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A Support Vector Machine-Based Water Detection Analysis in a Heterogeneous Landscape Using Landsat TM Imagery

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Abstract

Surface water mapping is essential for studying global environmental changes in the quantity and quality of water bodies. This study explores the applicability of machine learning algorithm Support Vector Machine (SVM) in detecting open water surface from land. The study also compares the SVM based water extraction method with computationally simpler water index, modified Normalized Difference Water Index (mNMDI). The St. Croix Watershed Area is used as a test site for its humid environment with wetlands, built area, forest cover, and shadows as the background noise. The study uses Landsat TM data to generate spectral water index of mNDWI. Zero thresholding is used to generate binary images showing water and non-water areas. Two different SVM models, that is, Linear and Radial Basis Function (RBF) are also used to classify the Landsat TM image into water and non-water class. The accuracy of mNDWI and SVM classifiers are tested and compared using error matrices, Kappa coefficient, overall accuracy and McNemar chi-square test. The results show that the mathematically simpler mNDWI performed better than computationally complex SVM in terms of overall accuracy and Kappa coefficient. Furthermore, mNDWI accurately extracted water from narrow streams and wide rivers while SVM extracted water more accurately from locations in close proximity to urban areas such as reservoirs, boat launching ramps and locations with preponderance of wetlands.

Keywords: Support vector machine, Water detection, Water Indices, Landsat TM

Introduction

Water is one of the most vital natural resources responsible for human survival and development. The detection and observation of water has become a trending research topic due to increasing population pressure on quality and quantity of water (Niemczynowicz 1990; Palmer et al. 2015), climate change (Middelkoop et al. 2001; Bouraoui et al. 2004; Barnett et al. 2004; Piao et al. 2010), and the need for efficient monitoring of natural hazards such as floods and droughts (Alsdorf et al. 2000; Islam and Sado 2000). In addition, water stored in lakes, rivers, reservoirs, floodplains, and wetlands varies in quantity and quality at different spatial scales (Alsdorf et al. 2007). Development of remote sensing technology for measurement of water variables has received widespread recognition in the past decade, in comparison to traditional *in situ* measurements, as it provides water data at varying spatial, spectral, and temporal scales (Alsdorf et al. 2003; Alsdorf and Lettenmaier 2003). Consequently, a multitude of water detection methods has evolved using both active and passive remote sensing data to manage the wide variety of remotely sensed dataset. Some of the commonly used approaches to detect water are the photo interpretative methods of water detection (Mckay and Blain 2013), traditional supervised and unsupervised classification approaches (Frazier and Page 2000; Sheng et al. 2008), digitization-based water-detection methods (Nath and Deb 2009; Li et al. 2014), and single-band/multi-band continuous water indices methods (Li et al. 2013; Feyisa et al. 2014; Zhou et al. 2017). Among the different methodologies, mathematically simpler continuous water indices have been considered as effective as the traditional thematic classification methods for water detection, especially at global and regional scale analysis (Ryu et al. 2002; Davranche et al. 2010; Yang et al. 2015). Yet these continuous indices-based methods to detect water address only one or two background noises in a satellite image.

Background noises are defined as the pixels that are more often confused with the pixels of interest in a particular study. For example, if low-albedo open-water pixels are the feature of interest, the background noise for the water feature detection could be other low-albedo pixels such as wetlands, built-up areas, shadow, forest cover, and paddy fields. Multi-band indices have been the prevalent choice for water extraction because of their mathematical simplicity, ease of use, less ancillary data, rapid reproducible products, and results comparable to the more complex counterparts of classification algorithms (Fisher and Danaher 2013; Du et al. 2014; Jiang et al. 2014). Yet, these indices were developed to address one or two background noises with respect to water extraction. For example, modified Normalized Difference Water Index (mNDWI) was developed to address the built area noise that NDWI was unable to address (Xu 2006), while NDMI was developed to detect water in a drought conditions (Gao 1996). Other indices, such as the wetness feature of the Tasseled Cap Transformation (TCW), were developed

to measure soil and plant moisture (Crist and Cicone 1984). Similarly, an Automated Water Extraction Index (AWEInsh and AWEIsh) was developed to address topographic shadows that are often confused with pure water pixels (Feyisa et al. 2014). Regardless of the popularity of the multi-band indices, they are disadvantaged in one profound way: most of our real-world landscapes do not have one or two background noises, especially at a global or regional scale. Furthermore, multi-band indices have been preferably used for global and regional scale analysis where field data or ancillary data is unavailable to use in a traditional classifier. Yet, regional- and global-scale water mapping would mean heterogeneous landscapes with different types of background noises that multi-band indices are ill-equipped to address.

