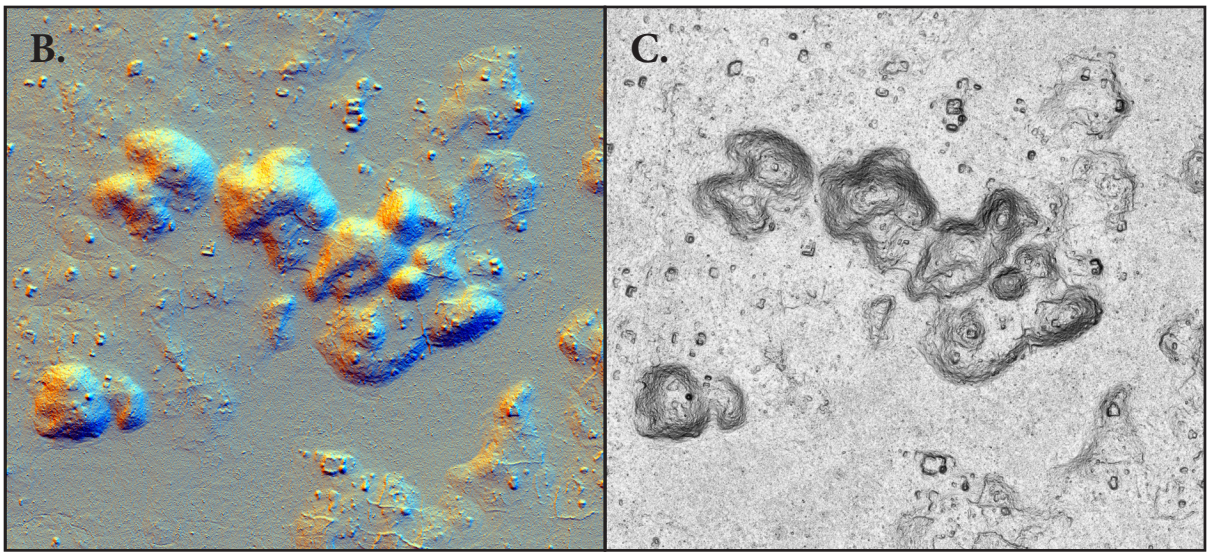


Figure 4. Principal component analysis (B.) and slope (C.) enhances topography and terracing.

analytical techniques with RVT 1.3, and displayed these images with greyscale/color mapping and histogram stretch in ArcMap 10.5 to examine individual traits and advantages for each technique in our project area (Table 3, Figure 3–6).

As a guideline to follow for visualization, analysis, and interpretation, we suggest beginning with a natural relief shading and an overlaid color-cast DEM. This form of visualization, despite its limitations, is most easily discernible, and a color-cast DEM helps understand levels of elevation and hierarchy of landforms. It becomes quickly natural to identify certain features when one compares this visualization to ground-based research and field-collected geospatial data. Additionally, relief shading in multiple directions

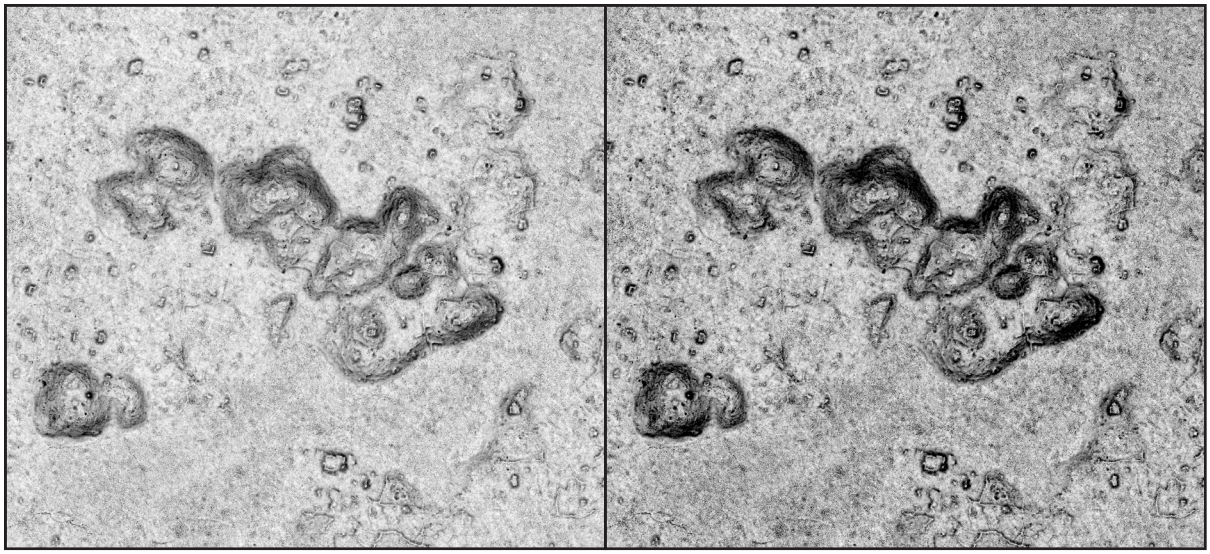


Figure 5. Sky-View Factor (D.) and Anisotropic Sky-View Factor (E.) accentuates ground texture.

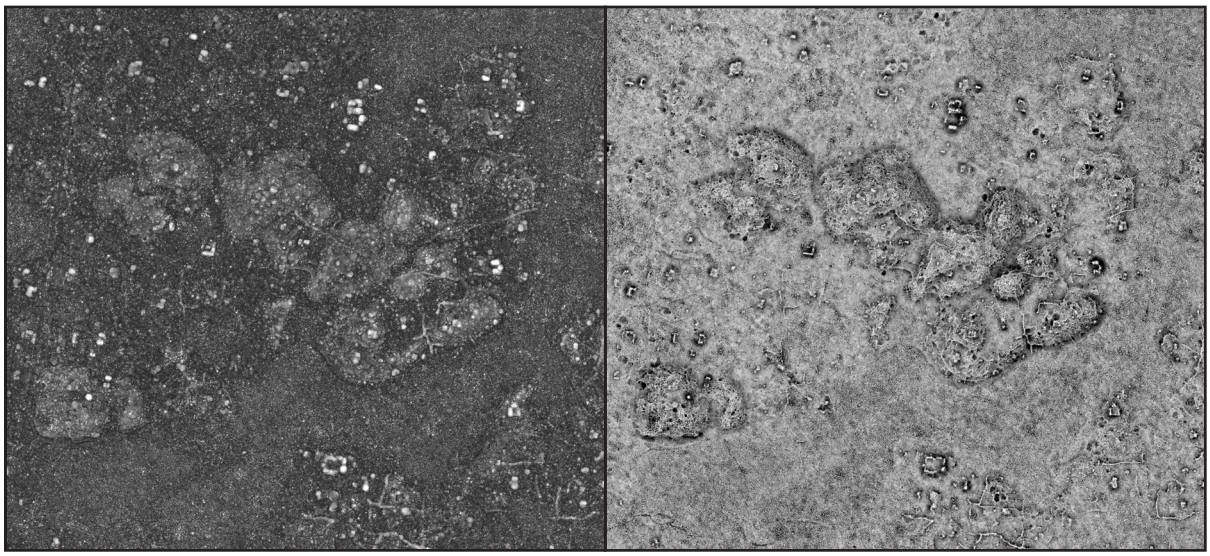


Figure 6. Negative Openness (F.) and Positive Openness (G.) Enhances Convexities and Protuberances.

can help portray the general topography and aspect while depicting most structures on the landscape. In our project area, a prominent mapped temple atop of N950 knoll stands out in conical form and later investigations confirm a second previously unknown temple to the southeast.

In an area of moderate to steep terrain, such as our region, a slope raster helps to enhance topography and low-relief structures. This dataset was frequently combined with other images because of its smoothed texture and reduced surface noise. However, we argue this visualization lacks attention to detail in lower-elevation areas like *bajos* and flood zones due to its smoothed nature.

Sky View Factor (SVF), on the other hand,

Table 4. Assessment of visualization techniques for representing general cultural landscapes in the region.

	Suitability (+) →					(–)
Agriculture	Slope	Local Dominance	SVF	PCA	Openness Negative	
Architecture	Local Dominance	Slope	SVF	Openness Positive	Openness Negative	PCA
Roads	Local Dominance	Openness Positive	SVF	PCA	Slope	Openness Negative
Soil/Vegetation Differences	Openness Positive	SVF	PCA	Openness Negative		

provides a visualization quite the opposite of slope because it accentuates the ground texture; however, structures sometimes become more difficult to interpret in SVF because of the increased surface noise (Štular et. al. 2012). Anisotropic Sky-View Factor (ASVF) became preferred because it accentuates differences in ecological zones; not to say ASVF is detecting vegetation types, but it is increasing surface texture, which is a result of differences in soil texture from vegetation and can be visualized.

The use of positive openness highlights topographic convexities, e.g. ridges of structures and rims of depressions; however, in a relatively flat area we suggest negative openness does not work well to highlight the lowest parts of concavities (Yokoyama et. al. 2002). These images do not display the topography or surface texture as well as the SVF, but work primarily well for visual feature detection of protuberances. Both visualization types could be used in the case of automatic feature detection; however, we suggest local dominance because of its minimum radius setting and reduction of surface noise (Kokalj et. al. 2017).

Respectively, local dominance is useful for most terrains and to identify culturally-modified features on the landscape; however, this visualization lacks a sense of depth, texture, or topography (Hesse 2016). Local dominance becomes useful for feature detection and classification of low and high points, but settings need to be adjusted appropriately for user preference and best outcomes. This type of technique is also useful for highlighting possible low-lying raised fields, which are not distinguished well in any other form of visualization. Further field research is required to confirm this interpretation (Table 4).

CONCLUSION

Applications of LiDAR visualization in the field of archaeology have been addressed by a limited few. Various authors have published nascent techniques of LiDAR visualization in archaeological research, but the field is far from being fully explored. This paper presents a comprehensive look at LiDAR-visualization applications and findings, which will be useful for much deeper and valuable analysis. One aspect in which improvements can be expected is the optimization of data processing, with the goal of automatically detecting anthropogenic features for archaeological prospection, protection, and heritage management. High-resolution DEM's derived from airborne LiDAR are becoming increasingly available on a regional and national scale, and have emerged as a valuable new data source in archaeology.

The aforementioned outlined processes will help Maya archeologists with preparing,

interpreting, and analyzing various LiDAR-visualization techniques for their project area. The process is simple and can be achieved by any researcher with an understanding of GIS fundamentals. This research is in its preliminary stages, but further geospatial analysis will shed light on size and boundary (if any) of Maya sites, the heterarchical relationship between commoner settlement and regional centers, landscape settlement patterns, and exploitation of natural resources.

ACKNOWLEDGEMENTS

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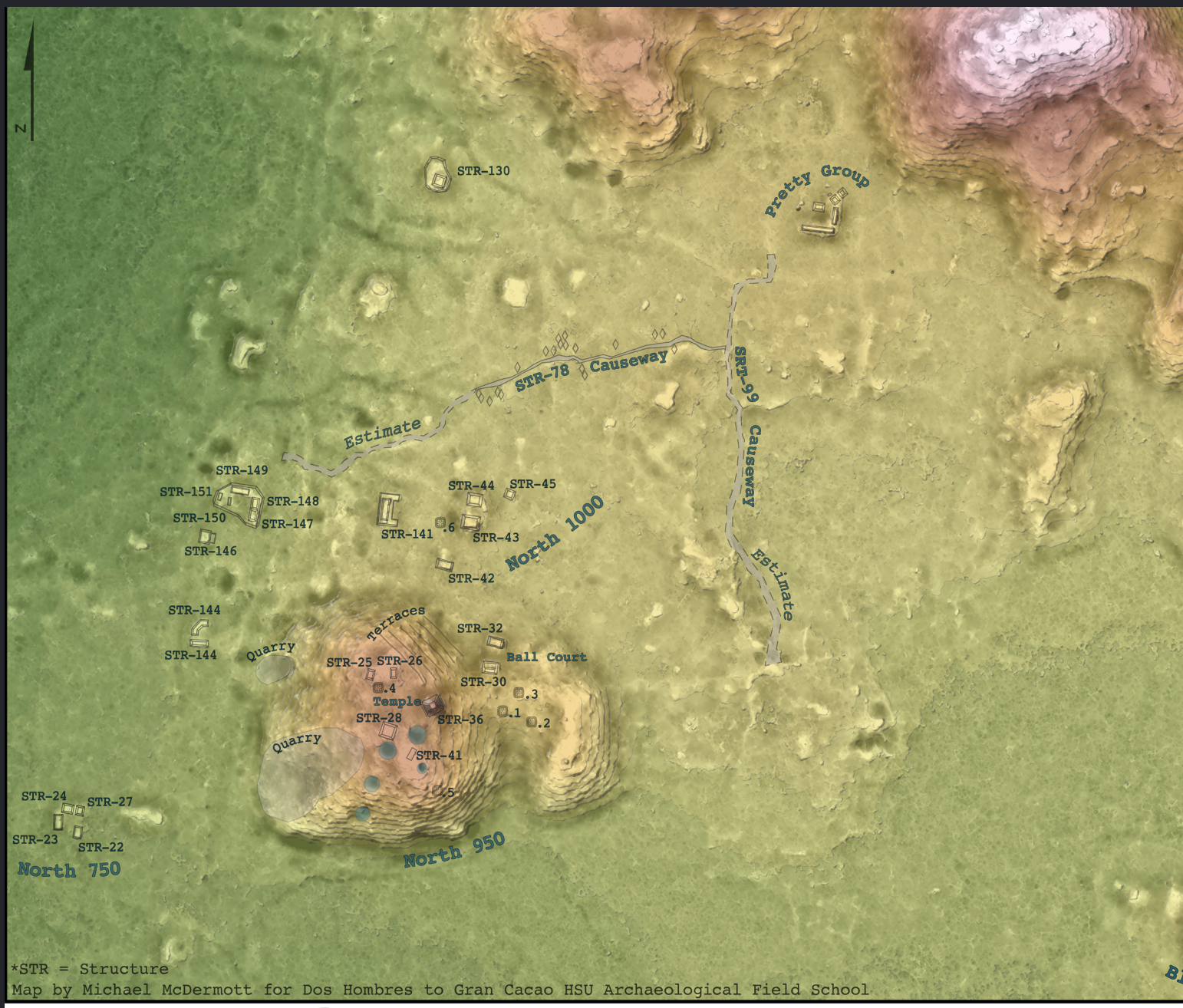
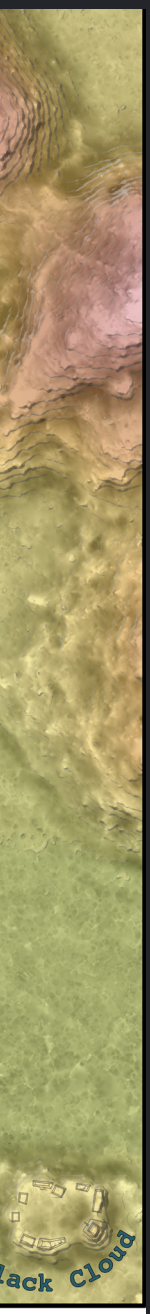
Jeremy McFarland is an alumnus of Humboldt State University, who earned a Bachelor's of Arts in Anthropology with minors in Geospatial Analysis and Scientific Diving. His passions are in cartography, marine sciences, and archaeology. His current research focuses on visualization of complex datasets, particularly ways to map and visualize the terrain and the environment in the Maya landscape. He is a Research Associate of the HSU Cultural Resource Facility, the GIS Program Manager for the Dos Hombres to Gran Cacao Archaeological Project in Belize, and contributes as a Scientific Diver to marine research along the Pacific Northwest Coast.

Marisol Cortes-Rincon, Ph.D., is an Associate Professor and the Interim Director for the Cultural Resources Facility in the Department of Anthropology at Humboldt State University. She directs the Dos Hombres to Gran Cacao Archaeology Project in northwestern Belize. Her teaching and research are focused on a variety of interpretive issues related to ancient Maya culture: sociopolitical organization, demography, subsistence, environmental management, economic structure, and warfare studies.

Michael McDermott is a senior Geography, GIS, and Anthropology student at Humboldt State University. For the past year, Michael has been involved with the Humboldt State Archaeology Laboratory, working on GIS projects for the Dos Hombres to Gran Cacao Archaeology Project (DH2GC) directed by Dr. Marisol Cortes-Rincon in northwestern Belize. Michael's recent interests include Maya Archaeology and understanding the cultural modified landscapes of Mesoamerica. He is also passionate about exploring and mapping the forest and trails of Humboldt County.

MICHAEL MCDERMOTT





This map displays the spatial relationships and distribution of residential features throughout a portion of the Maya hinterlands near the site of Dos Hombres in Northwest Belize. Combining high resolution LiDAR data with detailed archaeology field data has allowed for accurate mapping of the features in this Mayan landscape. A unique aspect of this particular site is the presence of a causeway or "sacbe" which was used by the ancient Mayan people to distribute resources and move throughout their environment. The background terrain was created by manipulating the LiDAR data to generate a unique visualization that displays the human modified features throughout the terrain.

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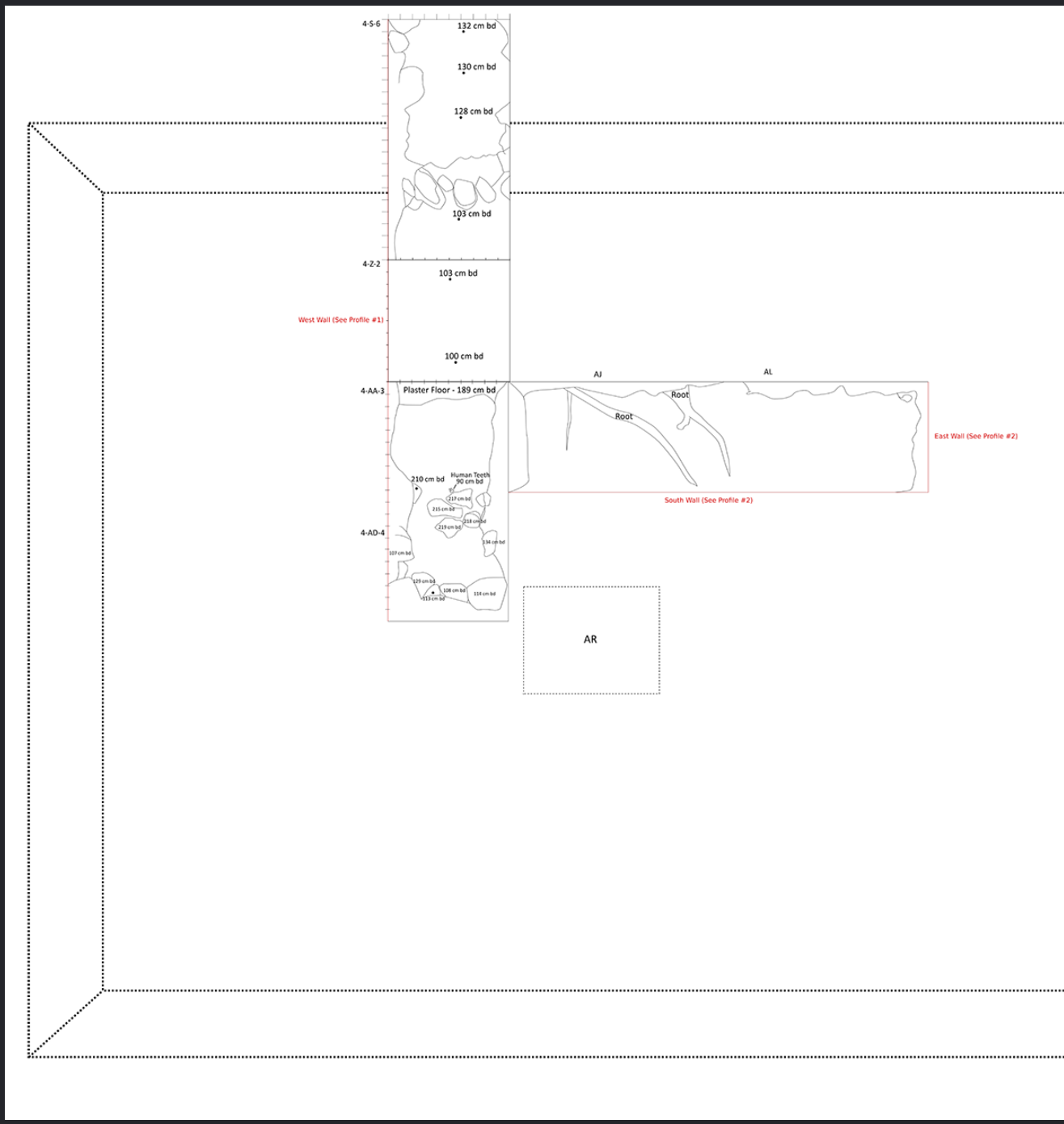
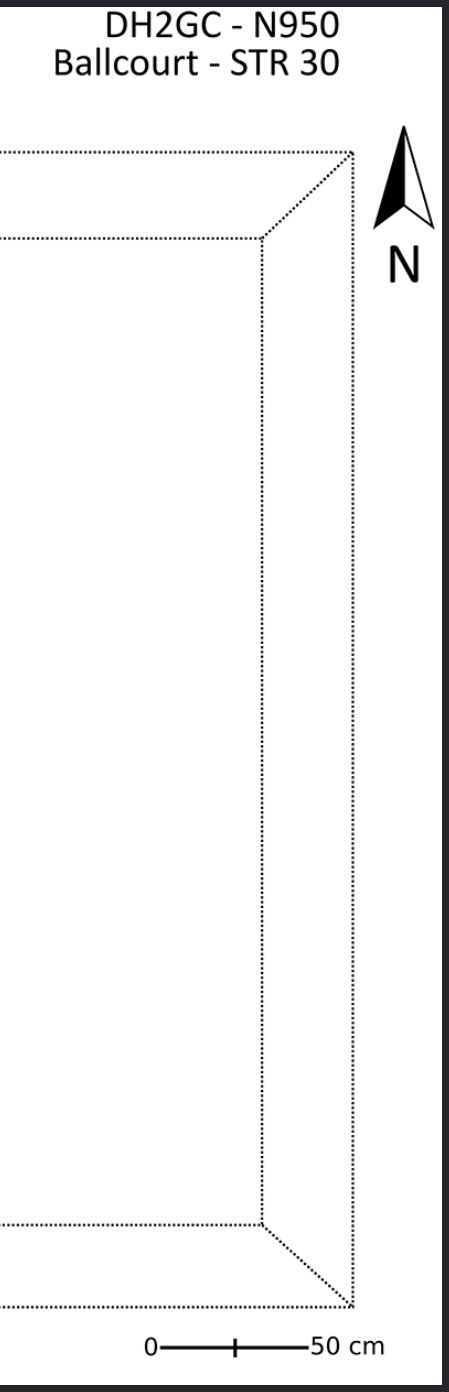
Adam Wall recently graduated from Humboldt State University in May, 2019 with a Bachelor's of Arts in Anthropology, specializing in digital archaeology. His research focuses on the development of a standardized methodology for digitally rendering archaeological data, and the use of such a methodology to make previously opaque, complex data easily accessible to anyone — not solely academia.

ADAM WALL





This is a composite map of Structure 30 (STR 30), an ancient Mesoamerican ballcourt in Belize, excavated and documented as an archaeological site by Humboldt State University students and alumni. Each demarcated square or rectangle corresponds to a separate excavation map; field notes were consolidated and digitized individually, then pieced together based on alignment and overlaid atop an outline of the entire structure. Satellite imagery of the site was used as a reference to ensure accuracy. By this method, the previously isolated pockets of data, inherent to individual field notes, instead become parts of a greater whole, allowing a fuller picture of archaeological sites rather than what similar documentation normally permits.

Smith, Byron, Stanton Morse. 2019. "Late Classic Soil Conservation and Agricultural Production in the Three Rivers Region." *Humboldt Journal of Social Relations* 41: 62–78.