To address a broad range of background noises, traditional classification algorithms such as a Gaussian Maximum Likelihood classification or the expert classifier have been the other methodologies for water detection when large number of training data, validation data, and ancillary data are available (McCarthy et al. 2003; Sheng et al. 2008; Li et al. 2014; Pekel et al. 2016). Yet, these traditional classifiers and expert systems are time consuming as they require a large number of training and other ancillary data and are not suitable for global- and regional-scale studies (Ouma and Tateishi 2006). Machine Learning (ML) has recently gained much attention from academics and practitioners in remote sensing as an improvement over traditional methods, in terms of accuracy of performance and automation (Yu et al. 2014; Belgiu and Drăguţ 2016; Lary et al. 2016) (Figure 1). One advantage of ML algorithms is that they limit human assistance in task performance. ML algorithms are also known for faster processing time for large study areas (Robinson et al. 2019). Within ML algorithms, Random Forest (RF), Support Vector Machine (SVM), and Artificial Neural Network (ANN) are more commonly used algorithms for satellite image classifications (Lary et al. 2016). Amongst the ML algorithms in remote sensing applications, Support Vector Machine (SVM) was developed as a binary classifier (Cortes and Vapnik 1995). SVM is also an ML approach that produces equally robust results with less training data, as compared to the more traditional classification methods such as Gaussian Maximum Likelihood classification, which require large training data (Wang et al. 2005; Foody and Marthur 2004; Foody and Mathur 2006; Mountrakis et al. 2011). Consequently, SVM could address the multiple background noise of a heterogeneous landscape that multi-band indices are unable to address yet require less training data.

This research explores how well the computationally complex ML algorithm SVM performs, as compared to the traditional, simpler water index method of mNDWI. Among the many water indices, mNDWI is selected for comparison, as past research has shown an overall better performance of mNDWI in comparison to other water indices in a heterogeneous landscape (Ji et al. 2009; Li et al. 2013; Feisha et al. 2015; Yang et al. 2015; Fisher et al. 2016; Adhikari 2019). The main objectives of this study are thus twofold: (1) extract open-water pixels using continuous water indices of mNDWI- and SVM-based linear and RGB algorithms; (2) statistically compare the robustness of the spectral indices-based method versus the machine learning-based classification algorithms SVM. With this paper we expect to contribute in one key aspect: By comparing the computationally simpler index (mNDWI) and computationally complex (SVM Linear and RGF), we identify the technique best suited to separate water from land in a very large, diverse landscape with wetland and built area as the source of noise.

This research uses St. Croix Watershed Area (SCWA) as a representative test site to test the robustness of accurately extracting water using an mNDWI and SVM classifier. The location has a large number of glaciated lakes and other open-water pixels in the form of reservoirs, rivers, and streams. The test site is ideal, as it includes a large number of wetland area with varying amount of grass, sedge, shrub, and woody cover in the northeastern and central part. The test site also has a substantial urban built area as well as forest cover, cloud shadows, and agricultural fields. Consequently, the test site provides ample background noises for our water detection comparison.

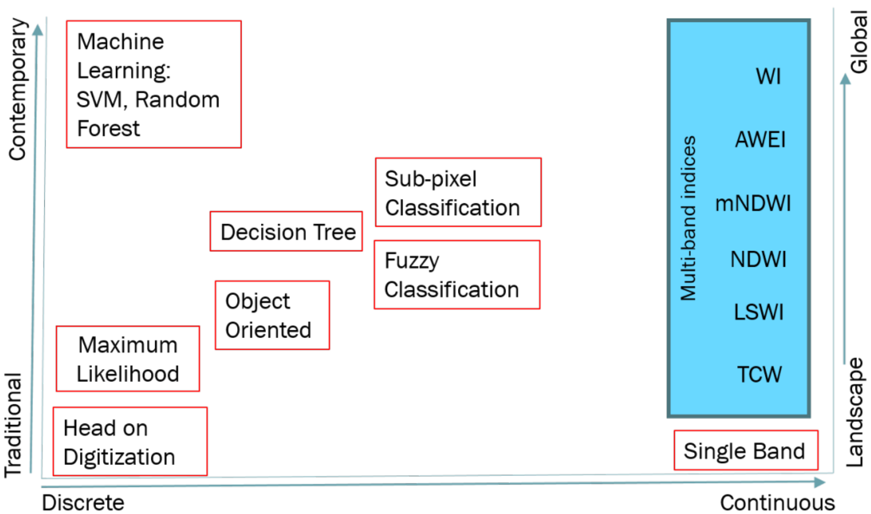

Figure 1.—Development of remote sensing techniques in water extraction (adapted from Southworth and Gibbes 2010).