Late Classic Soil Conservation and Agricultural Production in the Three Rivers Region

Byron Smith[a], Stanton Morse[a]

Abstract

Agricultural production during the Classic Period (c.1,700 to 1050 BP) in the Central Maya Lowlands was comprised of a variety of techniques that were used to satisfy dietary needs and to stimulate its subsistence economy. The complexity of those methods was a consequence of a variable topography and previous forest management practices that likely resulted in wide-spread deforestation, and subsequently large-scale erosion which limited arable land. The Classic Maya solution to limitations in arable land, augmented by increased erosion seems to have come in the form of geotechnical constructions placed in a variety of positions along the contours of hillsides that could have mitigated soil loss and provide leveled platforms for the cultivation of consumable resources. While retaining wall viability can be measured based on their ability to withstand earth pressures, the effectiveness of the planting platforms would have relied heavily on the nutrient availability required for plant development. This research sought to investigate the geotechnical constructions, as well as the soil properties resulting from their implementation and use at the Central Lowland Maya site of Yax Ch'am. While the results of this investigation indicated comparable designs in two retaining wall structures at the site, those structures had varied responses to lateral earth pressures. Consequently, soil analysis indicated increased phosphorus availability along the northern reaches of the hillside and deficiencies across the westernmost terrace.

Keywords

Geoarchaeology, Ancient Maya, soils, organic chemistry

Agricultural production in the Central Maya Lowlands was encouraged by an increased demand for subsistence resources that appears to have peaked during the Classic Period (c. 1700 to 1050 BP) in the Three Rivers Region of the Central Maya Lowlands. The complexity of methods utilized to produce subsistence goods was the result of a landscape that was naturally prone to varied degrees of erosion due to the stepped patterning of the landscape. That erosion was likely stimulated by previous forest management

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practices of the ancient Maya resulting in widespread deforestation dating back to the Preclassic Period (c. 3950 to 1700 BP). For evidence of deforestation in lake sediments (see: Anselmetti et al. 2007; for cave sediments see: Polk, Beynen and Reeder 2007). Pollen records retrieved near Dos Hombres, as well as those near Colha, appear to support suggestions of deforestation (Pohl et al. 1996; Dunning et al. 2003), and would have likely resulted in unmitigated erosion along the hillslopes of the region.

The implementation of geotechnical structures would have provided significant relief to soil retention efforts, while also providing platforms for cultivation through the natural leveling of the gradient (Beach et al. 2002). One such geotechnical structure that has been observed in past research is a terrace retaining wall which works to limit and divert run-off at varying degrees of inclination (Beach et al. 2002). Past research has shown that the Classic Maya of the Central Lowlands utilized a gravity enforced retaining wall (Figure 1) that consisted of unshaped limestone boulders (Kunen 2001) that were positioned to resist lateral earth pressures. More recently, research within the Three Rivers Region of northwestern Belize indicated the possibility of retaining wall structures surrounding a Classic Period household group in the hinterlands of Dos Hombres (Chenault and Boudreaux 2015). The household group consisted of several structures oriented around an area that lacked a centralized communal space, Ashmore (1981) referred to this arrangement of structures as an informal household group. Additionally, surveys of that household group suggested the presence of irrigation channels, as well as multiple water catchment features that may have been utilized to limit run-off in sensitive areas (Bryant 2015).

This project sought to confirm the presence of those retaining wall structures at the informal household group of Yax Ch'am located within

Figure 1. The four known types of gravity retaining walls in the Three Rivers Region, After Beach et al. (2002).

the hinterlands of Dos Hombres, and to evaluate their design and motivation. This project also sought to investigate the leveled fields contained within the retaining wall structures for evidence of anthropogenic soil alteration through nutrient analysis. A final goal was to define the irrigation strategy and identify areas that may have been considered sensitive to erosion by their occupants. The methods utilized to answer those questions involved both field and laboratory components and included: surface survey, excavation, soil sampling and analysis, and Geographical Information Systems (GIS). Those efforts resulted in the identification of a succession of retaining wall structures that followed the contour of the hillside surrounding two household groups that were distanced 70 meters apart. While some areas of the retaining wall structures did yield to lateral earth pressures, significant portions appear to have remained relatively

stable. Soil analysis identified areas of increased phosphorus (P) availability between the retaining walls of the northernmost terrace, suggesting variations in land management strategies across cultivated and uncultivated areas, however more research is needed to fully understand the nature of P availability across the landscape. Finally, the irrigation strategy at Yax Ch'am appeared to have been driven by water availability and household demand, which was identifiable through channel routes leading from the residential platform to water catchment features.

THE PHYSICAL ENVIRONMENT

While the geographic area of the ancient Maya was approximately contained within the boundaries of Central America including Guatemala, Belize, northern El Salvador and Honduras and the Yucatan Peninsula of Mexico, the area of interest for this project was within the Three Rivers Region of the Rio Bravo Conservation and Management Area (RBCMA) of the Central Maya Lowlands (Figure 2). The area gets its name from the three rivers (Rio Azul, Rio Bravo, and Booth's River) that converge in the area to form the Rio Hondo, which discharges in the Chetumal Bay to the northeast (Figure 3). This area is also the location of several prominent Maya ceremonial centers, which include: Rio Azul, La Milpa, Dos Hombres, and Blue Creek. The variable topography of the Three Rivers Region lies on the fragmented eastern edge of the karstic Maya block. Discontinuity resulting from the strike-slip fault of the North American and Caribbean plates produced a linear zone of shearing that trends 35° east and underlays the western half of the RBCMA (Figure 4). Faulting within the Rio Hondo shear zone and the subsequent slumping of the loosely consolidated limestone platform along the eastern margins of the plateau resulted in a progression of westward trending gradations containing upland regions, steep escarpments, and ravines (Figure

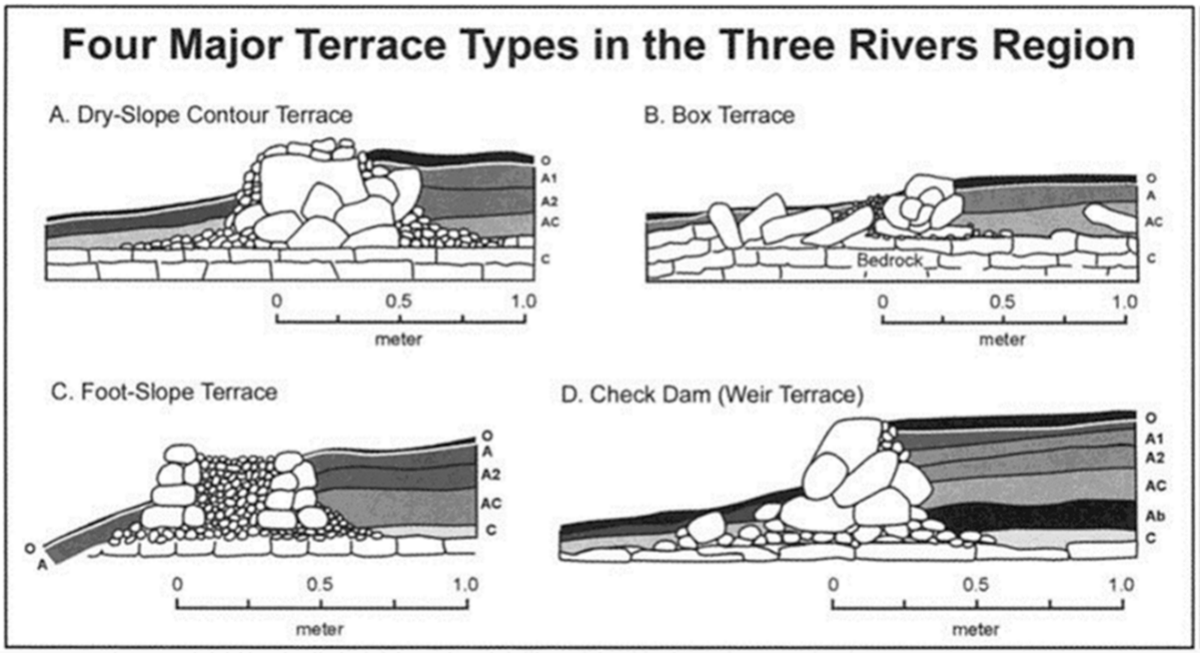


Figure 2. Classic occupations within the Three Rivers Region would have been heavily dependent on agricultural resources for subsistence and to maintain its economy.

5). The continuum of west trending stepped gradations ranges in elevation from 20 meters above sea level to more than 220 meters and creates a shallow trend of soil conditions that provokes a sequence of forest types including bajo swamps, transition, and upland forests.

The soils of the RBCMA are generally viewed as belonging to the Yaxa suite based on general classifications by Baillie et al. (1993). In their assessment, the Yaxa suite appeared to have resulted from the influence of the earlier Ram Goat and Irish Creek subsuites. The consolidation of those subsuites yielded the dark clays of the Yalbac and Jolja subsuites, which have been classified as Rendolls, Leptosols, Cambisols, Vertisols, Eutropepts, Udolls, and Uderts based on their location along the landscape.

THE CULTURAL LANDSCAPE

While there exists only limited evidence of settlement occupations in the Three Rivers Region prior to the Classic period, populations appeared to be thriving at the sites of Lamanai and Colha to the northeast (refer to Figure 3). It is at the site of Colha, an important source of chert and flint manufacturing in the region, that early signs of deforestation and ensuing agricultural production become evident through pollen samples extracted from the Cobweb Swamp near Colha (Pohl et al. 1996). That evidence also appears

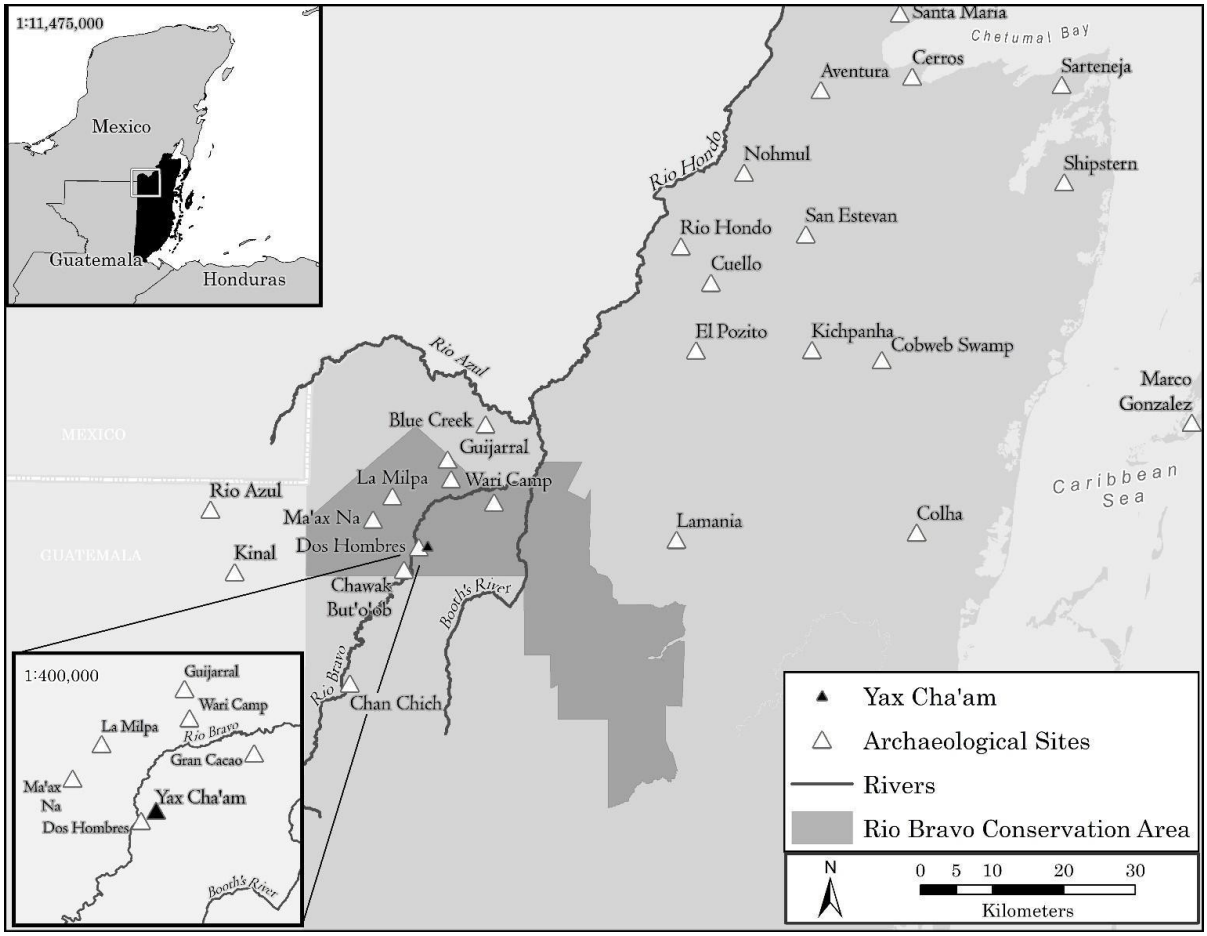
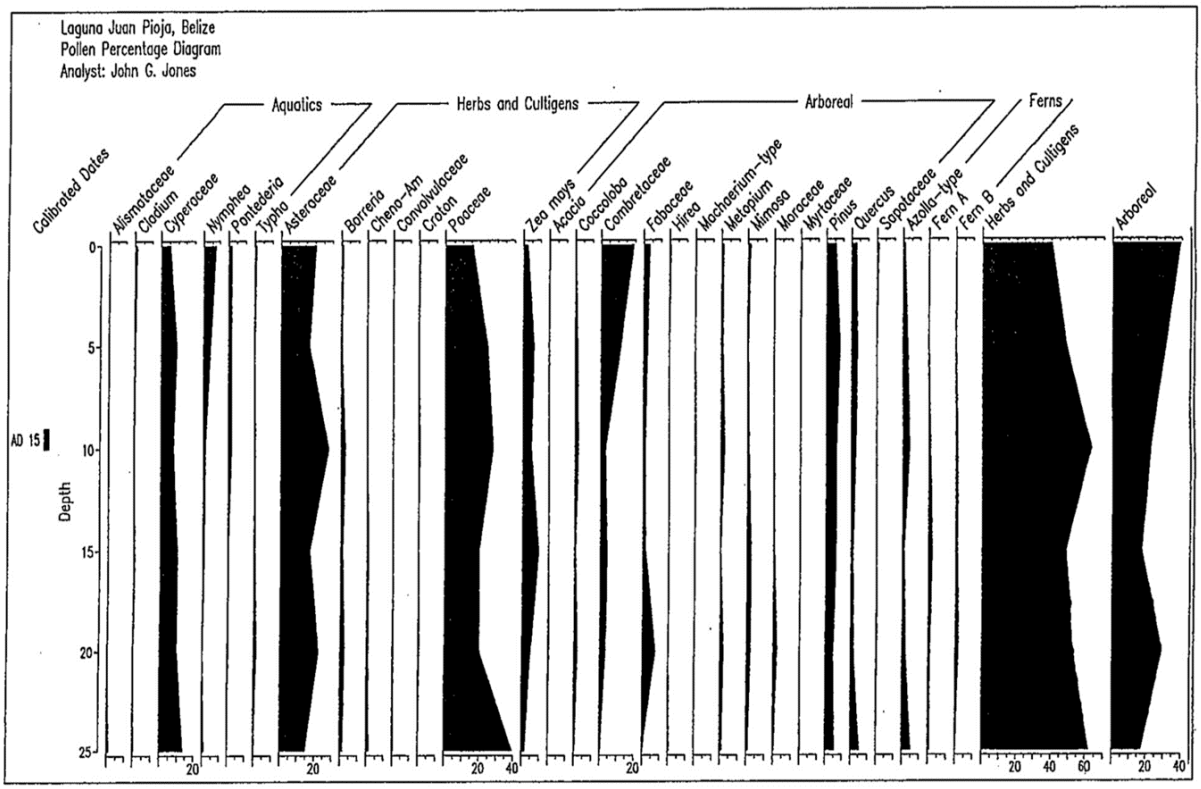


Figure 3. The Three Rivers Region is defined by the three rivers that converge to form the Rio Hondo.

along the Rio Bravo Embayment near Dos Hombres, where pollen samples taken from lake cores suggests decreases in arboreal species and increases in herbs and cultigens (Table 1: Dunning et al. 2003). Soil analysis elsewhere in the Three Rivers Region appears to corroborate previous pollen analyses in the area, by suggesting increased sedimentation in the bajo regions that resulted from widespread clearing (Dunning et al. 2002). Increased sedimentation likely converted many of the bajos in the area from perennial wetlands to wetlands that were inundated only during the rainy season. Considering the results of pollen analyses from Dos Hombres, it appears clear that while there exists only limited evidence of occupations in the Three Rivers Region prior to the Classic Period, herbs and cultigens constituted a significant portion of extracted pollen samples. This suggests that although the area was sparsely populated, it appears to have been utilized for timber extraction and resource cultivation.

It is during the Classic Period that fluctuations in populations become visible within the archaeological record of the Three Rivers Region through construction at regional sites, such as Dos Hombres and La Milpa, as well as household construction in the surrounding hinterlands. While that increase represents a modest change, the Early Classic (c.1700 to 1350 BP) is the time frame in which the first representations of political influence begin to appear in the Three Rivers Region at La Milpa. In addition to the erection of stelae (Hammond and Tourtellot 1993) signifying the politicization of the region, hydrologic constructions also began to appear through the

Table 1. Pollen samples from Laguna Juan Pioja core near Dos Hombres, from Dubbing, et al. (2003:22, figure 2.8).



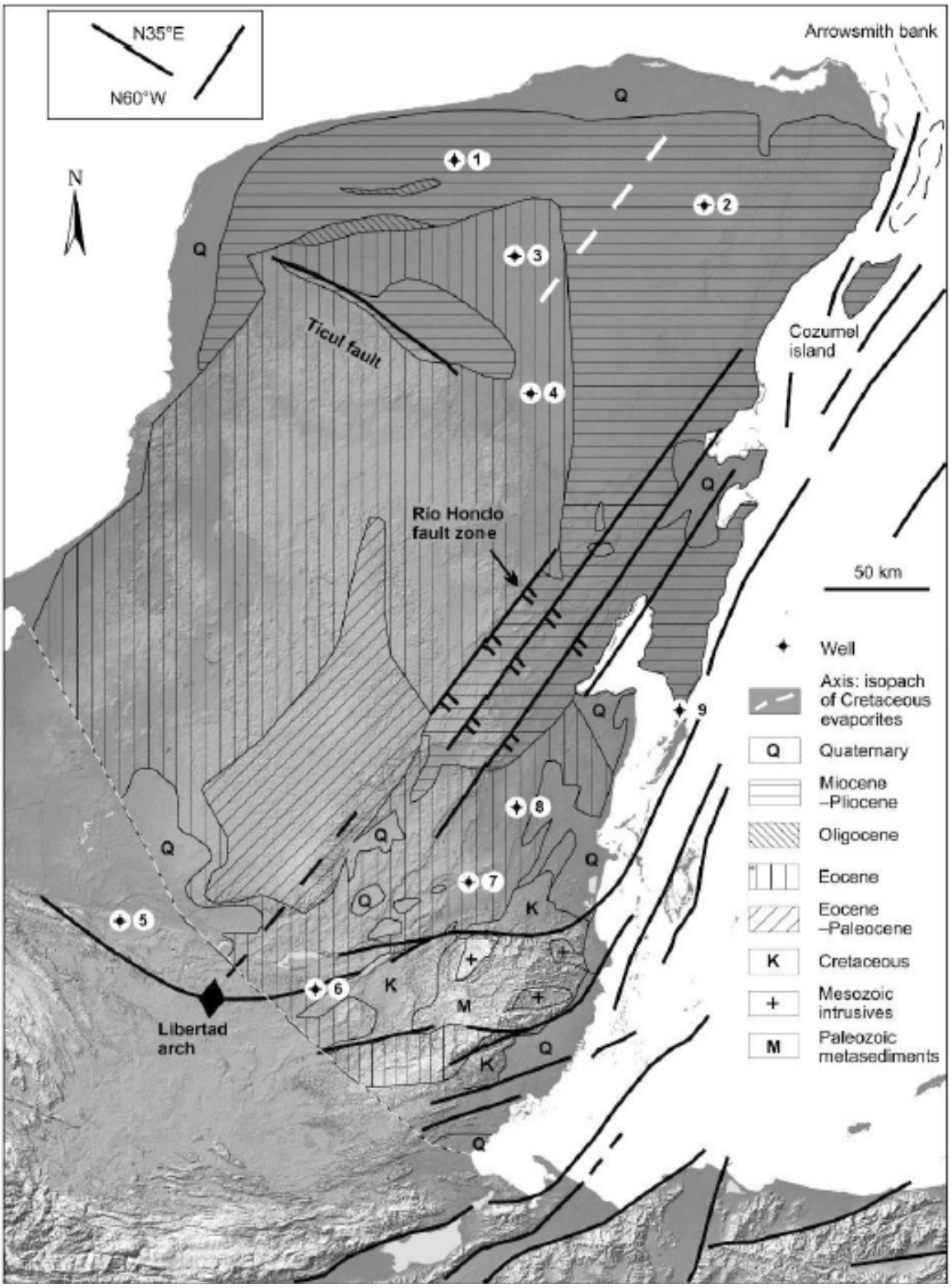


Figure 4. The Rio Hondo Fault Line trends at 35˚ northeast to southwest from the Chetumal Bay, after James (1989:9, Figure 111.5).

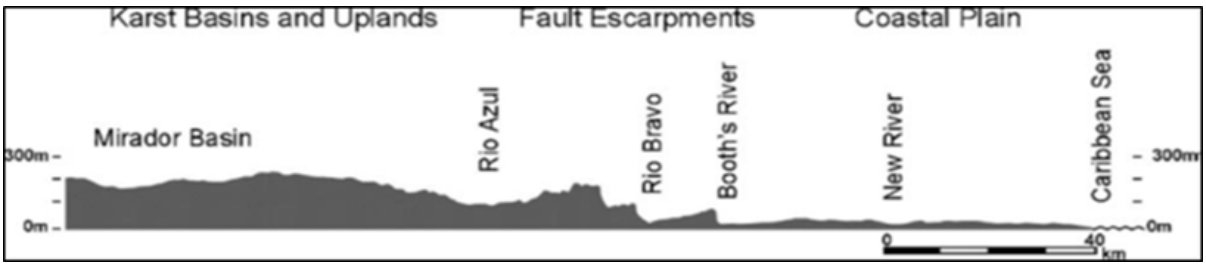


Figure 5. The Rio Hondo fault zone creates a stepped patterning of the landscape. After Dunning et al. 2003:16.

implementation of reservoirs and dams (Scarborough et al. 1995). It should be noted that while population fluctuations were minimal in the majority of the Three River Region, the sites of Rio Azul and Blue Creek appeared to thrive during this time (Adams 1990; Guderjan 2007). The Early Classic in the region was followed by a period of decline as the erection of structures and stelae were muted for a period of roughly one hundred years (Ashmore 1981, 2007; Culbert and Rice 1990). Recent suggestions point to environmental conditions leading to the discontinuity in occupations during the Classic Period (Webster et al. 2007; Turner and Sabloff 2012). However, following that period of decline, populations in the Three Rivers Region surged as structures began to appear within urban and rural context (Turner and Harrison 1983; Sullivan and Sagebiel 2003). Along with those constructions came the apparent adoption of terrace technology, which has been shown to support residential and agricultural frameworks. As mentioned above, previous research suggests the widespread clearing of the landscape witnessed prior to the Classic period, through pollen samples near Dos Hombres, resulted in unmitigated erosion that was enhanced in areas of variation in the landscape's gradient. Beach et al. (2006:168) suggest the possible displacement of "whole soil profiles" in areas of the Three Rivers Region as a consequence of prior deforestation.

TERRACING IN THE THREE RIVERS REGION

Classic Maya solutions to soil erosion came in the form of terracing, which utilized retaining walls to limit erosion and runoff. Terraces have been identified in a variety of contexts along the variable topography of the Three Rivers Region including at: La Milpa (Kunen 2001); Chawak But'o'ob (Hanna and Walling 2008); Guijarral (Hughbanks 1998); Las Terrazas group (Hageman and Lohse 2003); and within the suburban regions of Dos Hombres (O'Neal 1999; Trachman 2006). Terraces work to limit erosion and runoff by converting sloped landscapes into a succession of leveled platforms that can be used to support structures, as in the residential terraces at Chawak But'o'ob (Hanna and Walling 2008) or crop cultivation (Beach et al. 2010). For the Classic Maya, terrace construction likely involved excavations to bedrock that spanned the expected footprint of the retaining wall. Once excavated, large limestone boulders would have been positioned along the footprint of the retaining wall by hand with the largest boulders anchoring the base of the structure. Construction fill of midden materials and/or limestone and chert cobbles would have been added to occupy voids in the rock feature.