Site Description

St. Croix watershed area has a total area of approximately 20,000 km^2 and is located in northwest of Minnesota and east-central of Wisconsin (Figure 2). The average rainfall is around 28 to 33 inches annually, with humid continental climatic conditions. The watershed is drained by the St. Croix River for 276 km from its headwaters to its confluence with the Mississippi River. Some of the major tributaries that drain into St. Croix River are the Namekago, Snake, Kettle, Clam, and Yellow Rivers. The topography of the watershed is flat to rolling glaciated terrain, with a large number of lakes. Apart from the lakes and rivers, water in this region is also stored in smaller streams and a large number of seasonally and permanently inundated wetlands (Wegner et al. 2000). The wetlands in this region are diverse, ranging from large alder thicket/swamp hardwood riparian wetlands and shallow marshes in the northeast to open bog wetlands and conifer swamps in the northern part of the watershed and sedge meadows in the south (Bazzell et al. 2002).

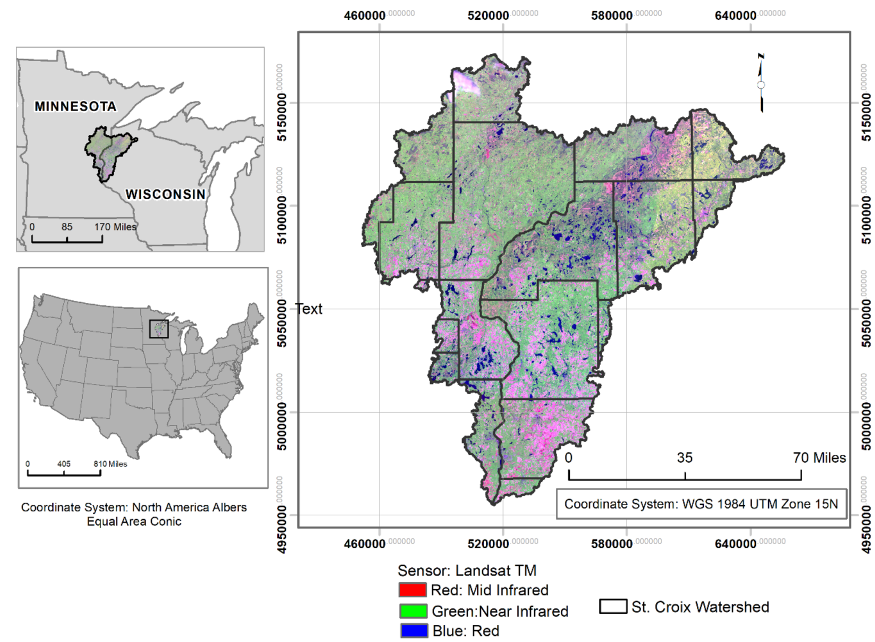

Figure 2.—Location of St. Croix Watershed in Wisconsin and Minnesota.

The watershed area is also divided into the upper and lower St. Croix, due to significant variations in land-cover and land-use types and dominant vegetation species. Upper St. Croix is predominantly forest cover (approximately 60 percent) followed by wetland, grass/pastureland, open water, and developed land. The Lower St. Croix is dominated by cropland, rangeland, and forest/shrub followed by developed, open water, and wetland. However, cropland has declined since 1940s with increased urban and suburban development of St. Paul-Minneapolis (Edlund et al. 2009). Less than 1 percent of land use has been for residential and commercial development, where the majority of the development occurred in the southern part of the St. Croix region, largely as a result of Minneapolis-St. Paul metropolitan sprawl (Wenger et al. 2000).

Methods

Data Acquisition and Image Preprocessing

The satellite images used for this study area are level 1 US Geological Survey (USGS) Landsat 5 TM, 2011. The images are cloud free and corrected for sensor and atmospheric calibration errors, to minimize the effects of sun angle and atmospheric condition, using the Center for the Study of Institutions, Populations, and Environmental Change (CIPEC) methods (Green et al. 2005). The manual, image-to-image co-registration method has been used to geometrically correct the images with a Root Mean Square Error (RMSE) of less than 0.5 pixels. The images are projected to zone 15 of WGS 1984 UTM. The study area boundary of the St. Croix watershed was created by using a vector layer collected from the Wisconsin and Minnesota Department of Natural Resources (DNR). Imagery for this study is chosen for June 7 (path/row: 27/28 and 27/29) and July 2 (path/row: 26/28), 2011, which are both within the wet season. These dates were selected as they are right after winter snow season in the St. Croix watershed area, the snow is mostly melted, and rainfall allows for easier detection of all open surface water features full of water.