Retaining wall designs throughout the Central Lowlands have come to be classified based on the context of their positioning, as well as on their design. Additionally, terraces have been classified

based on their cohesion with other geotechnical structures, such as with extensive terracing, which suggests centralized control and planning as opposed to a seemingly erratic layout which may suggest a more individual effort (Healy et al. 1983). Those arrangements include box terraces which are often found on well-drained upland slopes (Fedick and Ford 1990), dry slope terraces that either follow the contour of a hillside or are oriented vertically along the contour (Wyatt 2006), foot slope terraces located at the base of hillsides, and check dams used to divert run-off (Dunning and Beach 1994). While the purpose of terrace implementation has been hypothesized to include soil retention and resource production (for soil retention see: Beach et al. 2002; for resource production see: Scarborough and Valdez 2003), terraces appear to have been utilized in a variety of contexts including those previously listed, as well as for water retention and the support of structures.

While the viability of agricultural retaining walls rests in their ability to withstand active earth pressures, their effectiveness relies on the proficiency of planning, as well as continued labor inputs to ensure a sustained agricultural production (Healy et al. 1983; Treacy 1989). In light of the effects of intensive agriculture on a soil's nutrients (Reeves 1997; Vitousek et al. 2010), an adequate nutrient management scheme would have been a required task to ensure prolonged productivity. Those efforts would have come in the form of soil fertilization through the application of nutrient-rich materials.

THE SITE OF YAX CH'AM

What made the Three Rivers Region particularly interesting to this project were those suggestions of Classic Period (c. 1700 to 1050 BP) migrations into the region following periods of deforestation potentially leading to increased erosion. The consequence of which may have limited arable land in the region and further complicated solutions to increased subsistence demand resulting from population growth. With the central focus of this project squarely posited on consumable resource production in the hinterlands, past field work in and around the site of Yax Ch'am provided an incentive for research due to evidence of landscape modifications. The site was identified by researchers with the Dos Hombres to Gran Cacao Archaeology Project during previous investigations within the hinterlands adjacent to the medium-sized ceremonial center of Dos Hombres (Cortes-Rincon et al. 2015).

The site of Yax Ch'am lies 350 meters northeast of Dos Hombres and is characterized by approximately five structures positioned on top of a broad gently sloping hill (Figure 6). The site shows evidence of landscape modifications resulting in water management and soil conservation strategies (Bryant 2015). The layout of the structures represents an informal cluster based on Ashmore (1981), and ceramic analysis by Boudreaux and Sullivan (2015) place its occupations during the Early (c.1700 to 1350 BP) to Late Classic Period (c. 1350 to 1150 BP). Excavations at the site revealed the presence of jute shells (genus Pachychilus genus), and a granite metate sourced to the Maya Mountains in southern Belize. These artifacts suggest possible trade networks due their extraneous nature (Cortes-Rincon, personal communication 2016). Indications of landscape management at Yax Ch'am came from the identification of four water catchment features (known as aguadas), as well as evidence of an irrigation strategy which was identified by the presence of cut stones (Bryant 2015). Channels connect the three aguadas and possibly worked to redistribute moisture from over-flowing basins (Chenault

and Boudreaux 2015). Soil sampling and field analysis was conducted by Bryant (2015) and those samples were chemically analyzed by the Soil and Plant Tissue Testing Laboratory at the University of Massachusetts at Amherst. While soil testing was sparse at Yax Ch'am, the results suggested a predominately gypsiferous vertisol that was alkaline in nature and thinner along the terraced features (Bryant 2015).

METHODOLOGY

This project sought to investigate the site of Yax Ch'am and gain a better understanding of the nature of terracing at the site in lieu of potential soil limiting factors that could have affected agricultural production. The methodology for this project was designed to answer the questions of: whether the terracing was utilized for residential or agricultural purposes; whether the design of geotechnical structures correlated with other known structures in the area; to evaluate the reliability of the structures, and to determine whether the availability of P could be used to identify the boundaries of cultivation zones by identifying variations in P availability across the landscape. The field methods utilized to answer questions pertaining to landscape management relied on pedestrian and geodetic surveys to identify areas of possible retaining wall construction, excavations to expose the

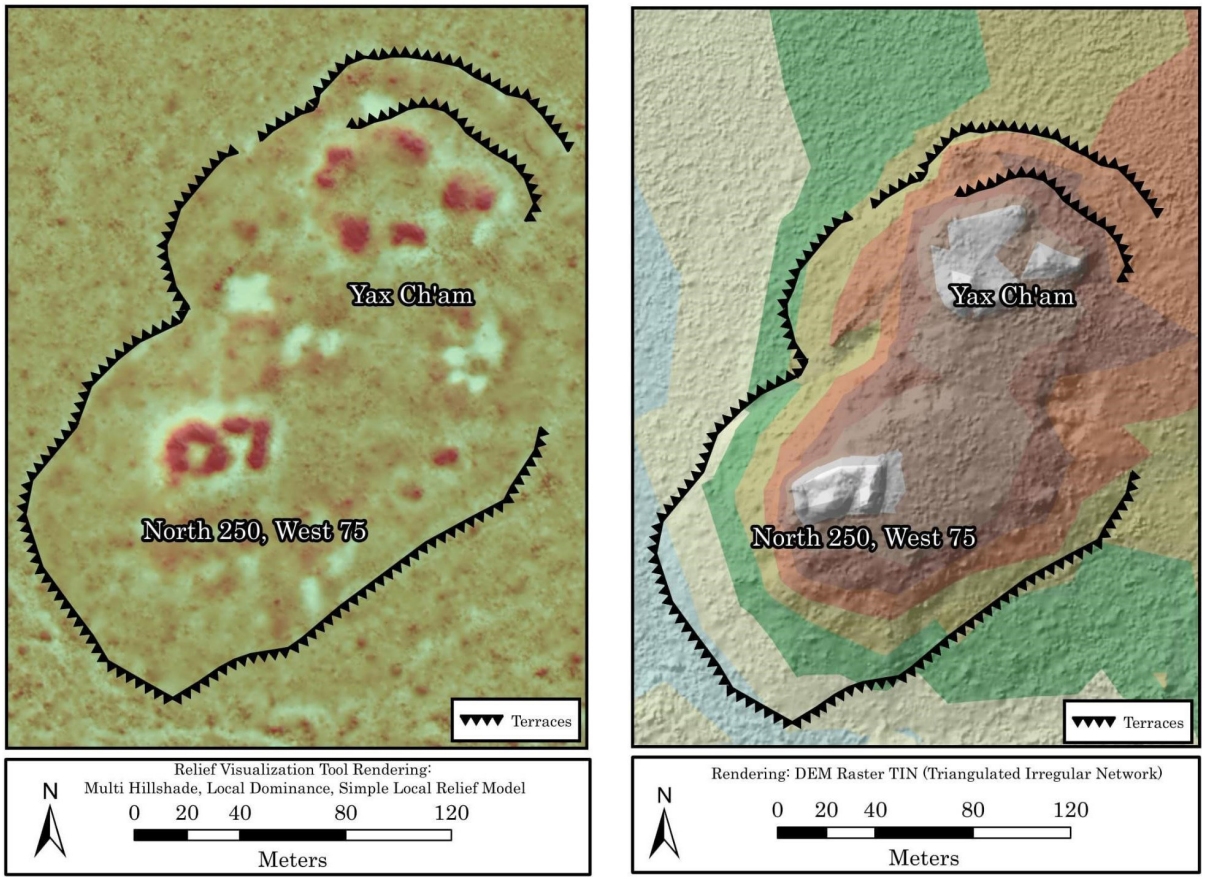


Figure 6. Yax Ch'am occupies a southwest trending mound that is surrounded by terracing and water features.

retaining wall design, and a soil sampling strategy oriented at analyzing soils both on and off of terraced features.

The normalized difference vegetation index (NDVI) contributed to the quantifiable biomass present prior to selecting excavation and soil nutrient sampling locations. By providing visualization variances from the surface reflectivity values, the site's feature locations could then be estimated. The reflectivity values depend on the chemical composition of surface elements and features, the presence of chlorophyll within vegetation, and the amounts of solar radiation which are either reflected, absorbed, or re-transmitted. Healthy vegetation reflects energy highest in the near-infrared (NIR) bands and lowest in the red bands (Tempfli et al. 2009). Whereas lower quantities of chlorophyll, often associated with unhealthy vegetation, reflects less of the NIR bands and more red bands which gives the appearance a yellowish hue. Even the slightest changes can be detected by utilizing the NDVI formula, NDVI= (NIR -Red) / (NIR+Red). The geotechnical features appeared linear on the ground as well as in the NDVI rendering which provided complementary verification for 'ground-truthing' accuracy (Figure 7). Future research utilizing optimized soil adjusted vegetation index (OSAVI) may be better suited for the thicker forest canopies within the project area.

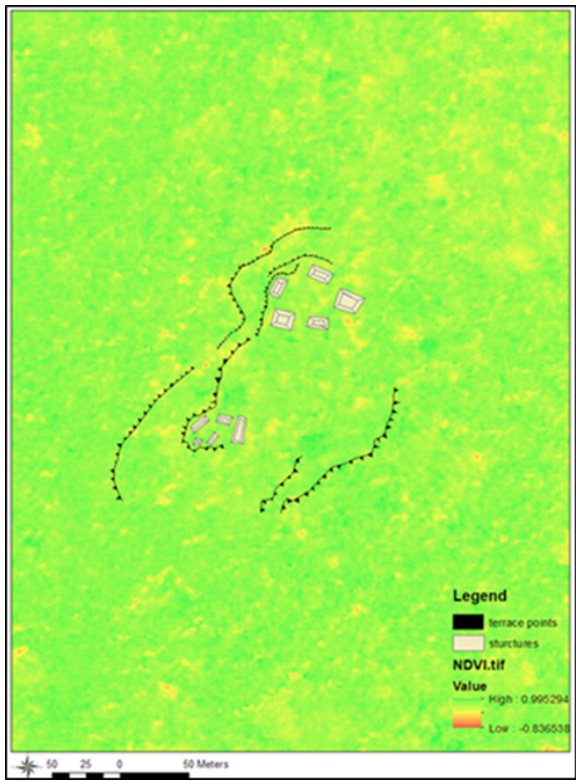


Figure 7. The NDVI analysis indicated areas of less healthy vegetation within the terraces surrounding Yax Ch'am.

SOIL SAMPLING AND ANALYSIS

A grid-based soil sampling strategy was utilized to regulate soil collection locations across the northern and western extents of terracing surrounding Yax Ch'am. A total area of 1,200 square meters were scrutinized along the northern terrace using four northeast (16 degrees) oriented columns. Sample collection points were spaced 10 meters apart and continued in a northeast direction for 30 meters. The total area studied along the western terrace equaled 11,500 square meters, and like the northern grid was subdivided into two columns oriented to the northeast (16 degrees). Soil samples were collected in the mid-section of each horizon present and extended to maximum depth of 44 centimeters.

Soil analysis was conducted by project researchers in the field, and at Humboldt State University's Archaeology Research Laboratory and Core Research Facility. Soil samples were collected from each horizon within the shovel test pits and visibly analyzed in the field for structure and color (Munsell Soil Color Chart). Soil analyses at the Archaeology Research Laboratory included texture (feel analysis method), pH and temperature (utilizing a portable direct-soil meter). The

methods that were used for structure and texture were based on those expressed in the Kellogg Soil Survey Laboratory Method's Manual (Burt 2014). Available P was extracted from soil samples and analyzed by project members within the Core Research Facility at Humboldt State University. The extraction of P in soil samples utilized a weak double acid solution containing: acetic acid (CH_3COOH) to decompose apatite, and keep the solution below a pH of 2.9 to prevent the precipitation of calcium fluoride; nitric acid (HNO_3) to increase the solubility of ferric iron (Fe) and aluminum (Al) phosphates while also extracting a portion of available calcium (Ca) phosphates; ammonium fluoride (NH_4F) to displaces P anions; ammonium nitrate ($(NH4)NO_3$) which can be exchanged with complex Al cations, and EDTA to enhanced micronutrient extraction by acting as a chelating agent (Mehlich 1984). Sample analysis depended on the ascorbic acid method which is based off the principle that ammonium molybdate ($(NH_4)_2MoO_4$)) and antimony potassium tartrate ($C_8H_{10}K_2O_{15}Sb_2$) react with orthophosphates in an acidic medium to form an antimony-phospho-molybdate complex, that can then be reduced by ascorbic acid to develop a bluish hue. Following reduction by ascorbic acid, absorbance was measured using a SpectraMax i3, with SoftMax Pro 6.4 as the operating system for spectrophotometry.

RESULTS

The efforts of field and laboratory methods resulted in the identification of two terraced features likely utilized for agricultural production, a possible residential terrace at the apex of the hillslope, as well as a defined irrigation strategy. The vertisols analyzed at Yax Ch'am consisted of clayey loam which were high in organic matter and granularly structured. In all, a total of 104 soil samples were collected which included 77 from the site of Yax Ch'am, and 27 from a comparative site located approximately 400 meters northeast (Smith 2017). P availability varied along the landscape ranging from less than 1 mg/kg to more than 7 mg/kg based on a double weak acid extraction method. The irrigation channels that were identified during previous research were revisited in an attempt to define their origin. Conclusions of that investigation identified two separate channels emanating from the southern reaches of the household group that appeared to unite and terminate at a natural or human-made pond (or aguada) along the southern periphery of the household group. Cut stones appeared to have been strategically placed along the route to redirect moisture towards those southern aguadas (Figures 8 and 9).

Retaining walls were identifiable during surface surveys through the protrusion of large limestone boulders from the soil in some areas, and by the variation in the hillsides contour when the boulders were not visible. The first geotechnical feature that was observed began to the north of the platform and continued west intermittently for an additional 40 to 50 meters before turning towards a southerly direction and becoming indistinct with the surrounding landscape. Identification of the second retaining wall was less easily achieved due to the lack of above-ground features. However, variation in the landscape suggested the presence of subsurface features and allowed for approximations. As a result, the inferior terrace was measured at more than 80 meters and encompassed a secondary household group. Excavations of the agricultural retaining wall feature located immediately north of the household group uncovered the remains of what appeared to be a double walled structure consisting of limestone boulders (Figure 10). Fill

Figure 8. Stone cut water channels were used to funnel water into the aguadas. Image taken by Byron Smith.

Figure 9. Two channels emanated from the household group and converged before feeding the aguadas. Image taken by Bryon Smith.

material consisting of limestone and chert cobbles, as well as small ceramic fragments, was concentrated around the northern exterior of the feature. Although not pictured, the westernmost retaining wall initially displayed a similar form to that of northern retaining wall, but as excavations extended into the subsoil, that form became distorted, likely due to erosion.

P availability varied along the landscape ranging from less than 1 mg/kg to a high of 7.4 mg/kg. Available phosphorus in the terraced area north of Yax Ch'am exhibited slightly higher available P compared to other areas surrounding the site, as well as the comparative site. Accumulations of available P in the O horizon along the northern terrace held a mean value of 5.8 mg/kg, whereas along the western periphery the mean was 3.8 mg/kg (Figures 11 through 14). Soil analysis also determined that those soils located nearer to the downslope retaining wall in both test areas maintained a higher range of available P, with those soils 1.5% higher than the adjacent soils upslope, and 3% higher than those nearer the preceding geotechnical structure. Soil pH at Yax Ch'am across all regions held an average pH of 7.4, with a high of 7.73 and a low of 7.0, firmly in the zone of alkaline soils, but also in the ideal range for maize cultivation.

DISCUSSION

Early analysis of the area's vegetation index seemed to correlate with the presence of terraces on site. As mentioned earlier, while the interest in locating retaining walls derived from past suggestions, attempts to visually identify them prior to excavation was aided by the use of the areas NDVI index. Specifically, the retaining wall to the west of the household group maintained a similar orientation to the area of the NDVI output indicating a change in vegetation density. Early intentions for utilizing an NDVI were centered around the effects of intensive agriculture on plant health through nutrient depletion. However, it should be noted that the area to the west also represented mixed forest growth as the contour of the landscape gave way to a transitioning forest. With that said, the application of remotely sensed vegetation indexes presents interesting possibilities for archaeological survey, but its analysis is needed on a broader to scale in order to enhance proficiency.

While the geotechnical design at Yax Ch'am

Figure 10. The retaining wall was a double walled structure. The smaller boulders to the north and south extremities appeared to have rolled out of place. Image taken by Byron Smith.

seemed to adhere to contemporary ideas surrounding lowland Maya terrace design, there were distinct differences between the two retaining walls identified at the site. The distribution of construction fill stones was more dispersed through the excavation unit associated with the lower terrace along the western facing slope, and the exposed retaining wall boulders were much smaller. The intermediate terrace on the northern slope also contained evidence of stone working that was witnessed through the presence of multiple limestone boulders that appeared to suggest a cohesiveness in design (refer to Figure 10). Notice the circular cut on the two larger boulders, as well as the spherical design on the boulder that has rolled out of place). The location of the two larger cut boulders, although toppled in different directions, seemed to serve some function at the apex of the structure.

The terrace located to the west of the household group was traced to a second household group located approximately 70 meters southwest of Yax Ch'am. The presence of the two household groups inside the span of the larger terrace suggests a community-focused organization of labor that may have had direct impacts on fulfilling the labor requirements of terrace implementation and agronomic efforts. Additionally, the Classic Maya method of no-till farming may have implications on soil testing results due to likely fertilization strategies in absence of tillage. While broadcasting and banding nutrient-rich material could be costly (in terms of labor and desired output), seed placement fertilization, and

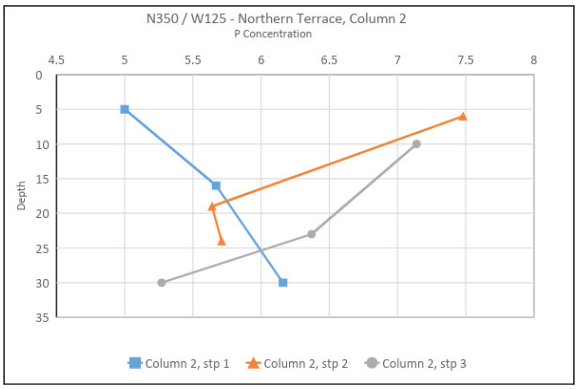


Figure 11. STP of second column represented an inverse accumulation of phosphorus by depth.

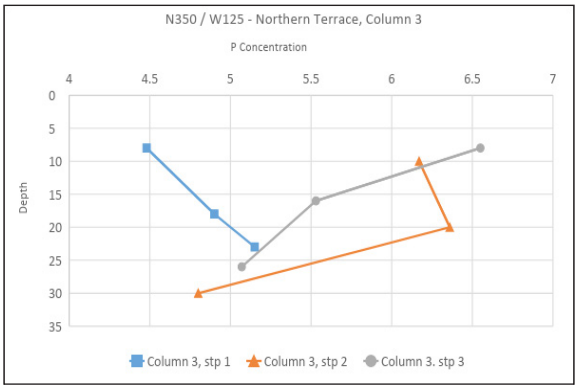


Figure 12. STP1 of the third column represented an inverse accumulation of P by depth.

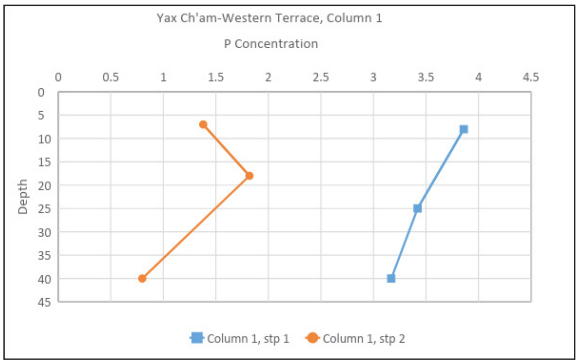


Figure 13. Soil at the depth of 17 centimeters represented a slight increase as compared to the surrounding soils.

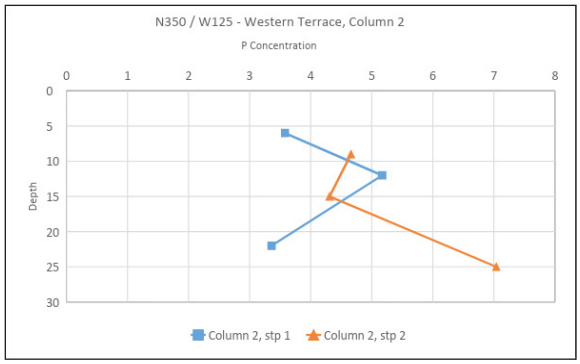


Figure 14. Soil P at the 25-centimeter depth represented a shar spike, as compared to the above soils.

to a lesser degree, methods similar to side dressing would target specific areas of growth and avoid areas where fertilization was not needed.

Two areas surrounding Yax Ch'am were sampled in order to determine the range of P availability. The sampling strategy to the west of the household group was devised to extend beyond the western extents of the terrace to include regions that were both on and off the terraced landscape. Consequently, some regions that extended beyond the recognized retaining wall were measured as having a slightly lower index of available P than those that were within the boundaries of the retaining feature. The two most common pH values at Yax Ch'am were 7.4 and 7.7. Those values suggest a predominance of (hydrogen phosphate) HPO42- which is more prevalent in alkaline soils. Also, at those pH values, phosphorus has a higher likelihood of fixating with calcium in the soil to form calcium phosphates. This process has implications on the methods of extraction used to separate phosphorus molecules in the soil, and future analysis would benefit from measurements that include levels of total P.

CONCLUSION

To summarize, this inquiry sought to evaluate the land management strategies of an informal Classic Maya household group in the hinterlands of

the Three Rivers Region in northwestern Belize. Surveys of the area were encouraged by previous fieldwork at the site, as well as distinctions in the health of vegetation displayed through the NDVI of the region. Excavations of features employed to retain upslope soils helped to expose feature design and reliability. Additionally, soil analysis was employed to distinguish soils within cultivated areas from those regions on the exterior. The lack of structures within the confines of those features, in addition to the expanse of land contained within, allowed for the suggestion of agriculture as the primary function of those terraces identified surrounding the site of Yax Ch'am. In order to further understandings of intended use, future analysis in the area of Yax Ch'am will focus on the detection of plant species in cultivation strategies to further understandings of crop diversity in relation to the landscape. This will be accomplished through the use of phytolith analysis of to provide a more comprehensive view of land use strategies relating to agricultural production.

While the terraces surrounding the site seemed to cohere with contemporary evidence of retaining wall design in the Three Rivers Region, distinctions existed between the two retaining structures identified at the site. The primary difference centered on indications of erosion disbanding the western wall in areas. While that deterioration appeared not to limit the amount of arable land surrounding Yax Ch'am, it does suggest the necessity of the continual maintenance of those structures to ensure overall reliability. Albeit a difficult endeavor, the identification of varying phases of construction would elaborate on the long-term labor requirements of subtropical terrace farming and as such, the importance of those fields to those who farmed the land, as well as the wider community.

Finally, although variations in P availability in and around terraced features allowed some insights into past land management strategies, future analysis will benefit from measurements of both soluble and insoluble forms of P in order to account for the fixation that occurs in calcareous soils. That fixation is a product of P adsorption and the precipitation of calcium phosphate and results in less soluble forms of P which becomes unavailable to plant life (including modern forested soils). The incorporation of insoluble forms of P with those soluble forms may allow for insights into the value of P analysis in investigations of abandoned cultivation zones and as a result the effectiveness of past fertilization methods.

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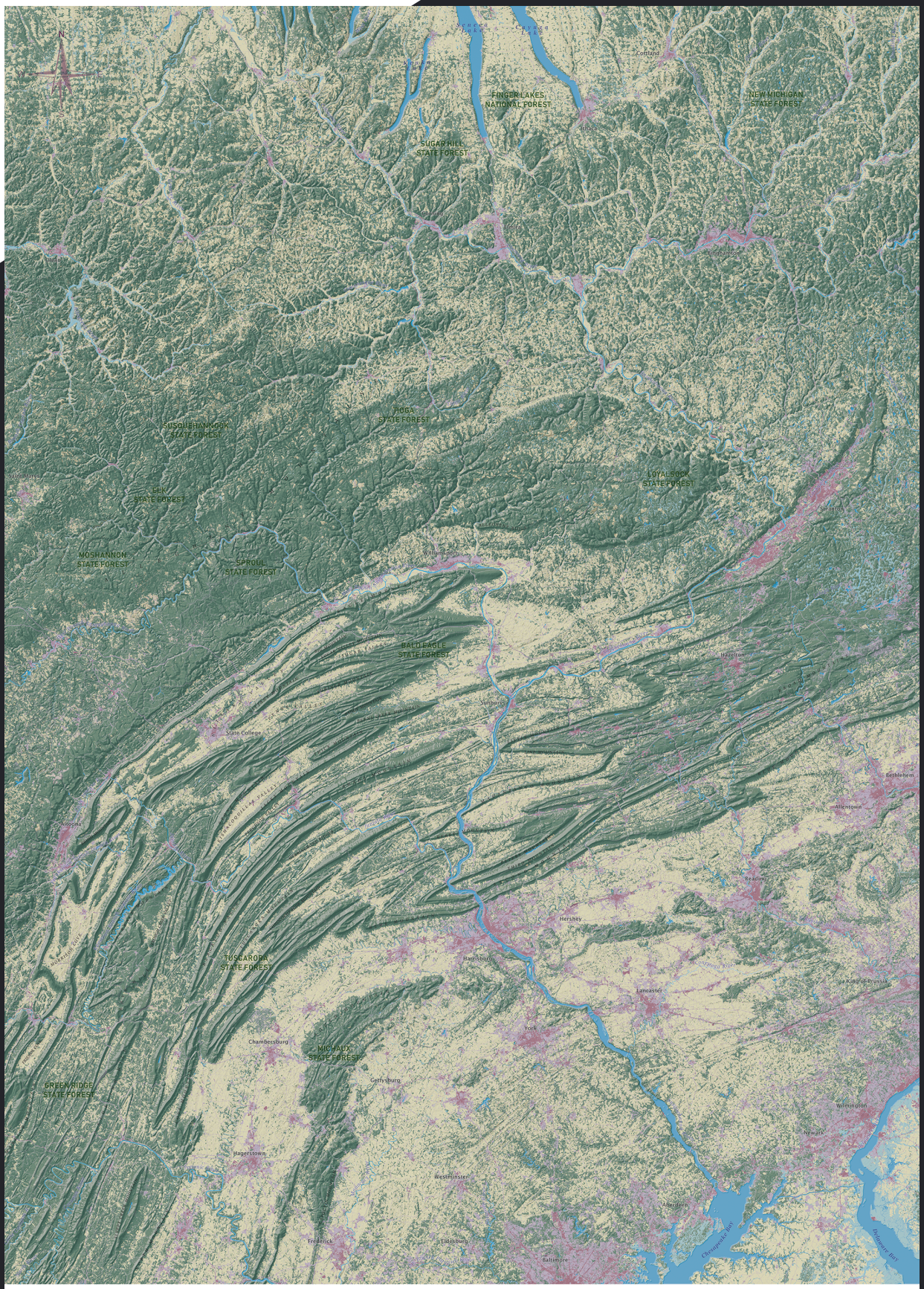
Stanton Morse (B.S. in Geography, Texas State University-San Marcos 2010; B.A.'s in Anthropology and Political Science, Texas State University-San Marcos 2015) is a graduate candidate at Humboldt State University in Arcata, California. His thesis research focuses on lowland Maya settlement patterns, ecology, and geospatial analytics. Stanton is currently a Field Crew Chief at Archaeological Research and Supply Company in Humboldt County, California. He also has consulted with the Humboldt County Coroner's Office in human remains identification and crime scene recovery. Additionally, he recently completed his tenure as Graduate Research Assistant and Lab Manager for the Archaeology Research Lab and Collections at Humboldt State University.

Joshua Shindelbower grew up in South Lake Tahoe, taking full advantage of every outdoor activity the Sierra Nevada has to offer. In 2016, he came to Humboldt State University (HSU) to complete his education. During his time at HSU he developed a passion for geospatial analysis and cartographic design, and enjoyed researching new methods in both fields. In December of 2018, he earned a Bachelor's of Arts in Geography and an advanced certification in geospatial analysis. Joshua is currently a GIS Mapping Technician with Green Diamond Resource Company, and he and his partner had their first child in February, 2019.

JOSHUA SHINDELBOWER

This map was created using a combination of GIS, photo editing, and graphic design software after an inspiring road trip through the area. It shows the wide diversity of land cover across the region, and a key weak point in the Appalachian Mountains, known as "The Gaps of the Allegheny," which allowed European immigrants to move toward fertile land deposited by millions of years of erosion. The reader can see that there is very little unused space in the region. Nearly every non-urban inch of land has been occupied for agricultural purposes, down to the thinnest sliver valleys. This map was meant to highlight one of the planet's more unique topographic landscapes, and perhaps inspire others to experience the area.



Northern Appalachian Land Cover

1:500,000

0 25 50 100 Miles

Developed Low Intensity | Agriculture | Shrub Land Herbaceous | Open Water | Forest | Barren | Wetlands | Developed High Intensity

Data: USGS & OpenTopo | Projection: NAD 1983 State Plane Pennsylvania North

Joshua P. Shindelbower | Humboldt State University | NcPinCushion.github.io/cartography

Cobb, Casey D. 2019. "A Geographic Account of Economic, Health, and Educational Disparities in Hartford's *Sheff* Region." *Humboldt Journal of Social Relations* 41: 82–98.

A Geographic Account of Economic, Health, and Educational Disparities in Hartford's *Sheff* Region

Casey D. Cobb[a]

Abstract

In the current study, I use geographic techniques to examine the distribution of key housing, economic, health, and educational indicators in metropolitan Hartford. I focus in particular on factors that bear upon the lives of children in this area, also known as the Sheff region—a reference to the long-standing *Sheff v. O'Neill* school desegregation lawsuit. The results reveal substantial disparities in the geographic distribution of important resources and outcomes across the racially and economically stratified region. Despite earnest school desegregation efforts, the opportunities, access, and resources available to children in municipalities across the metro Hartford region remain starkly different. Children of color living in central Connecticut's poor urban communities are disproportionately affected by a highly fragmented sociopolitical geography. Recommendations are made for more comprehensive, cross-sector policy interventions as well as regional collaboratives.

Keywords

Achievement gap, desegregation, inequity, Geographic Information Systems, geospatial analysis, education policy

Substantial disparities persist in academic outcomes between students of color and white students in the United States. The 2017 results from the National Assessment of Educational Progress (NAEP), also referred to as the "Nation's Report Card," show white-Black and white-Hispanic average scale score differences on 4th grade math and reading tests to be anywhere from .64 to .86 standard deviations, with similar trends evident in grades 8 and 12.[1] Performance gaps between students of high and low socioeconomic

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[1] Source: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2017 Reading and Math Assessment.

status parallel these differences and are made more pronounced by school districts that vary in wealth (Owens, Reardon, & Jencks 2016). Unequal educational resources, low quality schools, neighborhood poverty, and systemic racism are all named as possible contributors to the achievement gaps.

According to the NAEP, Connecticut has one of the largest racial achievement gaps in the country, and not too long ago had the nation's highest achievement gap (Rabe Thomas 2013; Rabe Thomas & Kara 2018). In 1989, in response to inadequate educational resources for students in Hartford, Milo Sheff filed a legal complaint against the State of Connecticut on behalf of Hartford Public School students, the vast majority of whom were poor, Black, and Latino.[2] Hartford and its surrounding suburbs represent one of the most racially and economically segregated regions in the country (Dougherty 2018). The *Sheff v. O'Neill* lawsuit resulted in a court settlement agreement that called for specific remedies to reduce the minority and economic isolation of Hartford students. The *Sheff* agreement authorized the construction of dozens of interdistrict magnet schools and the expansion of a suburban-urban student transfer program (*Sheff v. O'Neill* 2003). Both programs were unique in that they promoted *interdistrict* cooperation through voluntary school choice, which invited students to cross district lines.[3] Today there are nearly 19,000 students from metro Hartford (mostly suburban students) who attend one of the 42 *Sheff* region magnets (Torre 2017). Among the 21,034 Hartford-resident minoritized students, 7,152 are enrolled in a magnet school and another 2,171 attend a public school in the 32 surrounding suburban communities through the Open Choice program (Connecticut State Department of Education 2018).

Connecticut's response to *Sheff* has achieved varying results. The *Sheff* settlement, now in its fourth phase, has substantially increased the number of Hartford students of color who attend a "reduced-isolation setting" from 11.1% in 2006 (Dougherty, Estevez, Wanzer, Tatem, Bell, Cobb, & Esposito 2006) to 46.1% in 2018 (Connecticut State Department of Education 2018). Some studies have found positive achievement effects for students enrolled in integrated settings such as Hartford's interdistrict magnet schools (Bifulco, Cobb, & Bell 2009; Ellsworth 2013). Other accounts contend that *Sheff* has not worked to its potential or worked equally well for all students, most pointing to the limited opportunities for Hartford students, such as caps on seats available in interdistrict magnets or Open Choice suburban schools (Rabe Thomas 2018). As an example, more than 3,000 Hartford students were waitlisted in the 2017 school choice lottery and roughly 11,000 remained in district schools that are critically under-resourced compared to their suburban neighbors (Torre 2017).

In Hartford, and hyper-segregated urban cities elsewhere, schools (and school desegregation programs) alone are not able to break the cycles of poverty or eliminate structural forms of racism. Far more powerful and systemic forces bear upon the lives of disenfranchised children, starting with where they live. The present study rests upon the assumption that the "place and space" in which children grow up heavily influences their

[2] Sheff v. O'Neill, 238 Conn. 1, 678 A.2d 1267 (1996).

[3] Interdistrict school choice programs designed for a similar desegregative purpose are in operation in at least eight other metropolitan areas, including St. Louis, Rochester, Boston, Omaha, and Minneapolis (Wells, Baldridge, Duran, Grzesikowski, Lofton, Roda, & White, 2009).

opportunities to learn and access to resources. States are separated into counties, which are divided into cities and towns, which are divided further into neighborhoods. These layers of geography impact children's lives in a variety of ways, but most directly so at the local levels of governance. The impact is even more pronounced in states within New England that rely heavily on municipality-led governments. In the next section, I provide a brief review of the literature on how various health, economic, housing, and social factors can bear upon the lives of children. I then offer an overview of the Connecticut and metro Hartford contexts, before turning to the present study's aims, methods, and findings.

CONCEPTUAL FRAMEWORK

The current study assumes that neighborhoods can have profound short and long term influences on its residents, particularly children (Sampson, Morenoff, & Gannon-Rowley 2002). The deleterious effects of concentrated poverty on adolescents and academic outcomes are well established (Duncan & Raudenbush 2001; Leventhal & Brooks-Gunn 2000). Communities isolated in intense poverty restrict opportunities for upward social and economic mobility. If high poverty communities limit life opportunities, then the opposite may be true. Chetty, Hendren, and Katz (2016) re-evaluated data on Baltimore's Moving to Opportunity housing voucher program and found that children who grew up in "higher opportunity areas" demonstrated significantly better life outcomes, including a higher chance of attending college, earning greater incomes, and a reduced likelihood of single parenthood.

Berliner (2009) acknowledged that schools cannot do it alone when trying to reverse the ill effects of high poverty conditions on children. Schools are not equipped to eradicate inequities in health, opportunity, and academic outcomes. Berliner examined seven "out of school factors" that influence student success. These included low birth weight and non-genetic prenatal influences on children; inadequate medical, dental, and vision care (often connected to availability of medical insurance); food instability; environmental pollutants; family relations and household stress; neighborhood characteristics; and extended learning time, such as preschool (Berliner 2009).

Like Berliner's recognition of several out of school influences, my study considers the elements of neighborhoods and municipalities as comprising a system (Tamas, Whitehorse, & Almonte 2000). The elements of the system include housing, economic, health, and educational resources, which, taken together, constitute the social living conditions under which children grow and develop.

Housing

The benefits of home ownership extend beyond personal pride and autonomy. The recent mortgage lending crisis notwithstanding, home ownership allows individuals and families to build financial equity and generate wealth (Retsinas & Belsky 2004; Turner & Luea 2009). Ownership can more readily lead to upward economic mobility than renting. Middle to high-income families or families who benefit from intergenerational wealth, such as through estate transfers, are more likely to own a home. The opposite is the case for families in poverty who lack resources to access a mortgage. One of the advantages of home ownership, particularly for the middle and upper class, is that it offers greater opportunities to use existing wealth to live in—or move to—higher-resourced communities.

Beyond the benefits to individuals, communities with higher proportions of owner-occupied homes (and appreciable home values) generate their own advantages that directly benefit their local schools—through tax revenue support.

Home values represent proxies for community and neighborhood wealth, as higher valuations are typically indicative of higher affluence and a larger tax base (Kenyon 2007). In a study of 217 school districts in New Jersey between 2002 and 2009, Mensah, Schoderbek, and Sahay (2013) found a significant, positive relationship between local property tax revenue and school test scores. This finding suggests that communities that can generate higher local tax funds have a better chance of positively impacting student achievement. Other quasi-experimental studies (Black 1999; Clapp, Nanda, & Ross 2008) and a comprehensive review of the empirical literature (Nguyen-Hoang & Yinger 2011) reported similar strong relationships between home values and school quality.

Neighborhood Poverty

There is robust and ever growing evidence demonstrating the ill effects of poverty on student development and learning (Jencks & Mayer 1990; Reardon, Kalogrides, & Shores 2018; Sampson, Morenoff, & Gannon-Rowley, 2002). Studies have confirmed negative effects on the formation of infant brains (Cookson 2008), examined the relationship between neighborhood poverty and readiness to learn (Janus & Duku 2007), investigated the effects of neighborhoods on child and adolescent outcomes (Leventhal & Brooks-Gunn 2000), as well as on verbal ability among African American children (Sampson, Sharkey, & Raudenbush 2008). High poverty communities, and the families and children within them, are at a severe disadvantage from the start.

Health

Increasingly, studies are finding that inequities in student learning can be attributed to early childhood health maladies or undesirable environmental conditions (Fiscella & Kitzman 2009; Miranda, Kim, Reiter, Galeano, & Maxson 2009). For example, health disparities have been examined in relation to differences in school readiness (Currie 2005) and academic performance (Michael, Merlo, Basch, Wentzel, & Wechsler 2015). Moreover, there is growing evidence of a direct link between high blood lead levels and cognitive function among young children (Canfield, Henderson, Cory-Slechta, Cox, Jusko, & Lanphear 2003; Miranda, Kim, Galeano, Paul, Hull, & Morgan 2007). Childhood asthma has been identified as one of the leading childhood diseases and also causes school absences (Basch 2011; Hsu, Qin, Beavers, & Mirabelli 2016). African American children are three times more likely to suffer from asthma than white children. A Washington, DC study revealed that visits to the emergency room for uncontrolled asthma attacks were ten times more likely among DC residents in low-income neighborhoods compared to more affluent DC communities (Children's National Health System 2014). Lastly, access to appropriate healthcare and with adequate medical insurance is critical to early childhood development and cognitive function (Cohodes, Grossman, Kleiner, & Lovenheim 2014). Households in poverty exhibit lower levels of usage and higher barriers to health care than more wealthy families (Gorman & Braverman 2008).

In the preceding paragraphs, I have attempted to describe key elements of a social system of living conditions and their effects on families and children. I shift next to provide an overview of the study's setting—metro Hartford—and the greater sociopolitical context in which it is situated.

THE CONNECTICUT CONTEXT, METRO HARTFORD, AND THE *SHEFF* REGION

Connecticut is the nation's third smallest state in geographic area, but is carved up into 169 cities and towns. Like other New England states, Connecticut is characterized by provincial governments and a political culture of strong local

control. Since 1909 school districts have been coterminous with Connecticut municipalities (Gooch 2003), which have starkly different community resources, thus giving way to severe inequalities in resources for children. Given Connecticut's significant disparities in wealth based on zip code and even census tract, the state has engendered the designation, "the two Connecticuts" (Phaneuf & Silber 2018).

Connecticut's preference for local government control is of no small significance here. The boundaries that separate cities and towns in Connecticut are walls of inclusion and, ipso facto, also of exclusion. Each city and town has its own local government and most have their own schools, refuse/transfer stations, transportation services, parks and recreation departments, town or city managers, and zoning officials. Sharing of services across municipalities is limited, with efforts to regionalize and consolidate often facing strong opposition (Condon 2018). This has led to not only fiscal inefficiencies, but inequalities between municipalities. This provincialism perpetuates "the two Connecticuts," separating the haves and have-nots along racial and economic lines. Nowhere is this more evident than in metro Hartford, which has experienced what has been considered "white flight" over the past several decades (Dougherty & Lassiter 2012).[4]

Metropolitan Hartford is constituted of the city of Hartford, its immediate neighbors to the west and east (i.e., the cities of West and East Hartford), and the contiguous suburbs that surround those cities. This study considers an even larger group of cities and towns referred to as the *Sheff* region, which encompasses an outer ring of exurbs. The *Sheff* region implicates the 32 municipalities that are called upon to participate in its school desegregation remedy. The entire region is approximately 800 square miles.[5]

The *Sheff* region is shown in Figure 1, which conveys population densities among residents 18 years and younger (darker shades indicating higher populations) as well as the percentage of white children residing within those boundaries (the larger the circles, the higher the percentage of white children). Hartford is the most populous municipality in the region with approximately 32,000 children, and also one of the more diverse. It has the highest percentages of children of color (91%), most of whom identify as Black (42%) and Latino (44%).[6] Hartford's percentage of foreign-born child population is 6.3% and its adult foreign-born population is considerably higher at nearly 27%. Hartford Public Schools' population of English language learners was 18.6% and nearly three-quarters (71.4%) of its student body was eligible for free or reduced-price lunch.[7] In contrast, the suburbs of Hartford, especially those in the "outer ring" exurbs of the *Sheff* region, are distinctly whiter and wealthier.

RESEARCH AIMS

The study is motivated by the continued racial and economic school segregation of metro Hartford, which is reflected by intense patterns of residential segregation along the same lines. Pernicious racial achievement gaps persist among

[4] Incidentally, Jack Dougherty and contributors at Trinity College have published a unique interactive map that demonstrates the change in home values over the past century in metro Hartford; specifically, home values were originally highest in Hartford and lowest in the rural outlying towns, but over that time period the scenario was effectively reversed.

[5] The term *exurb* stems from Spectorsky's (1955) description of "extra-urban" communities. Nelson and Dueker (1990), among others, have defined the exurbs as a ring of generally affluent communities beyond the suburbs that remain commuter towns for an urban area.

[6] Source: 2013–2017 American Community Survey 5-Year Estimates.

[7] Source: District Profile and Performance Report for School Year 2016–17. Edsight.ct.gov.

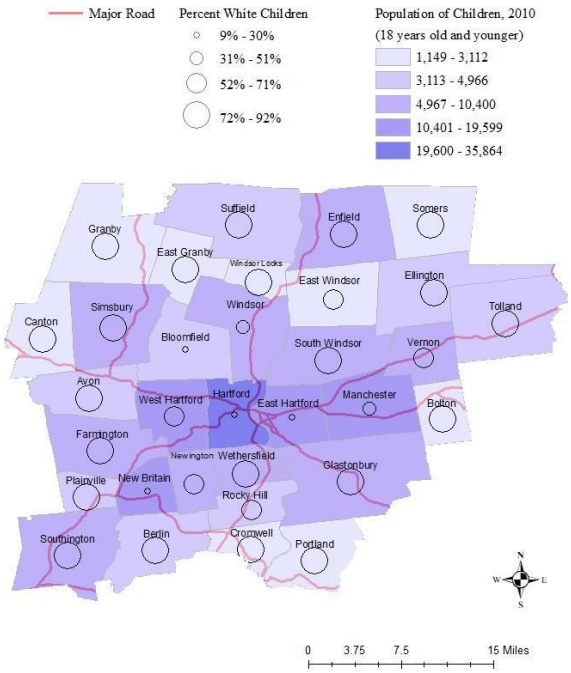

Figure 1. Total Population of Children (18 and under) and Percent White Children in Connecticut's Sheff Region. Source: 2010 US Census.

children and—fairly or unfairly—schools are continually asked to close these gaps. The present analysis uses a spatial lens to examine various social elements within a fragmented geography that may be contributing to these gaps. It was guided by the question: How do municipalities in a metropolitan area compare along a broad set of social conditions that impact child learning and development? Through the use of mapping techniques, I model the interrelation among economic, health, housing, and education factors that are all too often looked at in isolation from each other.

METHODS AND DATA SOURCES

In accordance with social epidemiology case analysis (Tate & Striley 2010), I examine the geographic distribution of various forms of capital associated with children in metro Hartford. The model draws upon geospatial analysis conducted by Jones, Harris, and Tate (2015), which examined residential segregation, education, and health disparities in metro St. Louis. My analysis draws on multiple sources, including data from the US Census, Connecticut Department of Public Health, Connecticut Office of Policy and Management, and Connecticut State Department of Education. The present case study is intended to inform policies that bear upon children's development by understanding community resources and conditions from a wide-ranging, geopolitical perspective. The modeling explores the relationships between and among various housing, health, economic, and educational indicators.

The social epidemiology case analysis relies heavily on a series of maps produced by geographic information systems (GIS) software. I used ArcMap 10.6 to generate the maps, geocode addresses, and join multiple databases to the spatial data (Environmental Systems Research Institute 2018). I began the mapping process by accessing a Connecticut "municipality" polygon shapefile from the UCONN Map and Geographic Information Center. Geographic coordinates underlie the polygons that represent municipalities across Connecticut. From this state map, I created a smaller basemap of metro Hartford by selecting the relevant municipalities. I also added a line shapefile to portray major highways in the area. Each map below was created using the same metro Hartford basemap and then adding geospatial data linked to the municipalities (polygons).

FINDINGS AND DISCUSSION

Housing and Property as a Resource

Local tax revenue is critical to supporting Connecticut's public schools, with 56.3% of the state's public education funding deriving from local sources (US Census Bureau 2018). Local property

taxes are the major source of revenue for municipalities in Connecticut. Figure 2a displays the tax bases across the *Sheff* region, as represented by the 2015–16 equalized net grand list per capita, which is a measure of taxable property excluding exemptions permitted by statute. Hartford and New Britain have the lowest tax base per capita in the region. Other poor cities such as East Hartford, Manchester, and Vernon, also have a relatively low tax foundation on which to raise funds for local schools. In contrast, affluent suburban towns such as Avon, Farmington, and Glastonbury have substantially larger tax bases. The main reason for the low tax base in Hartford, like other cities, is due to the presence of hospitals, universities and colleges, an airport, a trash-to-energy plant, and various state office buildings in the state's capital that make no local tax payments (Phineuf & Silber 2018).[8]

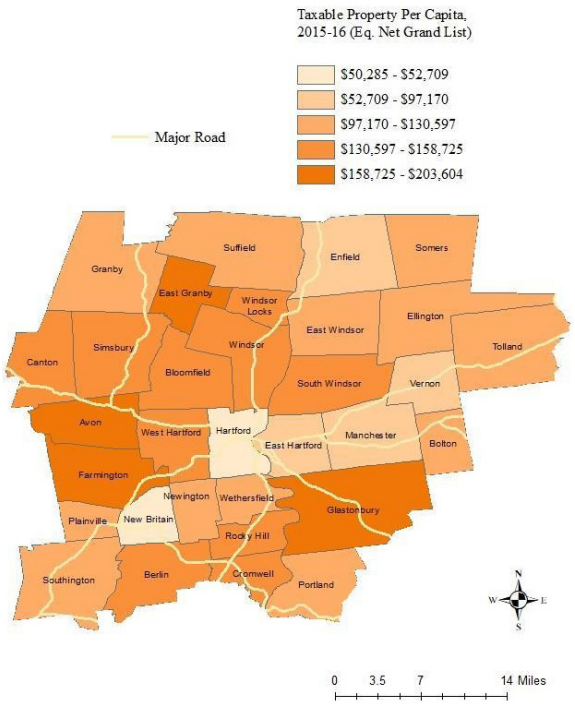

Figure 2a. Taxable Property Per Capita (Equalized Net Grand List). 2015–16. Source: State of Connecticut Office of Policy and Management.

Figure 2b presents equalized mill rates against the backdrop of median home values in the *Sheff* region. In Connecticut, the mill rate represents the tax rate assessed on taxable property, where one mill is equal to 1/1000 of a dollar. In other words, mill rates are the amount of tax payable per $1,000 of value for a given property. Thus, a mill rate of 30 would mean that a house with an assessed value of $200,000 would require the owner to pay $6,000 in annual property taxes. The "equalized" mill rate represents a statewide adjustment for the different times in which municipalities conduct re-valuations of property; revaluations occur on a set schedule established by the state.