Water Index-Based Approach—Modified Normalized Difference Water Index (mNDWI)

After careful consideration and literature review of commonly used water indices such as TCW, NDVI, NDMI, NDWI, mNDWI, and AWEI, mNDWI was chosen as the best water index approach for detecting water to compare with a machine learning approach. The mNDWI is considered an improvement over the NDWI (Xu 2006). Xu's mNDWI is calculated as (Green-SWIR1) / (Green+SWIR1), where Green represents the Green spectral band and SWIR1 is the shortwave infrared spectral band. The mNDWI values ranges from -1 to +1, whereas water pixel values range between zero and +1. The mNDWI attempts to maximize the reflectance of water body by Green band and minimizes the low reflectance of water in the SWIR1 band, thus providing better contrast between water and non-water pixels (Xu 2006).

The delineation of water pixels from non-water pixels in spectral indices such as mNDWI is done using image binarization method. Image binarization is a method of using an optimal threshold value to convert a continuous satellite image or a spectral index image into two discrete classes of zero and one (binary) (Jensen 2015). This study applies a zero binarization method. Zero thresholding is the simplest binarization method, which assigns zero to all values less than zero and 1 to all values greater than zero in the index. Therefore, for mNDWI, all values coded 1 represent water features and all values coded 0 indicate non-water features.

Machine Learning Approach—Support Vector Machines (SVM)

A Support Vector Machine (SVM) is a supervised, non-parametric statistical learning technique originally formulated by Vapnik (1979). SVM constructs optimal separating hyperplanes between classes in feature space through the use of support vectors. An optimal hyperplane is a decision surface that can separate classes from each other with maximum margin, and support vectors are the data points nearest to the hyperplane that are most difficult to classify (Figure 3).

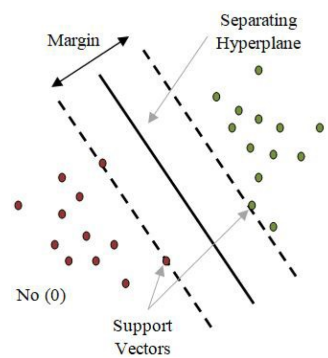

Figure 3.—A demonstration of SVM hyperplane, margin, and support vectors.

The hyperplane can be expressed mathematically as follows:

$$h(x_i) = w.x_i + b \quad \begin{cases} \mathbf{w.xi + b \geq 0} & \mathbf{y = +1} \\ \mathbf{w.xi + b < 0} & \mathbf{y = -1} \end{cases}$$

Where the feature space {xi, yi}, i=1,…,n and yi∈{-1,+1}. The reflectance value (pixel value) of Landsat TM bands is represented by x, and y is a binary label for water and non-water pixels. The coefficient and constant of the hyperplane are represented by w and b, respectively. Many hyperplanes could possibly fit the equation (x), but SVM looks for the optimal hyperplane, which maximizes the margin between support vectors. Studies that focused on mathematical formulation of SVMs can be found in previous researches on machine learning (Cortes and Vapnik 1995; Burges 1998).

SVM was originally designed to partition two linearly separable classes (a binary linear classifier) (Cortes and Vapnik 1995). However, SVMs are further extended to deal with non-linear classification by using a non-linear kernel function. In other words, kernel functions offer the option of transforming non-linear spaces into linear ones. Several commonly used kernel functions include linear kernel, polynomial kernel, radial basic function (RBF) kernel, and sigmoid kernel (Ayat et al. 2002; Ayat et al. 2005) (Table 1). It is difficult to determine which kernel would work the best for the study. This study used the radial basic function (RBF) kernel which is commonly used for image classification.