Unsurprisingly, the median home values show a similar distribution across the region as the equalized tax base (Figure 2a). The 2016 median home value in Hartford ($159,100) is nearly half that of adjacent West Hartford ($318,800). Figure 2b geographically illustrates the inverse relationship (r = -.50) between median home value and mill rate. That is, municipalities with low median home values have high mill rates, and vice versa. These data indicate that citizens in property poor cities and towns must exert greater tax effort to raise an equal amount of revenue as their wealthier counterparts.

Finally, the percentages of owner-occupied housing units are presented in Figure 2c. Owning a home has shown to be a major factor in achieving economic upward mobility. As is the case in other poor urban communities in Connecticut,

[8] It should be noted that Connecticut, like other states, offers state aid on a sliding scale to municipalities (based on community wealth and student needs) to support public schools. That is one reason why Hartford's 2018 average per pupil expenditure ($19,616) is above the state average ($16,988). (Source: ctschoolfinance.org)

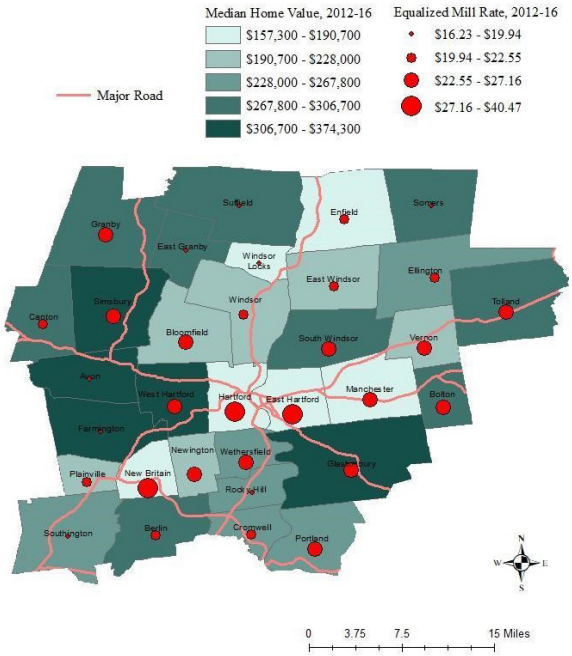

Figure 2b. Median Home Value by Equalized Mill Tax Rate, 2012–16 (per $1,000 home value). Source: State of Connecticut Office of Policy and Management.

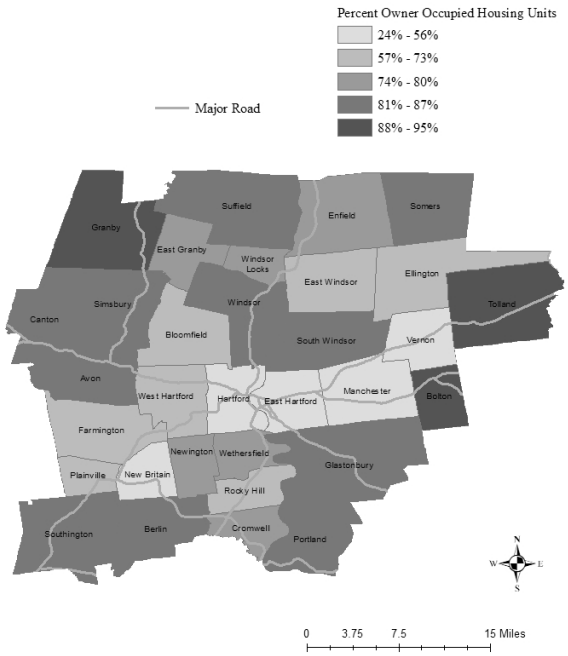

Figure 2c. Percent Owner Occupied Housing. 2012–16. Source: American Community Survey 5-Year Estimates.

the percentage of Hartford residents who own their own home (23.7%) is considerably lower than most suburban towns (ranging 80%–92%). Neighboring West Hartford has roughly triple the percentage of homeowners, at 71.3%, than Hartford. East Hartford falls in between at 56.4%.

The Connecticut Fair Housing Center (2017) sponsored a study to explore how local zoning practices in suburban areas outside of Hartford influence the number of income-restricted housing available. They found that municipalities with more restrictive zoning rules had fewer people of color as residents. In a separate study on discriminatory lending practices, the Center (2015) found that:

> from 2010 to 2014, African-Americans and Latinos were denied home mortgage loans more often than Whites, even when controlling for income. Very high income African-Americans were more likely to be denied home purchase and refinance loans than low income whites. Mortgage lending activity is also depressed in racially diverse and majority non-white neighborhoods. Regardless of race and income, applicants are less likely to obtain home loans in such areas.

In their follow up investigation, which relied on in-person appointments, email inquiries, and walk-in tests with bank loan officers, they found that every testing scenario evidenced differential treatment according to race (Connecticut Fair Housing Center 2017). More than half (53%) of the testers who were people of color were treated less favorably than white testers.

The Open Communities Alliance conducted an opportunity gap analysis via opportunity

mapping (Boggs & Dabrowski 2017).[9] They created an Opportunity Index for each town in Connecticut based on educational, economic, and housing quality indicators. The Alliance specifically examined government-sponsored subsidized housing and found that:

> Approximately half of Latinos and Blacks in Connecticut reside in the 2% of the land area of the state assessed less likely to have access to opportunity structures like high performing schools, safe streets, and employment opportunities. Only 9% of Whites live in such areas. This deep level of segregation and opportunity isolation undergirds the web of structures that create some of the deepest racial opportunity gaps in the country in educational, employment, health, and criminal justice outcomes. (Dabrowski 2017)

Family Income

Figure 3 shows the intense concentrations of poverty in Hartford and New Britain, and to a lesser extent in smaller cities like East Hartford and Manchester. These poverty data are based on 5-year estimates (2012–2016) from the US Census American Community Survey (ACS), table B17001. The ACS provides estimations based on probabilistic sampling and, as such, there are margins of error associated with these estimates. Hartford has by far the largest percentage of households below the federal poverty line at 31.93% (±1.78% margin of error). Nearby West Hartford has a considerably smaller proportion at 7.69% (±1.13%). The state percentage of all households in poverty was 10.36% (±0.21%). However, child poverty is even worse across

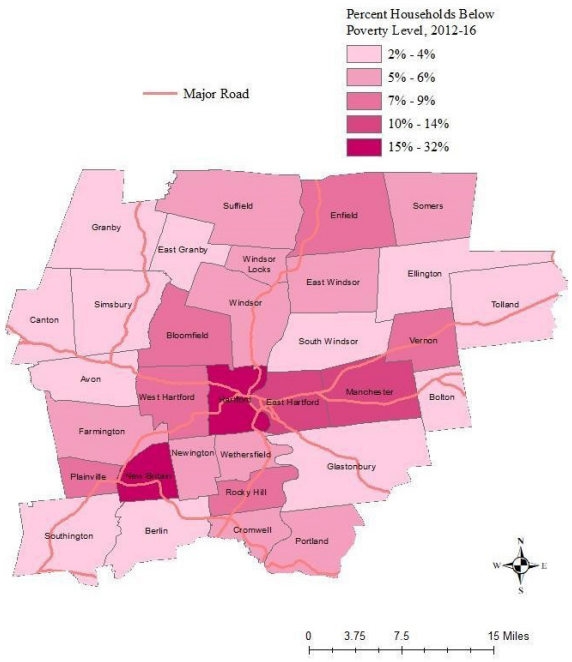

Figure 3. Percent of Households Below Federal Poverty Line, 2012–16. Source: American Community Survey 5-Year Estimates.

Connecticut with 14.1% (±0.33) among children under 18 below the poverty line. Hartford's child poverty rate is an alarming 43.17% (±3.06%). High concentrations of community poverty have known deleterious effects on child development and educational outcomes (Duncan & Brooks-Gunn 2000; Engle & Black 2008).

Child Health Outcomes and Access to Healthcare

Per state statute, Connecticut public schools must collect data annually on students who have asthma. These data become part of the school Health Assessment Record and are reported to the state. Figure 4a displays childhood asthma rates calculated for 2009–2012. Inspection of the map indicates urban communities in the *Sheff* region are disproportionately affected by child asthma. The three cities with the highest incidences

[9] For more on the opportunity mapping method, see Reece, Gambhir, Olinger, Martin, and Harris (2009).

of childhood asthma are Hartford (24.0%), New Britain (27.1%), and Windsor (24.7%). The average rate across the *Sheff* region is 14.5%. This disproportionate impact is not uncommon in urban areas elsewhere (Eggleston 2007). For instance, 18% of children in Washington, DC were reported to have asthma (the national rate is 9.5%). *Sheff* region cities with higher levels of child asthma appear to be located along interstate corridors. Indeed, there is some evidence connecting major highway pollution to increased asthma rates (Neidell 2004).

The Connecticut Department of Public Health requires physicians, by law, to screen children between 9 months and 35 months for lead exposure during annual checkups. Department of Public Health officials are to be alerted if a child has 5 or more micrograms of lead per deciliter of blood. At these levels, lead has been shown to negatively affect IQ, ability to focus, and school performance. The effects of lead exposure cannot be reversed or remedied (Centers for Disease Control, n.d.). Figure 4b shows the percentage of children with blood lead levels of 10 micrograms per deciliter (mpd) or more across the *Sheff* region. Windsor Locks, which is home to Bradley International Airport, had the highest rate, followed by several other *Sheff* cities on the eastern side. Research suggests a direct relationship between aviation fuel exposure and child blood lead levels (Miranda, Anthopolos, & Hastings 2011; Zahran, Iverson, McElmurry, & Weiler 2017). Generally speaking, the eastern side of the *Sheff* region is notably less affluent and more equally distributed among multiple ethnic identities than the western side, which is predominantly white and middle to upper income.

Lastly, Figure 4c shows the geographic location of all pediatrician offices in the region against the backdrop of child population. The list of currently licensed pediatricians was obtained from the

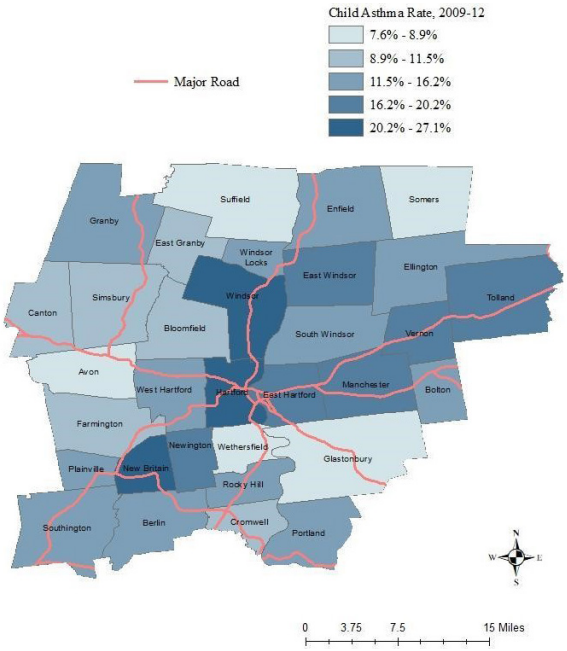

Figure 4a. Child Asthma Rates, 2009–12. Source: Connecticut Department of Public Health.

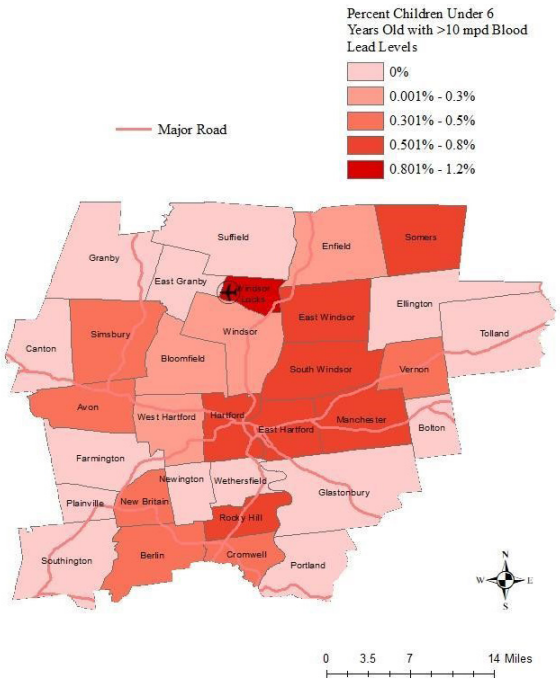

Figure 4b. Percent of Children Under 6 Years Old with > 10 MPD Blood Levels, 2009–12. Source: Connecticut Department of Public Health.

Connecticut Department of Public Health website. Their office addresses were downloaded and geocoded using ArcMap 10.6. Office locations are presented in the context of child population of each municipality to discern any patterns in under or over-representation.

The map shows the largest number of pediatric offices located in West Hartford and Farmington. Farmington is home to a major hospital, UConn Health, and thus likely experiences some physician spillover effects. Very wealthy, but relatively low-populated rural-suburbs, such as Simsbury, Avon, and Glastonbury, appear to have a disproportionately higher number of pediatricians. A direct comparison of East and West Hartford shows a substantial difference in pediatric offices, with West Hartford home to 84 licensed pediatricians located at 72 unique offices. In contrast,

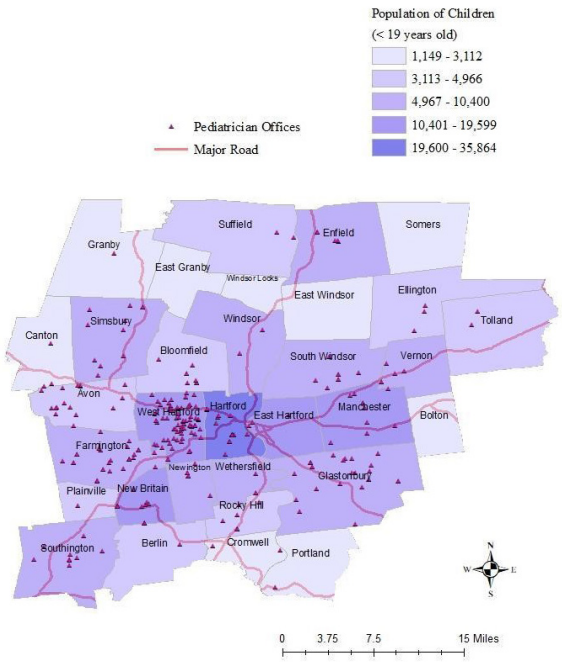

Figure 4c. Pediatric Offices and Child Population. Source: Connecticut Office of Public Health; 2010 US Census.

only 3 pediatricians in 3 offices were listed in East Hartford. West Hartford may experience some level of a physician spillover effect from both Farmington's UConn Health hospital and Hartford's two major hospitals. It does not appear that East Hartford, however, experiences any spillover from the Hartford-based hospitals. East and West Hartford are of similar size in terms of child population, but East Hartford is considerably poorer (West Hartford's median household income is nearly double that of East's) and less white (with 35% of its residents being white compared to 73% in West Hartford).

Hartford is home to two major hospitals—including a Children's Hospital—which may explain the strikingly low number of pediatric offices according to Figure 4c. The very low number of pediatric offices in Hartford is somewhat misleading, however, given that over 40 licensed pediatricians work at 282 Washington Street, the address of Connecticut's Children's Medical Center. Notably, there are no pediatric offices listed in the database with addresses in the very poor neighborhoods, north of Interstate I-84. Hartford's neighborhoods are fairly provincial, and, despite public transportation, research suggests mobility is restricted among high poverty families, which in turn, negatively impacts their access to healthcare (Giuliano 2005; Syed, Gerber, & Sharp 2013). A limitation of this map and inferences thereof may be the omission of child health services offered in locations not accounted for by the Office of Public Health regulatory database. For instance, the city of Hartford offers a number of needs-based programs to support maternal and infant healthcare.[10] Nonetheless, proximity and ready access to pediatricians are undoubtedly factors that disproportionately affect high poverty families and their children.

[10] See http://www.hartford.gov/hhs/maternal-child-health.

Education Outcomes

The percentages of kindergartners who attended preschool in 2013–14 are presented in Figure 5a. Data are reported by parents during kindergarten registration and collected annually by the Connecticut State Department of Education. The map reveals that very few communities had participation rates above 94%. A few, relatively affluent rural towns on the outskirts had the highest pre-K participation rates (Somers, Tolland, and Canton). Hartford, East Hartford, and Manchester, among other higher-poverty municipalities, exhibited preschool participation rates on the lower end, between 50–72%. Research demonstrates the advantages that preschool provides to children in later elementary grades (see, e.g., Magnuson, Ruhm, & Waldfogel 2007). Urban, poor districts in the *Sheff* region do not offer pre-K experiences at the same rate as their suburban counterparts.

Reading proficiency, particularly in the early elementary grades, is highly predictive of future academic performance (Duncan, Dowsett, Claessens, Magnuson, Huston, Klebanov, & Sexton 2007). Results from the 2016–17 Connecticut state reading exam are presented in Figure 5b. The map shows the percentage of students scoring at level 3 or 4 (the top two highest performance categories).[11] The distribution across the *Sheff* region is indicative of Connecticut's now oft-reported achievement gap. Disparities in academic performance between wealthy, primarily white communities and poorer communities of color are stark.

Finally, the percentage of adults 25 years and older who obtained at least a bachelor's degree are presented in Figure 5c. These data were

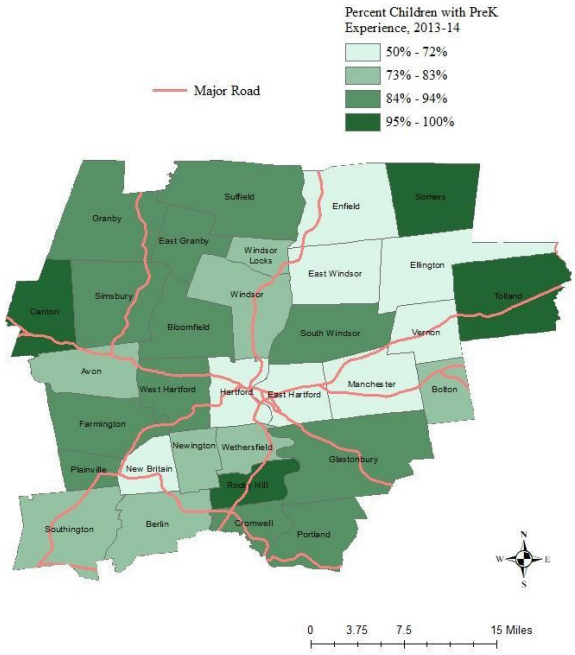

Figure 5a. Percent of Children with PreK Experience, 2013–14. Source: Connecticut Department of Education.

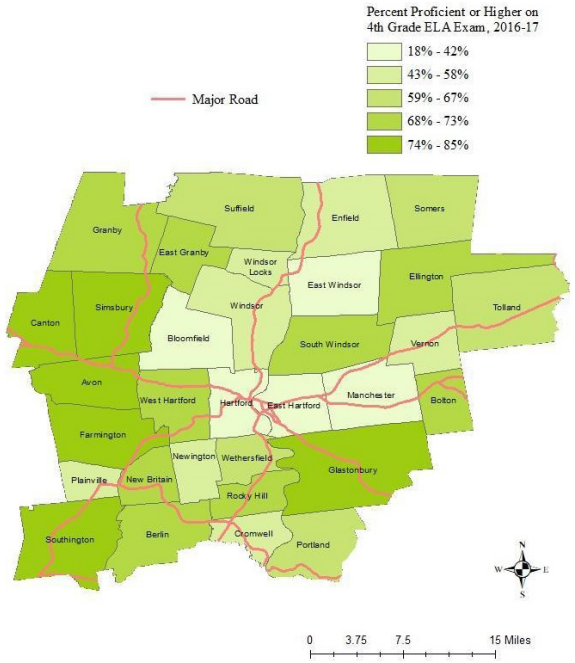

Figure 5b. Percent Scoring Proficient or Higher on 4th Grade ELA Exam, 2016–17. Source: Connecticut Department of Education.

[11] These data derive from public school districts, which in Connecticut are typically contiguous with town and city boundaries. However, these exam data do not represent the entire population of resident grade 4 students because a handful of charter schools and magnet schools are not included here--only the exam data reported by school districts not home to charters and magnets.

obtained from the US Census and have margins of error associated with the point estimates; however, the margins of error are not accounted for in the map. Unsurprisingly, this measure of socioeconomic status is fairly synonymous with the distribution of other economic indicators shown above (e.g., median home values, households below poverty). Higher-educated communities are located around (not in) the central cities of Hartford and East Hartford, where less than a quarter of the population has a bachelor's degree. The relationship between educational attainment and income is well established, as well as the relationship between parents' highest level of education and child academic achievement (Davis-Kean 2005).

LIMITATIONS AND CAUTIONS

The study models the relationships among social factors across a geography and is not equipped to confer causality. The analysis is primarily descriptive and relies on correlational accounts, and therefore does not lend itself to causal inferences. The social indicators that comprise this case model are not exhaustive but rather implicate a sample of known factors associated with child development, economic well-being, and educational outcomes.

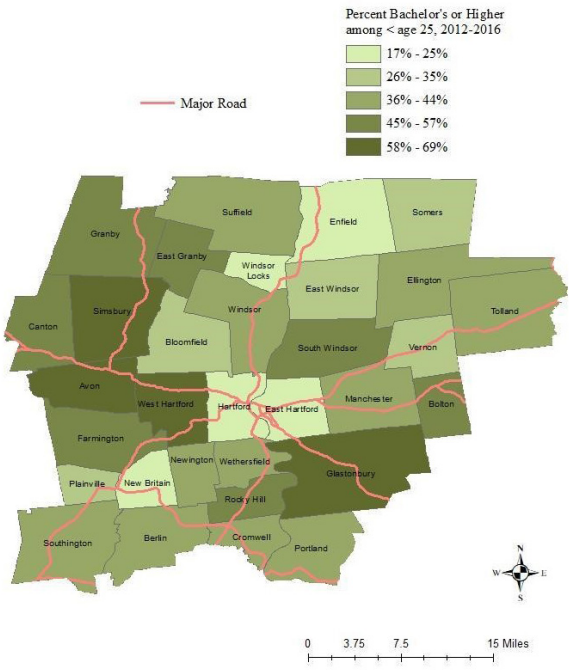

Figure 5c. Percent of Bachelor's or Higher Degree among < age 25, 2012–16. Source: American Community Survey 5-Year Estimates.

Spatial audits of this sort, which show great disparities between urban and suburban regions, can unwittingly reify stereotypical attributes of the "urban poor." While geospatial equity audits are important for revealing resource disparities in terms of economic, health, environmental, and education, we have to be wary of not adopting a deficit-oriented view of urban centers such as Hartford. This equity audit does not highlight the many community assets inherent across stereotyped poor communities in Connecticut. Geospatial analyses that identify and promote neighborhood assets for the purposes of community development are also quite necessary. Consider, for example, the opportunity mapping conducted by Reece, Gambhir, Olinger, Martin, and Harris (2009) on behalf of the Kirwin Institute. Boggs and Dabrowski (2017) aptly cautioned, "We must use the mapping to, in some cases, transcend assumptions about neighborhoods and, instead, base prescriptions for what a neighborhood needs on the hard numbers generated by the Opportunity Mapping analysis" (p. iii). Further, the community(ies) are not solely responsible for the areas where resources are lacking, but instead those areas of challenge can be traced to the political environment and lack of structural support for the citizens in those neighborhoods.

CLOSING THOUGHTS

The current study revealed substantial variation in housing, economic, health, and educational indicators that represent strong connections to

child development and learning. School desegregation through controlled school choice programs and magnet schools remains one of the few viable policies to break up concentrations of poverty that disproportionately affect urban students of color. Students of all racial and economic backgrounds who attend diverse schools benefit in a variety of ways, including expanded access to social networks, stronger intergroup relations, increased academic achievement, and enhanced life trajectories (Linn & Welner 2007; Mickelson 2008). One might speculate that a second, grander purpose of school desegregation is to break the pernicious cycle of poverty by prompting upward economic mobility among those marginalized.

School desegregation policies alone, however, are limited in their ability to diversify the residential neighborhoods and communities in which they operate. Housing integration policies, such as housing-voucher programs and mixed residential development projects, have been called on to pursue such goals. Other community-based development projects, such as the Chicago Area Project and the Harlem Children's Zone, take a comprehensive and integrated approach to neighborhood revival —tapping into social, economic, health, and education resources to support not just students, but entire living spaces.

A spatial lens highlights the sharp contrasts in resources and outcomes across a deeply fragmented and stratified metropolitan Hartford. The visual data are troubling, but the hope is that a more holistic accounting of disparities in neighborhood features will spur policy reform efforts that go beyond solely the education domain. Strategies to integrate our society and break down the unremitting concentrations of urban poverty call for a broad range of solutions that collectively and comprehensively address housing, labor, health, and education. Cooperative initiatives such as the multifaceted effort of the Connecticut Interagency Council for Ending the Achievement Gap (ct.gov) are encouraging, as are explorations to regionalize services in a socially stratified region heavily fragmented by many small cities and towns. So, too, are efforts to bring together coordinated efforts in child health care, such as those proposed by Dworkin, Honigfeld, and Meyers (2009). Indeed, cross-sector, integrated policy strategies are required to reverse the insidious cycle of poverty that disparately impacts children of color and families in poverty.

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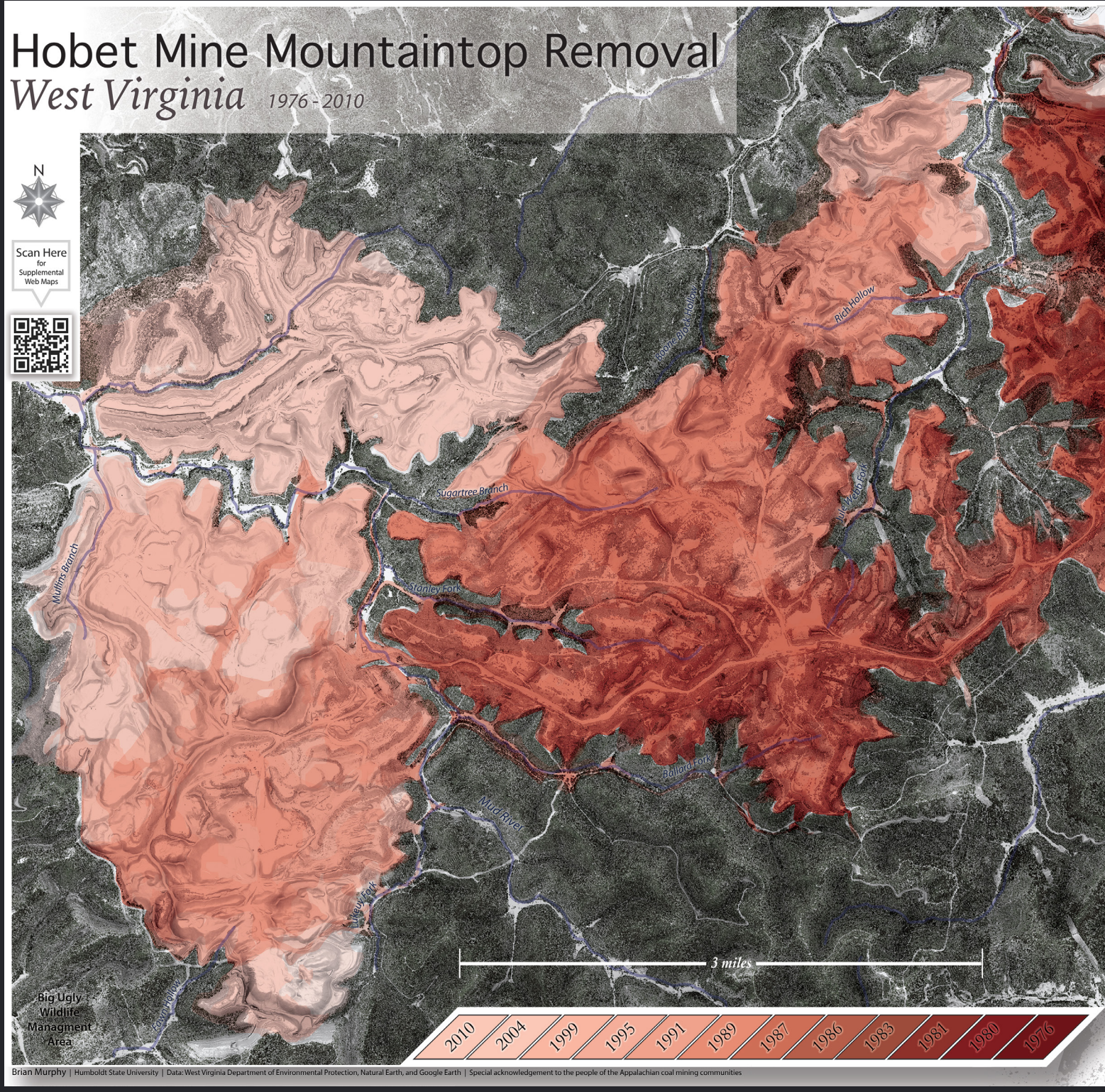
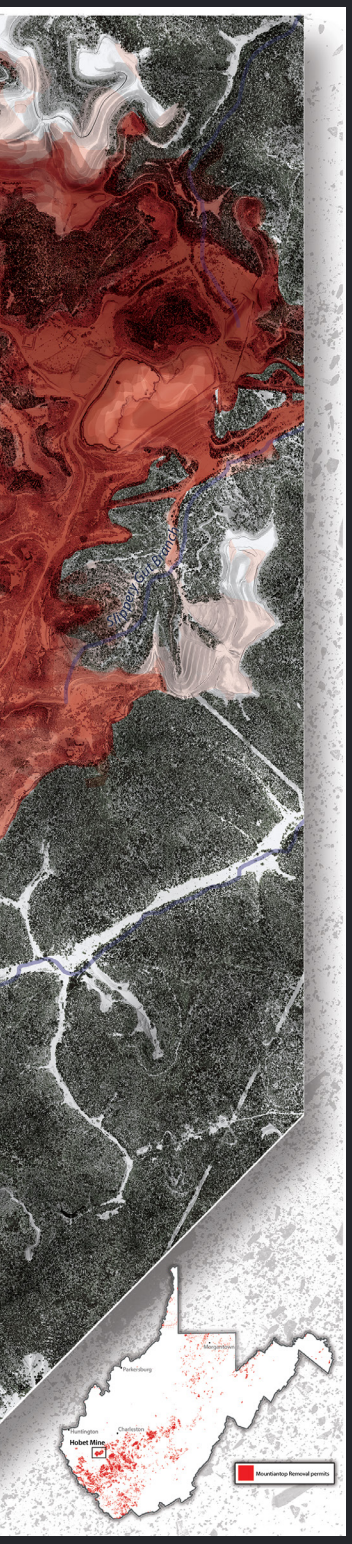
Brian Murphy is currently an undergraduate at Humboldt State University (HSU) majoring in Environmental Science and Management with a concentration in Geospatial Science, and minoring in Geography. Brian is currently working as an Instructional Student Assistant for the geospatial curriculum, and as a watershed web map developer. He also serves as the President of the HSU Cartography Club. Brian's research interests and experience include blending remote sensing data with cartography, generating 3D terrain models using CAD software, and investigating the role of maps as a tool for igniting public discourse.

BRIAN MURPHY

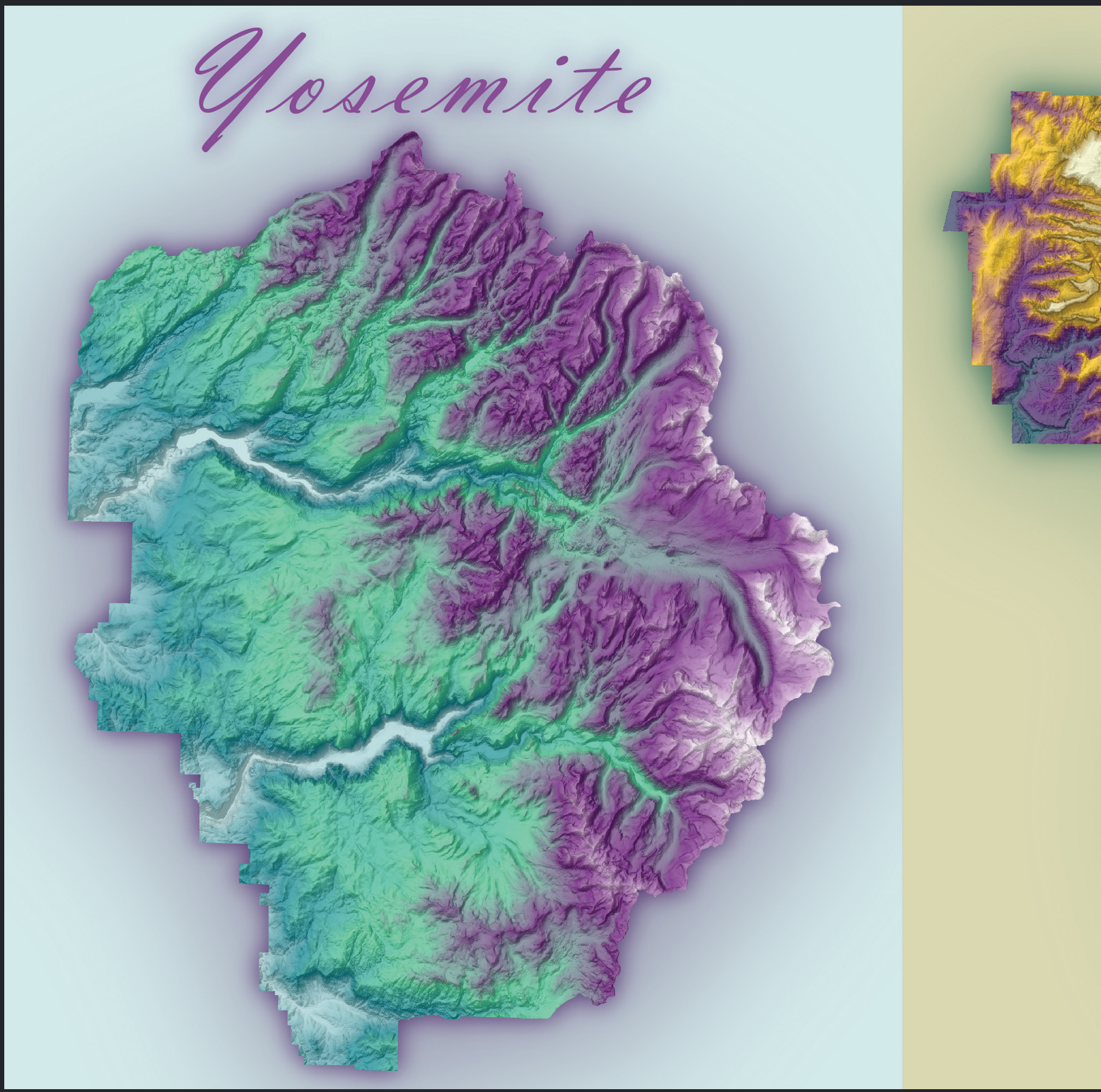




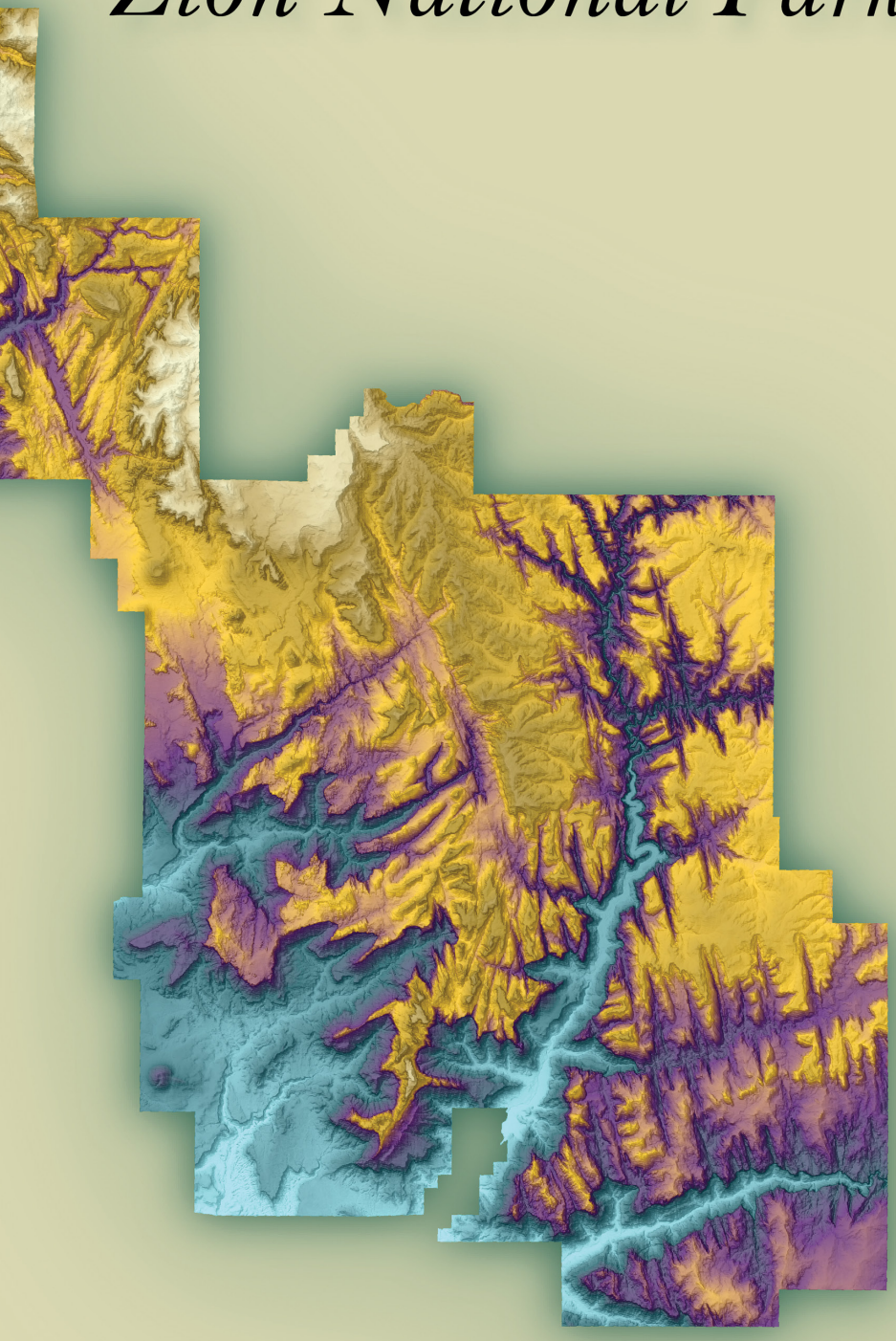
The Hobet Coal Mine is located in West Virginia, and was an active mining site for 41 years. At the time, it was one of the largest surface coal mines in the United States. The impacts of this particular mine are especially pronounced because of the sheer scale of alteration to the landscape caused by removing the peaks of mountains to retrieve the coal. The once verdant and biodiverse mountains have been obliterated, and when the coal is removed, the remaining earth is filled into nearby valleys, creating a flat plateau. This terrain has been destroyed, poisoned, and exploited by human greed. This map aims to visualize this conflict between human and nature by showing the progression of this mine over its lifetime.

Sean Fleming is a graduate student at Humboldt State University in Natural Resource Science with a focus in Environmental Science and Management. Geospatial science and remote sensing are the main focuses of his research. Sean is a Geospatial Analyst/Research Assistant with the U.S. Forest Service through Humboldt State University's Sponsored Programs Foundation. He has done a majority of his research on watershed and riparian habitat modeling, fire emission modeling, alpine and arctic remote sensing, augmented reality in GIS, and political mapping with volunteered geographic information.

SEAN FLEMMING



Zion National Park



This map displays exciting color gradients representing the variation of the elevation in both Yosemite and Zion National Parks. It was created utilizing United States Geological Survey (USGS) National Map 3DEP 1/3rd arc-second Digital Elevation Models and Adobe Photoshop.

Sugata, Michihiro C. 2019. "Cartographies of Debt: Auto Title Loans and Spatial Inequality." *Humboldt Journal of Social Relations* 41: 104–119.

Cartographies of Debt: Auto Title Loans and Spatial Inequality

Michihiro C. Sugata[a]

Abstract

Despite being a decade removed from the 2008 Financial Crisis, an alarming number of Americans are turning to alternative finance service providers (AFSP) for "short term" loans. These loans typically carry triple digit interest rates and can contribute to exacerbating the financial precarity of the borrowers. This article investigates the relationship between the spatial distribution of the AFSP industry and considers the impacts of this saturated presence on the individuals who live in these neighborhoods. Using the Phoenix metropolitan area as a site of exploration, I examine where the industry has pooled and look at the descriptive characteristics of those spaces. Mapping the industry's presence provides a rich cartography of debt that breaks upon ethnic, racial, and class lines. To link the spatial dimensions of debt practices to the body I draw upon Jacques Derrida's (1994) conception of ontopology, an amalgam of ontology and topos, that stresses the co-constitutionality of space and corporeal subjectivity. I argue that the spatial production of debt provides a richer lens through which to view the uneven distribution of difference that reinforces historical inequalities.

Keywords

Alternative finance, auto title loans, payday loans, debt, subjectivity, precarity

Carla, as I will call her, said she had no time to sit for an interview. To this day, I'm unsure of why my 20 minute encounter with her continues to haunt me. Many of the interviews I conducted in Phoenix, Arizona while I was researching alternative finance service providers (AFSP[1]) stretched well beyond two hours, and yet it is this brief encounter that always comes back to my mind. Perhaps the brevity of the meeting has simply left my imagination to fill in the details that I cannot know; perhaps, it's because I felt guilty for taking up 20 minutes of her break between the lunch and dinner shifts at an El Salvadorian eatery, knowing full well she must have had other plans for those precious minutes. And yet, she squeezed me in, the same way I imagine she squeezes in all the other tasks that fill her daily routine. For her, the few minutes we shared

[1] AFSP refers to non-traditional banking institutions that provide short-term loan opportunities, but include considerably higher fees and interest rates than traditional banks. The most common forms of AFSPs are check cashing services, pawnshops, payday loans, and automobile title loans.

were most likely forgotten during the dinner rush that marked the middle, rather than the end, of a long day. She told me that she also cleans office buildings at night with her husband, who lost his job framing houses six years prior, when the real estate market collapsed. The mornings are busy getting three children off to school and caring for her youngest. All of this is done in the blue Pontiac, which while worn, seemed to be in good working order. Incidentally, it is this car that has led to our crossing. Eighteen months earlier, irregular work and mounting bills had forced Carla to borrow approximately $1000 through an automobile title loan. She mentions she had borrowed money before, but that she had been able to repay it. This time, however, time has dragged on and her tone contained little optimism that she was approaching the end. About two months after she borrowed the money she said her family had "many problems," and that the cash went quickly. She did her best to keep up with the payments, but says she fell far behind, and kept worrying that she would wake up and the blue Pontiac, her family's lifeline to "keeping going" would be gone.

Remarkably, Carla's life is unremarkable in many ways. She is one of the estimated two million individuals who take out an automobile title loan each year to cover the expenses of daily life (Pew Research 2015). While AFSPs are often regarded as operating on the fringes of traditional finance, for millions of individuals who lack access to mainstream credit markets, these short-term, high interest loans are increasingly utilized to cover income gaps and unexpected costs associated with a range of life circumstances, such as vehicle repair, medical expenses, and job loss (Pew Research 2015; Hawkins 2012). While it is important to note the precarious life circumstances that structure these loan agreements, it is equally important to consider the subjectivities that are fashioned through a debtor-creditor relationship that rapidly compounds the financial fragility of the debtor. As will be discussed, this particular type of loan model not only requires a debtor who faces specific financial constraints, but also one who is constrained to a degree which will require the loan to be renewed and rewritten multiple times. Thus, any critical inquiry of AFSPs requires not only consideration of the mechanics of the industry, but also the specific strategies used to identify and capture this particular market of borrowers. In other words, we need to examine how this type of debtor is produced.

This essay is underwritten by Michele Foucault's (1980) assertion that any inquiry of power, in this case financial power, must begin "where it installs itself and produces real effects" (97). Thus, my study of the circuitry of alternative finance is simultaneously a study of space, specifically the spaces where these products become embedded within the visual and experiential landscape. If we indeed produce space as Henri Lefebvre (1980) insists, it is also necessary to consider the ways in which space produces us. Our role as financial subjects depends not only on access to favored financial instruments, but I will show how these instruments implicitly define spatial boundaries that procure the terms of inclusion and exclusion. In order to ground my study, I focus on the intertwined shifts in the political, financial, and physical landscapes of my hometown of Phoenix, Arizona, where changes to the legal framework required capital interests to rapidly reorganize their operational strategy. The rejection of Proposition 200

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in 2008, effectively ended payday lending in Arizona[2]; yet, what was initially perceived as a victory for the voters quickly became a testament to the adaptability and innovation of the alternative finance industry.

While title lending did operate in Arizona prior to 2010, it did so in a limited capacity[3] due to the fact that payday lending was the preferred instrument of high-interest lenders in the state. Payday lending legally operated in Arizona from April 2000 to June 2010 under a 10-year provision that allowed lenders to register as "deferred presentment companies." In 2008, voters overwhelmingly rejected an extension of this provision, and thus payday lending became illegal on July 1, 2010 when the provision expired. While this did lead some lenders to leave the state, many others took advantage of the Motor Vehicles Time Sales Disclosure Act (Ariz. Stat. 44–281 et seq.) to reorganize their operations as title lending stores. Approximately 40% of title lenders currently operating in Arizona were previously registered as payday lenders prior to July of 2010 (Fox, Griffith, and Feltner 2016: 9). While this shift in operational focus was not wholly unforeseen, the speed at which the industry adapted to circumvent the will of the voters was staggering. By the end of 2010, the industry was well prepared to not only replace the payday market, but to also expand upon it.[4] Hence, the Phoenix-market provides a fascinating site to examine how financial power responds to political changes through new spatial articulations.

My interest in the spatiality of debt stems from the changes I encountered in my own lived environment. The economic decline I saw in the community I had grown up in coincided with a dramatic reconfiguration of space. Title lending storefronts came to visually dominate nearly every major intersection; I became fascinated thinking about how such a dramatic urban change had almost innocuously crept up on my senses. This line of inquiry drew me to consider not only *how* AFSPs operate, but also *where* they choose to operate. As I moved through the city, I began to take notice of where AFSPs clustered and where they dissipated. A cartography of debt began to take shape in my mind and I sought to trace its outline more accurately.

To do this, I turned to geographical information software (GIS) to map the presence of title lenders in the greater Phoenix-metropolitan area. Sorting through the business registries of the Arizona Office of Financial Institutions, I compiled a list of 434 title lenders who were legally operating in the Phoenix-metropolitan boundaries. Mapping this data in GIS allowed me to better identify where we could find the clusters and concentrations of AFSPs across the city. Overlaying this data with demographic information extracted from the US Census Bureau provided another lens through which to consider the experience of those living within concentrated spaces of alternative debt. I follow the trajectory of Doreen Massey (2005), who recognizes space as a "product of interrelations; as constituted through interactions, from the immensity of the global to the intimately tiny" (9). She stresses the heterogeneity of space and the need to account for the particular power relations that are embedded

[2] The rejection of Proposition 200 in 2008, prohibited an extension of the provision that had allowed payday lenders to operate in Arizona. However, businesses were permitted to legally operate until July 2010 when the original provision expired (Ballotpedia.org).

[3] According to the Arizona Department of Financial Institutions, approximately 150 title lenders were registered to legally operate in Arizona in 2008. By 2016 that number had increased to approximately 650 (azdfi.gov).

[4] By mid-2015 (only five years after the "sunset" provision), there were more title lenders operating statewide than the peak number of payday lenders prior to 2010 (Fox et al., 2016).

within the social (specifically gender, and race). Thus, my spatial analytics serve as a bridge to connect the abstract workings of finance capital to the embodied experience of those who face increasingly constrained choices regarding debt living and subsistence.

Observing the ways the object of debt is built into urban space informs how discourses of financial power are grafted into social and cultural histories. Again, Phoenix provides a fascinating backdrop to consider the multiplicity of ways that space is enmeshed within the larger political economy. Indeed, space has arguably been one of the city's most valuable resources. It has been the vast amounts of cheap, arid land that drove the agricultural/ranching industry that birthed the city, and it has been that same cheap, arid land that has tenuously sustained the massive expansion of the city. Yet, throughout the numerous economic transitions experienced by the city, the cheap land (space) has been cultivated by cheap labor. As one of the four U.S. states sharing a border with Mexico, it is little surprise that Phoenix-metropolitan has one of the largest Hispanic populations in the United States; out of 4.5 million people roughly 40 percent, or 1.8 million, self-identify as Hispanic (US Census Bureau 2019). A low wage workforce has therefore, been built into the economic viability of the city as it has long relied on seasonal and migrant labor in specific sectors. This has led to new spaces, spaces of vulnerability and spaces of security, as Hispanic populations have concentrated in certain areas of the city. As will be discussed more explicitly in subsequent sections, neighborhoods with higher racial/ethnic concentrations are often underserved by traditional banks, thereby opening space for AFSPs to proliferate. Indeed, a number of AFSPs, such as Tio Rico Te Ayuda (translated as, *rich uncle will help you*), specifically cater to the needs of these populations. Phoenix, allows us to consider how the land and the people have co-constituted the space of the city and how economically vulnerable individuals negotiate their lives within these spaces.

The remainder of this essay is divided into three sections. In the first section, I provide an overview of the AFSP industry. While auto title lending is the primary focus, it is helpful to consider the industry as a whole, particularly the payday loan industry, in order to gain a fuller understanding of the industry's mechanics. The second section examines the spatial distribution of the title lending industry in the Phoenix metropolitan area. I utilize GIS software in combination with census tract data to analyze the racial and class distinctions of areas that house high densities of AFSPs. In the third section I return to the space where I encountered Carla to consider how her story, and that of many others, is tethered to a longer history of capital (dis)investment and displacement.

THE STATE OF LENDING

Alternative Financial Service Providers is an umbrella term that encompasses a wide range of banking services that occur outside the traditional banking sector. The vast majority of individuals who use these services are typically referred to as "unbanked" or "underbanked." Approximately 9% of US households are unbanked, meaning that the head of the household does not have either a checking or savings account (Friedline, Despard, and Chowa 2015; Rhine, Greene, and Toussaint-Comeau 2006; US Senate 2002). However, when one includes the underbanked population, that is households that maintain a checking or saving account but continue to rely on AFSPs for a range of services due to access, trust, or credit limitations, this number quickly swells upward of 28% to 36%; thus, over one quarter of the US households "may be excluded from

the mainstream banking institutions at any given time" (Friedline et al. 2015: 3). Unsurprisingly, the demographics of this population reveal clear disparities in racial, gender, and income distributions. 24% of all minority families report being unbanked in comparison to only 5% of whites (Rhine et al. 2013). Likewise, the unbanked are more likely to reside in low to moderate income neighborhoods, earn less, hold fewer assets, and to be female and less educated (Caskey 1997; Rhine et al. 2013; Friedline et al. 2015). For these families, AFSPs provide an outlet for basic financial services such as check cashing, money orders, and money wire transmissions, but the sustaining profits of the industry come through small-dollar loans that rely on excessive fee structures and high interest rates: most commonly, these take the form of payday loans or auto title loans.

The modern AFSP industry developed in the 1990s around cash advance services. Lending branches would, for a fee, provide an advance loan equivalent to the amount collateralized in a customer's post-dated personal check, which the lender would defer cashing for an allotted period of time (Mann and Hawkins 2007). These services quickly evolved into the modern payday loan industry, which operates in the same manner, although many lenders now establish electronic access to the borrowers bank accounts whereby automatic payments are deducted to cover the principal of the loan and all incurred fees. Typical payday loans charge $15–$18 for every $100 borrowed. The principal plus interest must be repaid within a two-week block or the loan rolls over with interest added (and sometimes additional fees). While a $15–$18 surcharge for access to immediate funds may not initially strike one as overly excessive, the compounding of interest every two weeks yields an annual percentage rate (APR) ranging from 391%–572% (Graves and Peterson 2008). As a result, many borrowers find themselves paying off the principal three to four times over, and compounded rates can often climb upwards of 1,000% APR. The Center for Responsible Lending (CRL) reports that twelve million Americans a year find themselves indebted with triple-digit interest loans. These borrowers typically hold their debt for over six months and make an average of nine transactions per year (Burke et al. 2014).

What is perhaps most striking about the payday lending industry is the pace at which it established its presence within the urban landscape; nationally, the number of payday loan offices exploded from under 200 offices in the early 1990s to nearly 23,000 offices by the end of 2005 (Elliehausen 2009). Mirroring the business model of payday lending, the title lending industry has followed a similar trajectory of rapid expansion since the late 1990s. Over 8000 stores now operate across 25 states, and service over two million individuals a year (Pew Research 2015). The Center for Responsible Lending (CRL) estimates that borrowers annually take out $1.6 billion in loans and spend $3.6 billion each year in interest and fees (Fox et al. 2013). Loans are typically made at $25–$40 interest per $100 borrowed and are paid or renewed every 30 days (compared to the two-week interest period associated with payday loans). Thus, while the APR tends to be somewhat lower (a mere 300%) than payday loans, the principal is typically much higher, often making it more difficult to repay. Title loans are structured so that individuals repay the principal borrowed in a lump sum payment at the end of the 30-day loan period. If the borrower is unable to produce the payment in full, the loan is renewed, or rolled-over, with additional fees tacked on. In court documents, John Robinson, the President of TitleMax, the largest auto title loan company in the United States, laid out the profit model of the industry in very specific terms:

> Customer Loans are typically renewed at the end of each month and thereby generate significant additional interest payments beyond the face value of the Prepetition Receivables. The average thirty (30) day loan is typically renewed approximately eight (8) times, providing significant additional interest payments. (TitleMax Holdings 2009: 13)

Within the industry this consistent renewal process is referred to as loan churn because an initial loan is *churned* over and over again to the benefit of the lender who simply collects additional fees and interest. The total amount of wealth that is extracted from the financially vulnerable communities is staggering. Consider that in 2014, in Texas alone, the total dollar amount of loan extensions on single payment title loans was $368,072,229; additionally, these extensions were then refinanced (churned) extracting another $1,036,294,334 (Credit Access Business 2015). In total, the Center for Responsible Lending estimates that $3.8 billion dollars in annual fees are taken out of communities to finance this type of debt (Standaert and Davis 2017). Thus, it is not only the astronomically onerous interest rates that make the AFSP industry predatory, it is the degree to which the profitability of the industry is directly linked to an expectation of non-payment. The fact that loan churn effectively serves as the primary profit model for the industry reveals the extent to which the viability of the industry is contingent upon the inability of customers to pay off their loans[5]. In this way, the financial precarity of the target clientele is effectively weaponized and turned against them. Hence, what becomes very apparent is that AFSPs are a very specific conduit within the circuitry of finance capital. Title loan stores market specific products strategically designed to capitalize on an individual's exclusion from mainstream credit markets, and the financial precarity that coincides with such condition.

There is no perfect archetype of the AFSP customer or title loan borrower. However, it also must be noted that the vast majority of individuals who enter into these types of loans do so because of income constraints and/or the lack of access to other forms of capital. 75% of title loan borrowers earn less than $50,000 a year, and 54% earn less than $30,000[6] (Pew Research 2015). Because borrowers typically come from lower income households, they are rarely able to pay off the principal within 30 days. The Pew Research Center, which conducted the first nationally representative phone survey of title loan borrowers in 2015, found that the typical $250 fee per $1000 borrowed far exceed individuals' ability to repay the loan. The average borrower renews their loan eight times and pays approximately $2,000 interest on every $1,000 borrowed[7] (Fox et al. 2013). Even when the loan is eventually paid off, nearly 50% of borrowers state that they are unable to repay the loan without receiving a cash infusion from some outside source; this includes taking out a second title loan, pawning or selling personal items, or borrowing from family or friends (Pew Research 2015).

[5] While I was unable to find any studies that calculated the volume of loan churn within the title loan industry as a whole, three studies conducted on payday loans show that loan churn accounts for over 75% of the total volume of loans (Parrish and King 2009; Montezemolo 2013; Burke et al. 2014).

[6] Other studies have found these numbers to be even higher, for example an analysis of payday and title lending in Illinois showed that 90% of customers earned less than $50,000 per year, and nearly 75% earned less than $30,000 (Cowan et al. 2015). In New Mexico, regulators found that the average title loan borrower earned less than $25,000 (Montezemolo 2013).

[7] Due to the fact that there is no national database, tracking alternative loan products these numbers can be difficult to quantify. Pew Research (2015) approximates that the average borrower spends $1,200 annually on a $1000 loan This amounts to roughly $3 billion dollars a year in interest and fee payments.

Despite the insistence of the AFSP industry that they are providing a necessary safety net for families that need emergency relief from unexpected economic hardships, a closer inspection of the strategies and tactics of the industry reveal that the intent of these loans is to construct and reinforce a subjectivity which ensures participation in, and the proliferation of, a debt-credit system that requires debt to subsist. The tenuousness reality where debt becomes the means through which the basic requirements of life are purchased undergirds what Andrew Ross (2015) refers to as a *creditocracy*. He elaborates:

> [f]or the working poor, this kind of compulsory indebtedness is a very familiar arrangement, and has long outlived its classic expression under feudalism, indenture, and slavery. Each of these systems of debt bondage were followed by kindred successors—sharecropping, company scrip, loan sharking—and their legacy is alive and well today on the subprime landscape of fringe finance, where "poverty banks" operate in every other storefront on Loan Alley (P. 11–12).

What Ross aptly points out is that the asymmetrical power relationship endemic to the debtor-creditor relation is by no means new; it has found numerous expressions throughout history. The creative marvel of capitalism has always been the ability of capitalists to adapt to economic and political changes in order to keep money moving, and part of this has involved creating new systems and new instruments of debt. Yet, to say that the use of debt as a financial weapon is nothing new does not mean that it is not being used in new ways. The importance of examining how fringe finance is operating today is that it reveals the depth to which debt has become a normalized component of daily living. As Ross points out, 77% of U.S. households identify as being in serious debt (2015: 12). The debtor class no longer defines the most marginal nor the destitute; rather, it is descriptive of the majority. And yet, the terms of debt and the instruments of debt are not distributed evenly across the populous. Debt is still used to mark social and bodily difference, but it does so in new ways, and, as I will show in the following section, it also does so in different spaces.

DEBT'S CARTOGRAPHY

Jacques Derrida (1994) uses the term *ontopology*, an amalgam of ontology and topos, to refer to our condition of being that is inextricably linked to our exteriority. It is crucial to note that Derrida is not locating a specific form of social or economic subject, but rather a fluid subjectivity whose ontological value is situated in, and shaped through, its locational presence. Such framing directs us to a deeper consideration of how physical space is interminably mapped onto our being. Ontopology provides a way for us to think of the intersection of lived vulnerability and space that extends beyond the labor we produce. I am reminded of Elizabeth Povinelli's (2006; 2011) notion of enfleshment to speak of the manners through which we become embedded in the sociality of space to the point where the vulnerabilities of others become constituent components of our own being. In this way, our topos not only speaks to the built environment we live within, but also to the networks of social and money capital that cross our bodies. Recognizing title lenders as conduits of capital circulation and debt distribution, the topographic presence of these lenders can be seen as a cartography of debt. It is a mapping of debt's pathways, and of the social differentiations utilized by lenders to locate profit opportunities.

To better understand the subjectivity that is produced through high-interest debt, it is then useful to gain a deeper understanding of debt's

spatial dimensions. To do this, I began by mapping the presence of all title lenders in the greater Phoenix-metropolitan area. By sorting through the business registry of the Arizona Department of Financial Institutions, I identified 434 businesses operating as registered automobile title lenders. I geocoded this data into ArcGIS software to produce an outlay of these stores across the Phoenix valley[8], and overlaid the data with median household income data from 2012–2016 American Community Survey (ACS) (see Figure 1). Breaking the median household income data into quintiles provides clear distinctions between areas of higher and lower annual earnings.

A general survey of the data immediately reveals the intensity with which title lenders cluster in, and follow the paths of, lower income neighborhoods across the metropolitan area. While it is possible to identify some title loan stores in darker hued (higher income) sections of the city, these seem to exist as outliers that would be expected within a large data set. We also note that there are clusters of title shops with similar intensity in the three lowest income quintiles. Thus, we see that title lenders are distributed fairly evenly across lower income neighborhoods. This should not surprise us as title loan shops clearly target the working poor rather than the extreme

8 Due to the tendency of title loan stores to cluster at major intersections, the geocoded markers often overlap with one another and cannot be individually distinguished at this scale. Therefore, each visible black dot can represent multiple title loan stores.

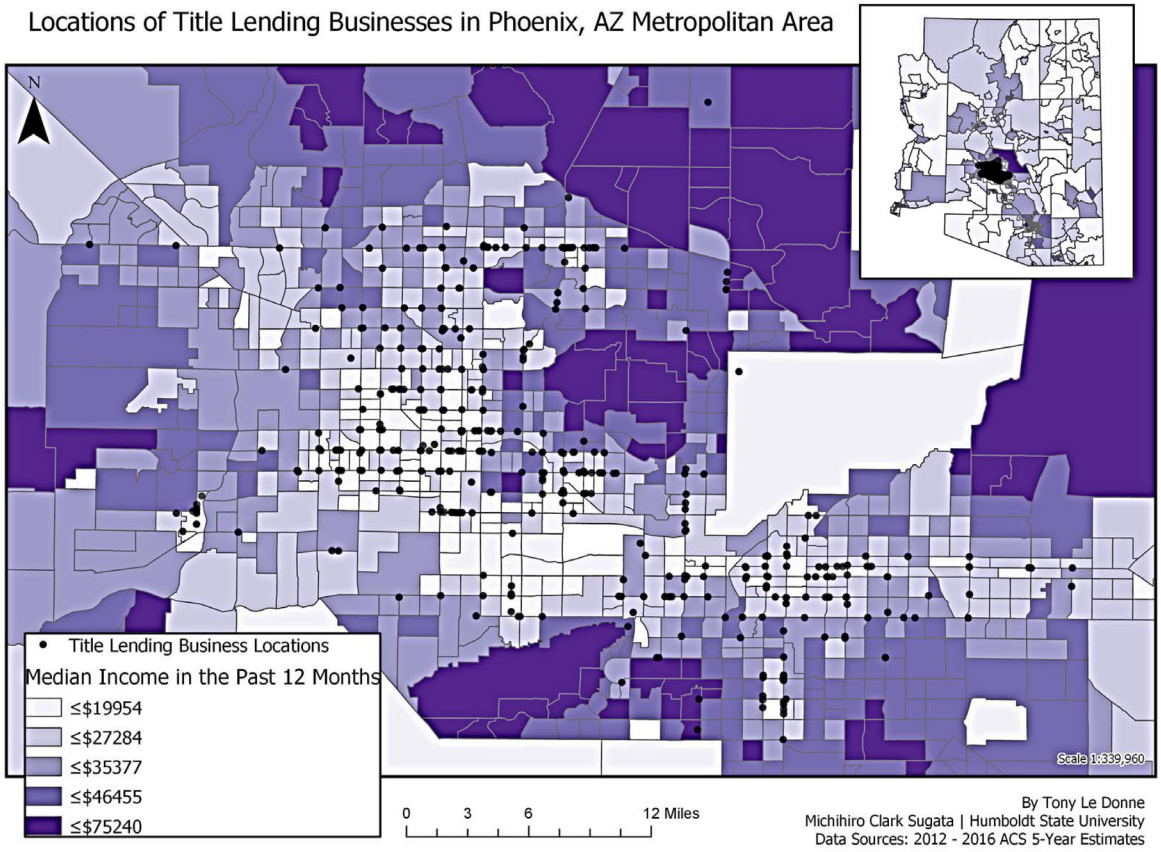

Figure 1. Locations of Title Lending Businesses in Phoenix, AZ Metropolitan Area.

destitute. Thus working families making approximately $20,000–$35,000 a year serve as the predominant customer base.

A physical count of the title shops reveals that only 8 stores (2%) are located within or directly on the border of census tracts that are in the highest income quintile (those making over $75,000 per year). Another 79 stores (18%) lie directly in or on the boundary of the census tracts where the annual income is above $46,455. In total, only 20% of all title shops across the Phoenix-metro area are located in or on the boundaries of neighborhoods with a median income above $46,455. A key advantage of this perspective is that it allows us to not only locate spaces of clustering, but also places of absence. While lower income areas contain upwards of 8–12 stores wholly within their boundaries, only one tract from the upper two quintiles contains more than one title store fully within its boundaries. This is true even of tracts that are bordered by lower income tracts that are heavily populated with title stores.

Yet, if ontopology is about the enfleshed experience of spatial vulnerability then we must take notice of the flesh itself. While the spatial clustering of high-interest debt in low-income neighborhoods tell us something important about the mechanics of the industry and the production of indebted space, there is more to be said about the bodies that inhabit these spaces. Using the same data, I chose to take a closer look at the racial demographics of these spaces to interrogate

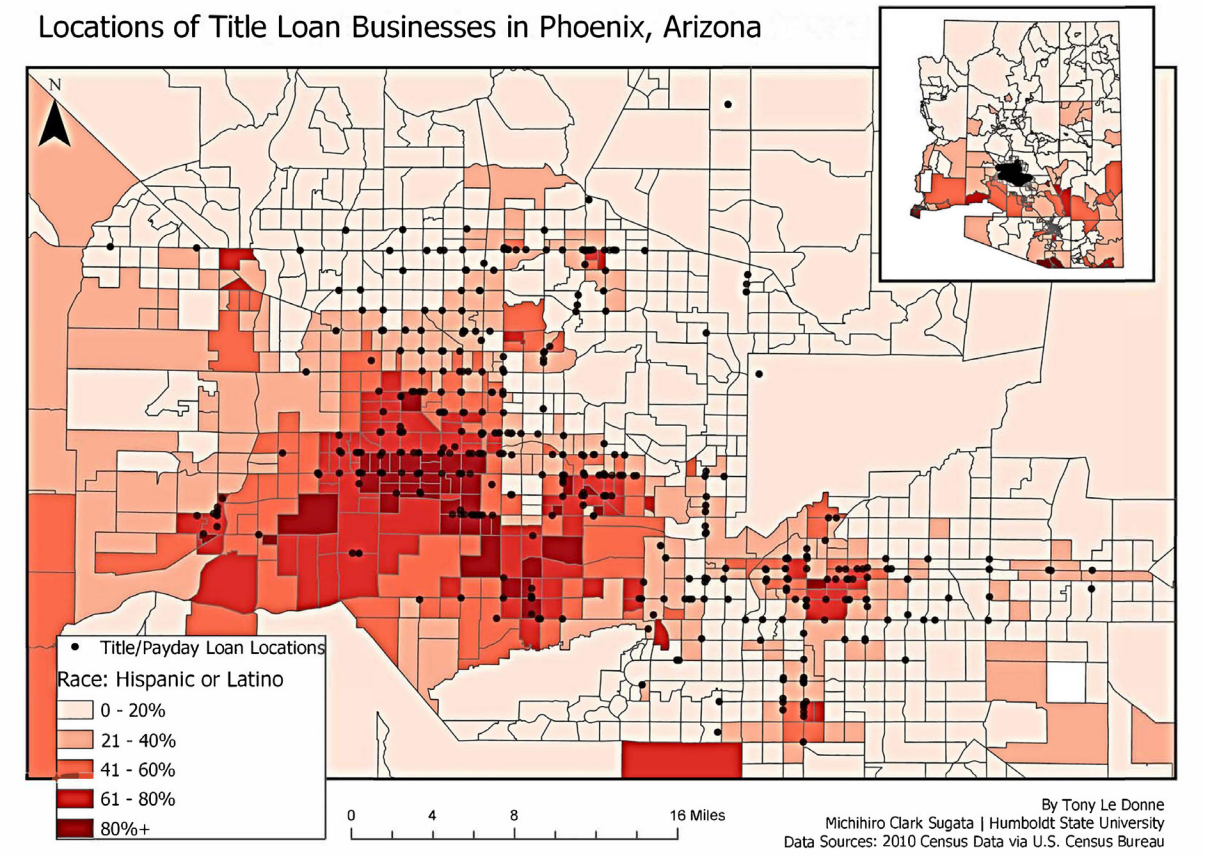

Figure 2. Locations of Title Loan Business in Phoenix, Arizona.

the degree to which the clustering of debt mapped onto Hispanic and Latinx[9] bodies. Due to its proximity to the southern US-Mexico border, Phoenix is home to a vast number of individuals with Hispanic and/or Latinx roots. In fact, 42.5% of those living in the fifth largest city in the US identify as Hispanic and/or Latinx, making this group the largest minority population in the city by a wide margin (US Census Bureau 2019).

Figure 2, depicts the concentration of Hispanic and Latinx communities across the valley in conjunction with the presence of title lenders. Similar to our findings regarding annual income, the map allows us to clearly see the demographic divisions that define the spaces where title lenders choose to operate. Here, the darker color hue corresponds to an increase in the percentage of residents who identify as Hispanic or Latinx, and it is within these spaces where we find the tightest clustering of title lenders across the city. Focusing on the central portion of the map, where the highest number of title lenders is concentrated, one can noticeably see how quickly the number of title loan shops begins to thin out as we move north into less Hispanic populated areas. Likewise, on the eastern side of the city we can see a clear "lightening" of space where title lenders are less prominent. While some title lenders can still be found in less-Hispanic neighborhoods, the heavy clustering of stores in Brown-bodied neighborhoods is unmistakable.[10]

I was struck by how cleanly the presence of title lending stores mapped onto the racial and class divisions sewed into the landscape. Identify nearly any section of map where high and low-income tracts, or Hispanic and non-Hispanic tracts collide, and a spatial pattern repeats itself. It is as if each mile away from the cluster of debt represents an added rung on the social ladder. As one moves away from these spaces, income climbs and skin color lightens. It is as if these places of debt hold their own gravity, but unlike the gravity of nature, the force of attraction is not equally applied to all bodies. While some bodies pass through effortlessly on their daily commutes, other bodies like Carla's become tethered to the space.

MARYVALE AND THE DISTRIBUTION OF DIFFERENCE

Maryvale—the space where I met Carla—is not a city, but rather a district of the city of Phoenix that spans across 32 square miles and six zip codes. However, when locals talk about Maryvale they are referring to a much more condensed tract of land, the heart of which stretches along Indian School Road from 43rd to 83 Avenue. The area took its name from the wife of famed city developer John F. Long, who sought to recreate, but also improve on the Levittown model of planned communities that had been widely successful in the Northeastern United States.[11] Inspired by Bill

[9] In my discussion, I choose to use the gender neutral term "Latinx" to refer to individuals whose racial/ethnic identity stems from Latin America. However, the term "Latino" is utilized in Figure 2 in order to remain consistent with the categorical labels utilized by the 5 year, American Community Survey.

[10] Studies that focus on the spatial distributions of high-interest loans have revealed that the AFSPs are indeed most commonly located in low-income neighborhoods, with high concentrations of racial and ethnic minorities (Apgar and Herbert 2006; Burkey and Simkins 2004; Cover, Spring, and Kleit 2011; Graves 2003; Fox, Griffith, and Feltner 2016; Gallmeyer and Roberts 2008; Martin and Longa 2012; Smith, Smith, and Wackes 2008; Sugata 2015).

[11] Levittown was a series of planned communities constructed by the firm Levitt and Sons. The eldest son, William "Bill" Levitt, served in the Navy during WWII and believed that the demand for housing during the postwar boom could best be met through sprawling planned communities of low-cost, mass produced homes. The communities were wildly successful and soon became the symbol of an emerging white middle class. However, by the mid 1950s Levittown also came to represent the clear disparity between white and black America in the postwar years as well as the discriminatory housing practices that resisted desegregation.

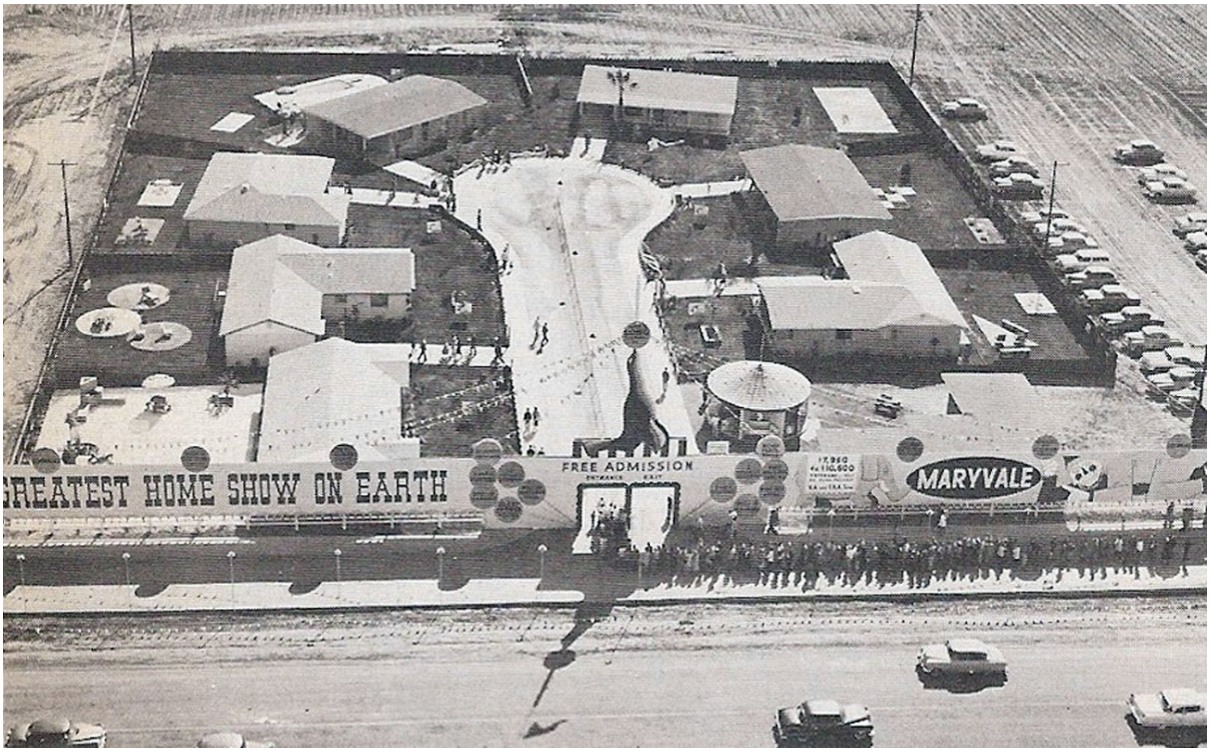

Figure 3. John F. Long's "Funset Strip" model homes in Maryvale, mid-1950s.

Levitt's idea to mass produce homes though efficient design, Long developed the single-story, ranch-style home that would become a hallmark of Phoenix neighborhoods. However, rather than constructing homes in a grid like fashion, Long designed curvilinear streets with cul-de-sacs for a more aesthetic appeal (see Figure 3); he used high walls and large trees to create privacy and serenity. The homes came with new electric kitchens, large lawns, and many had swimming pools. As a member of the Phoenix City Council, Long ensured that other developments such as shopping centers, schools, and parks all complimented the living space of the community. As promoted, Maryvale represented the future for many families seeking to cash in on the boom that Phoenix was undergoing.

Yet, in many ways the success of Maryvale would lay the groundwork for its own demise. The emphasis on speed and efficiency resulted in a monochrome template of homes built with cheap materials. As planned communities continued to spread across the valley, wealthier residents would often leave for the newest style of tract housing. The processes of Maryvale's gentrification worked in tandem with a series of other spatial changes that moved money and bodies to new places. The desire of the political and business elites of Phoenix in the 1980s to serve as a hub for national and international travel resulted in a mass expansion of Sky Harbor airport that subsequently destroyed many of the older Hispanic neighborhoods in the downtown area (Talton 2015). These residents pushed outwards with many settling in the Maryvale area. Subsequently, this drove the original white population out to newer planned communities that had ironically been modeled on the initial success of Maryvale. Migratory patterns of Mexican seasonal workers and those who sought permanent settlement, documented

Figure 4. (Source: Google Maps)

or otherwise, steadily increased throughout the 1980s and accelerated after the passing of the North American Free Trade Agreement (NAFTA) in 1994 (Gibson and Lennon 1999; Laubey 2008; Sears 2014). As corporate and investment capital pushed south, the bodies pushed north. The fluctuating demand for cheap labor intermixed with the anti-immigrant fervor that has marked post 9/11 society has led to a particularly complicated scenario for the intergenerational families that have anchored themselves in areas such as Maryvale. These histories are embedded in, and retold through a landscape that is so clearly demarcated along difference.

By the time Carla and my paths crossed in a crude parking lot, any visual marker of Maryvale's past glory had long faded from view. The average detached home was valued at only $83,000 compared to $230,000 for Phoenix as a whole (city-data.com 2016). The green lawns that once so invitingly defined the property lines of the American Dream had succumbed to the heat of the desert and now lay scorched and barren. Stagnate home values meant that it was nearly impossible to build asset wealth, thereby applying downward pressure on the local economy as a whole. A community that is largely Hispanic, where 32.5% of the residents are foreign born, has replaced the once nearly all white population (city-data.com 2016). At $36,927, the median household income is roughly 20% below that of Phoenix, meaning that the vast majority of income goes directly to paying for life essentials with very little left over for savings or emergency (city-data.com 2016). The financial stability that allowed John P. Long to sell homes with as little as $300 down has given way to fragility where permanent housing is a tenuous venture. When I met Carla in 2016, the country was nearly a decade beyond the 2007 housing crisis, yet of the 409 homes listed for sale in the Maryvale district, 40% (164) were in foreclosure (zillow.com 2016). Clearly, some spaces shake off the dust of crisis more quickly than others.

Despite the fact that the density of title lenders in Maryvale are not as concentrated as some

other locations, their presence can still feel suffocating. There is a consistent spread of shops down both major drags of the district (Indian School Rd. and Thomas Ave), and each intersection is dominated by the visual presence of this easy-to-purchase debt. Figure 4, shows an aerial view of Maryvale today.

The shown intersection lies directly across the street from the Maryvale Village, which was once a sprawling complex of shopping centers, markets, and homes that rested at the very center of John F Long's visionary plan. Today the space is filled with a mixture of small retail outlets, office space, and fast food restaurants. The surrounding streets reflect the weathered reality of Maryvale's present. Storefronts, such as CheckSmart and LoanMax, make use of vacated space to sell quick cash and other products to cope with the stress of being financially vulnerable. Within the four square miles that really hold the heart of the area, there are 24 title loan shops, meaning that every square mile an individual travels he/she is presented with an average of six opportunities to temporarily alleviate their financial struggles. Debt is a commodity to be sold and, as they say, location is everything.

From a business perspective, Maryvale represents a near perfect market to peddle debt. Residents, like Carla, are not destitute, rather they would seem to typify the working poor. Moreover, Maryvale's distance away from the city center means that private automobiles are the primary means for transportation: households average 2 cars a piece (on par with the Phoenix average) meaning there are plenty of assets to be wagered on (city-data.com 2016). Watching the human traffic that files in and out of title lenders and check cashers every evening between 4:30–6:30 one begins to see patterns in the people. The men typically arrive still carrying the manual labor they have sold. The women wear plain clothes, many with aprons, as they are finishing up or going into an evening shift. Both observations are supported by the demographic data which show low participation rates in management employment and greater than expected rates in manual labor jobs.[12] What I am struck by is the motion—the flow of bodies, the circulation of money, the transfer of wealth—all of which exemplifies Maryvale. Week to week, I see the same faces. I recognize the same company logos for pool repair, landscaping, and concrete work. I can't help think that this combination of human productivity and financial vulnerability so perfectly meets the needs of a capitalist system of accumulation that normalizes precarity as profit opportunity. I am both overwhelmed and captivated by it all. In Maryvale, I just watch.

CONCLUSION

The space of Maryvale brings me back to ontopological considerations and the vulnerabilities that are built into the landscape. My affinity for the term ontopology is derived not only from what is conceptually included in the term, but also from what it resists. A common approach to the study of space is to draw clear distinctions between varied categories of space, such as absolute space, relative space, and relational space. And while I recognize the value of these conceptual breaks, the understanding of such space often remains flat and homogenous within each designated category. Thinking of debt as an embodied experience that happens

[12] In Phoenix, approximately 10% of male workers and 8% of female workers are employed in management positions; in Maryvale, the respective percentages are 3.2% and 2.9%. Conversely, just over 10% of male workers in Phoenix are employed in construction, extraction and maintenance occupations; in Maryvale, over 23% of males work in these industries (City Data 2016).

through space and not simply *in* space changes the way we approach questions of both debt and the body. If our lived vulnerability is heightened through financial processes that direct our bodies through varied conduits of capital's circuitry, then space cannot be seen as a neutral variable. Rather space shapes us; it produces the indebted subject. The suffocating presence of two or three title lending shops on every intersection, the prominent advertisement of quick and easy cash on billboards down city streets, the integration of small banking services within loan companies, and the absence of traditional banks, all shape the inner-subjective condition of those who breathe that air. Because of the body, space is not so clean.

Understanding space to be intimately tied to the bodies that produce it, we find that the cartography of debt extends beyond the physical presence of title lenders. The clusters and gaps merely point to the normalized distribution of difference across space or what Katherine McKittrick refers to as the "material spatialization of difference" (2006: xvi). A closer inspection of the land reveals the social hierarchies that are reinforced through histories of capital movement and the mechanics of debt finance. Again, Massey (2005) helps us understand how the capacity of space to produce "us" lies in the very fact that social life and social landscapes are sedimented onto and into each other; thus, there can be no clear distinction between whom we are and the places in which we are embedded. As such the geographical histories of space and place become important to the telling of our own ontopologies. This is what I unearthed in Maryvale. I sensed the lived history of space that was gone and still present. I stumbled upon the multiple histories being told all at once: the stories of cheap space and white development intertwined with brown migration and expensive debt. All of this is woven into the landscape that is animated by quick encounters in lonely parking lots standing next to blue Pontiacs.

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ABOUT THE AUTHOR

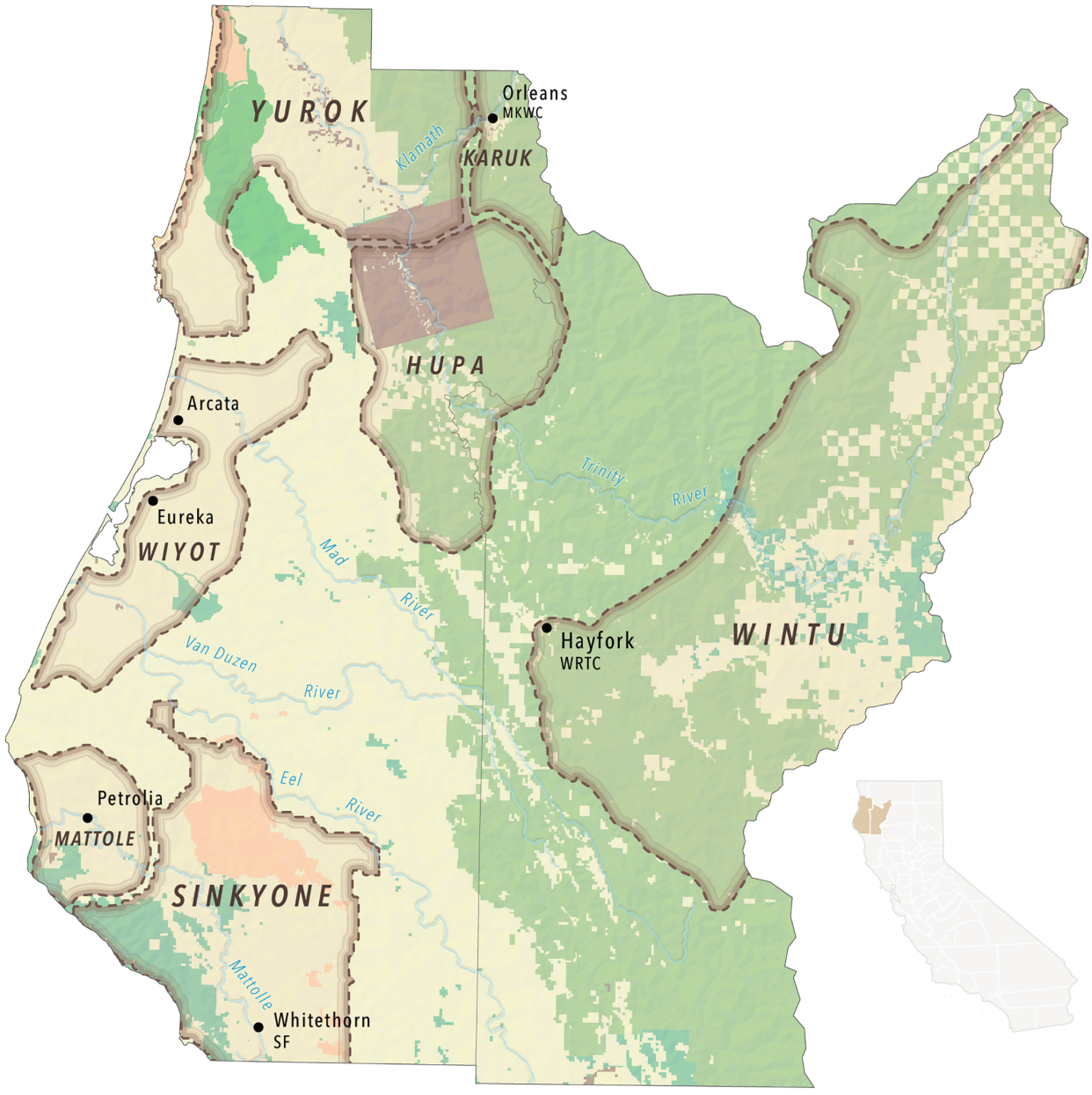
Michihiro Sugata is Assistant Professor of Criminology and Justice Studies at Humboldt State University (HSU). His research centers on financial violence and subjectivities created through the debt economy. His work examines the embodiment of debt in marginalized communities and how it complicates the ways in which we understand differential distributions of vulnerability within society. He would like to thank both the office of Research and Sponsored Programs, and the Emeritus Retired Faculty Association at HSU for supporting parts of this research. Also, a special thanks to Tony LeDonne, Erika Aoki, and Kerri Kidwell for their contributions to parts of this research.

Nathaniel is a freelance Cartographer based out of the Eugene, Oregon area. He is passionate about maps and all things geospatial, and is contracted by companies such as Apple Maps and Green Trails Maps to revise and create dynamic map products. Nathaniel graduated from Humboldt State University with a Bachelor's of Arts in Geography, and a minor in Geospatial Analysis. This fall, he will be pursuing a Master's Degree through the Department of Geography at the University of Oregon with research interests regarding cartographic story-telling, emotional perceptions, cognitive cartography, and participatory mapping.

NATHANIEL DOUGLASS

This map titled "Public, Private and Tribal Lands in Humboldt and Trinity Counties" was a commissioned project by Dr. Yvonne Everett in the Environmental Science and Management Department at Humboldt State University. The purpose of the map was to depict the overlap in land ownership and native, pre-European territories. The most challenging part of the project was finding a way to successfully represent multiple land ownership layers while also distinctly calling out former aboriginal territories, all in one map. For this, bold dotted lines with soft concentric halos seemed to do the trick. These aboriginal territories were manually digitized from another map, and only include a select few tribes pertinent to Dr. Everett's research. A light hillshade was also added, providing subtle texture to the map.

Public, Private and Tribal Lands in Humboldt and Trinity Counties



N

20 km.

20 mi.

Federal

- Private Lands
- USDA Forest Service
- National Park Service
- Bureau of Land Mgt
- State Lands
- Tribal Lands

- Aboriginal Territories
- Rivers
- Communities
- SF — *Sanctuary Forest*
- WRTC — *Watershed Research & Training Center*
- MKWC — *Mid-Klamath Watershed Council*

Nathaniel A. Douglass

Sources: Cal Trans, Humboldt GIS, USGS,

BOOK REVIEW

A new GIS working textbook, *Making Spatial Decisions Using ArcGIS Pro: A Workbook*, penned by Kathryn Keranen and Robert Kolvoord, explores the many applications of the soon-to-be-standard ArcGIS Pro software. Both authors have a wealth of GIS teaching experience as K–12 ESRI instructors, in class curriculum development, and in other relevant fieldwork backgrounds. Their workbook is the 4th in a textbook series published by ESRI Press, and it combines many of the same exercise types as previous versions, but with a primary focus on using ArcGIS Pro. This college-level and easily accessible workbook aims to provide users with a uniquely versatile perspective through scenario-based projects which follow step-by-step formatting. These projects incorporate a variety of scenarios that some GIS users have recently encountered in the United States. The scenarios presented in this workbook feature

REVIEWED BY

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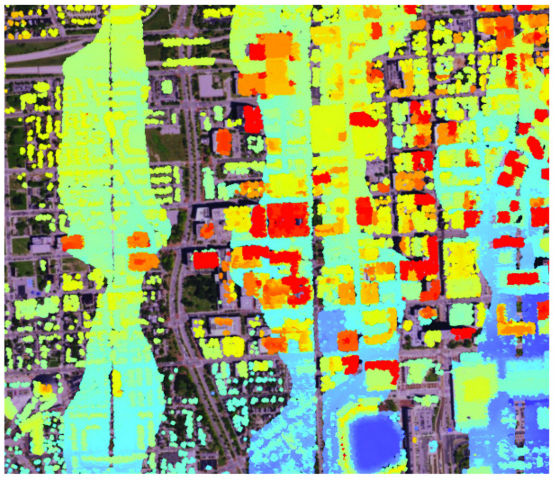
a little bit of everything from crisis management to LiDAR to imagery classification and processing as well as utilizing various data types. When purchased, this workbook comes with an *Advanced* license code, access to ESRI online resources, and data needed for completing the projects within the modules. Previous texts in this series include *Making Spatial Decisions Using GIS*, *Making Spatial Decisions Using GIS and Remote Sensing*, and *Making Spatial Decisions Using GIS and LiDAR*.

The target audience seems to be geared toward users with at least some ArcGIS Pro experience, and overall, could be an excellent transitional text for users who are more familiar with the older standards of ArcGIS for Desktop. It is recommended by the authors that users have at least a minimal working knowledge of GIS before perusing this ArcGIS Pro-centered edition.

The workbook offers two projects in each of its nine modules, and each of the projects have a suggested time commitment of two hours. For clarity, *modules* are equivalent to chapters and *projects* to exercises. The authors do a great job structuring each module in which all first projects give simple step-by-step instructions, whereas all second projects require user application of what was just learned in the previous project. Here, users could consider *project one* as the equivalent of using training wheels, and *project two* as having the training wheels removed. The module titles one through nine include: Hazardous emergency decisions, Hurricane damage decisions, Law enforcement decisions, Composite images, Unsupervised classification, Supervised classification, Basic lidar skills, Location of solar panels, and Forest vegetation height.



Keranen, Kathryn, and Kolvoord, Robert. 2017. *Making Spatial Decisions Using ArcGIS Pro: A Workbook*. Redlands, CA: Esri Press.

pp. XV – 360
$69.00
ISBN: 978-1-58948-484-9

Each module also has at least one brief introductory paragraph (some have more) for understanding the upcoming topic and what is coming next. The general workflow follows a set pattern seen earlier in their textbook series and is easy to track. The workflow delineation for each project is as follows: 1) Define the problem & scenario, 2) Identify project deliverables that support mapping decisions, 3) Document, set environments, and examine the data, 4) Perform analysis starting with the base map, and 5) Present and share work. Nested within these steps is the push for note taking, which the authors refer to as the process summary. The hope is to first have users revisit the newly learned steps later for reference, but to also allow for others to follow their instructions to replicate their work. However, after careful consideration, there are a few drawbacks.

The main critiques from what this reviewer perceived as "confusing" or "lacking" included navigating a non-intuitive interface, the lack of descriptive instructions for sharing data in ArcGIS Online, the author's approximated time commitments per exercise (2 hours suggested), and the lack of global representation within the data provided.

Issues with navigating the interface, especially with any new tool or software can be challenging and this workbook is no exception. On a positive note, the authors did attempt to address the interface navigating issue by suggesting more time for exploration in order to get more familiar with ArcGIS Pro's usability functions and the location of each tool type. Still, the workability and flow are quite different from ArcMap, so take as much time as you need to get familiar with ArcGIS Pro.

This aspect somewhat coincides with the aforementioned issue of the authors' suggested time commitment of two hours per exercise. It is not clear in the workbook if the authors intend this edition to work as more of a standalone self-teaching resource or if it is more designed for a formal classroom setting. If the latter is the intention, then the additional guidance in the form of visual aids from the instructor(s) would certainly help bring continuity.

A lack of global representation within the exercises was not a major hurdle to understanding the workflow or to learning the tools; however, equally representing "place" from various scales and aspects would set this text apart from previous versions. Essentially, inclusivity of anywhere other than the United States could be a selling point for users wanting foreign language translations. Perhaps other translations have additional regional examples?

The authors' instructions for integrating ArcGIS Online data were somewhat confusing at first glance and throughout the first few modules. Although, the nature of the iterative process did bring some clarity by the end of Module 4. Again, this would not likely be an issue if users worked through an introductory ArcGIS Pro textbook as suggested by the authors.

The preface and introduction are must-reads for all users because they cover some of the basic expectations and directionality of learning. A few examples of these expectations include functional design and layout, achieving an acceptable figure-to-ground relationship, and a brief rundown of Pro-specific applications.

A few more minor issues included a few confusing pages of composite images in the introduction of Module 4.1, the need for instructional images for exercises using the time slider function, and the need for adding a brief explanation for when and why to use what datum. Nevertheless, this working text does have some great aspects that should be mentioned as well.

Several positive aspects were discovered when working through the text. The first was how the authors ended each project with either presenting

or sharing an online map depending on the needs of the intended audience or project. This would be helpful for regular users in the field, as well as for layman types in communicating the results and findings. Module 2.1, which centered around damage from Hurricane Katrina, was outstanding at illustrating some of the realities regarding a rapidly changing climate and how to quickly address crises. The Carr Fire in Paradise, California comes to mind as an example of an even more recent scenario in which the authors' methods here could be applied for damage assessment.

Additionally, it is important to note that all modules within the text address relevant problems and/or real-world scenarios which can be applied to a multitude of disciplines. Interdisciplinary and applied work are seemingly where most research is headed, and this text illustrates some of these entities and levels. Certainly, not all disciplines are represented in the nine modules, but the systematic and processual frameworks introduced are more dynamic than not. The module pages are also color-coded for quick and easy access, and have an exceptionally high quantity of instructional images. This latest version also incorporates more images than previous editions which benefit those, like myself, who are more visual learners.

ArcGIS Pro's ribbon replaces the older toolbar seen in ArcGIS for Desktop and is mostly straightforward after reaching module 4. The authors also include a list of peer-reviewed sources at the beginning of each module which sets the user's mind at ease knowing that they are reliable. It also gives the user an opportunity to add to their proverbial toolboxes by seeking out other sources to see if they used the same methods or slightly different ones.

SUMMARY

Overall, *Making Spatial Decisions Using ArcGIS Pro: a Workbook* is an excellent text for college-level students who have had a formalized introduction to ArcGIS Pro. The authors expertly provide an expansive list of methods and applicable knowledge yet to be had from previous versions. Surely, the text is not perfect, but what it lacks can be remedied by knowledgeable instruction. Kathryn Keranen and Robert Kolvoord succeed in offering a new lens to view the bright future of ArcGIS Pro to those of us still reluctant to entirely switch.

ABOUT THE AUTHOR

Stanton Morse (B.S. in Geography, Texas State University - San Marcos 2010; B.A.'s in Anthropology and Political Science, Texas State University - San Marcos 2015) is a graduate candidate at Humboldt State University in Arcata, California. His thesis research focuses on lowland Maya settlement patterns, ecology, and geospatial analytics. Stanton is currently a Field Crew Chief at Archaeological Research and Supply Company in Humboldt County, California. He also has consulted with the Humboldt County Coroner's Office in human remains identification and crime scene recovery. Additionally, he recently completed his tenure as Graduate Research Assistant and Lab Manager for the Archaeology Research Lab and Collections at Humboldt State University.

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GEOSPATIAL TECHNOLOGIES IN SOCIAL SCIENCES

Geographic Information Systems (GIS) engages with a variety of important policy issues through linking social science data with spatial analysis and by demonstrating the importance of applied GIS in both the public and private sector. GIS, though commonly used in the realms of city planning and natural resource analysis, have a far broader range of applications ranging from analysis of ancient community interactions to modern social media data.

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