Table 1. SVM Kernel Functions

Kernels	**Formula**
Linear	k(x,y) = x.y
Sigmoid	k(x,y) = tanh(ax.y+b)
Polynomial	$k(x,y) = (1+x.y)^2$
RBF	$k(x,y) = \exp(-a\|\|x-y\|\|^2)$

The SVM algorithm consists of two stages of training and testing. In the training stage, this study used Quantum GIS to collect training samples and labeled them as 1 for water and 0 for non-water pixels. The study used National Land Cover Database 2011 (NLCD, 2011) definition to define water and non-water. Water is defined as any open water pixel with less than 25% cover of vegetation or soil. Non-water is defined as all pixels that are not water pixels, such as urban, agriculture, soil, wetland, bare, forest, and shrubland. These training sites are input data to the SVM algorithm to train the SVM Classifier. The decision boundary generated based on the training sites is used to classify all the image pixels into water and non-water. The study used SVM classifier of the Orfeo Toolbox (OTB) using Monteverdi software, an open source toolbox for remote sensing image processing developed by the French government space agency, National Centre for Space Studies (CNES).

Validation and Comparison Test

For testing the classification accuracy of all the three binary images of SVM Linear, SVM RBF, and mNDWI, reference point samples were collected based on Foody's (2004) binomial probability theory. A total of 200 random samples were generated with equal proportions of water and non-water points, using the NLCD 2011 land cover data as the stratum. The reference points were further verified using Collect Earth, free and open-source software developed by the Food and Agriculture Organization of the United Nations (FAO) to assist in land data collection, management, and analysis (Bey et al. 2016). After careful visual analysis of the random points, 100 non-water and 99 water points were used to run accuracy assessment for the three classified images.

The three classified images were validated using total error, overall accuracy, Kappa coefficients, and error matrices. As classification accuracies are based on sample points used and only provide an estimate (Foody 2004), McNemar's test was calculated. To calculate statistically significant differences between pairwise classifications, McNemar's chi-square statistics with continuity correction were computed as shown in the equation below (Foody 2004) for mNDWI, SVM Linear, and SVM RBF.

$$X^2 = \frac{([f_{12} - f_{21}] - 1)^2}{f_{12} + f_{21}}$$

where, f_{12} and f_{21} denote the number of samples that are correctly classified by one classification method but wrongly classified by the other. McNemar's chi-square test was computed for pairwise comparisons for mNDWI, SVM Linear, and SVM RBF. A ≥ 3.84 would show a significant difference between two classified maps at one degree of freedom at a significance level α= 0.05.

Results

This research applied mNDWI and SVM methods of water extraction to Landsat TM image of St. Croix watershed area to separate water and non-water features. The research dealt with a heterogeneous landscape with background noise such as forest cover, built areas, wetlands, agricultural area, cloud cover, and shadow. A zero-thresholding method was used for mNDWI to separate water and non-water. For SVM models, training data for water and non-water was used to create the hyperplane to separate water from non-water. Results were analyzed visually and quantitatively. The visual overviews of classified images are presented in the qualitative results section, and a comparison of statistical accuracy assessment results is discussed in the quantitative results section.

Qualitative Results

The visual inspection of the three water maps (Figure 4) shows that the water surfaces delineated using mNDWI, SVM Linear, and SVM RBF were similar to the actual water distribution in the NLCD 2011 data. To verify the accuracy of the water extraction, the maps were compared visually for different water types such as narrow streams, man-made reservoirs, and lakes. Reservoirs and other water bodies in close proximity to urban features are better extracted by SVM models.

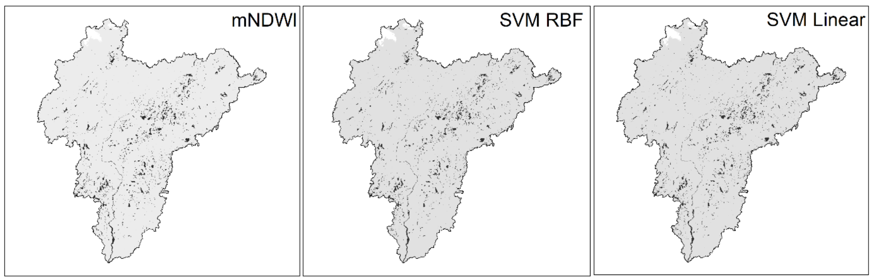

Figure 4.—Classified map of St. Croix watershed showing water and non-water classes using mNDWI, SVM RBF, and SVM linear methods of image segmentation.

Figure 5 shows a bridge and boat ramp over the river, which are misclassified as water by mNDWI water index approach. Comparatively, both SVM linear and SVM RBF extracted the bridge and boat ramp more accurately than mNDWI as a non-water feature. Similarly, mNDWI detected all three reservoirs as one water feature, while SVM classifiers, particularly SVM RBF, accurately separated each reservoir with non-water pixels (Figure 6). However, visual inspection shows that the narrow water features such as streams are more accurately extracted by mNDWI method (Figure 7).

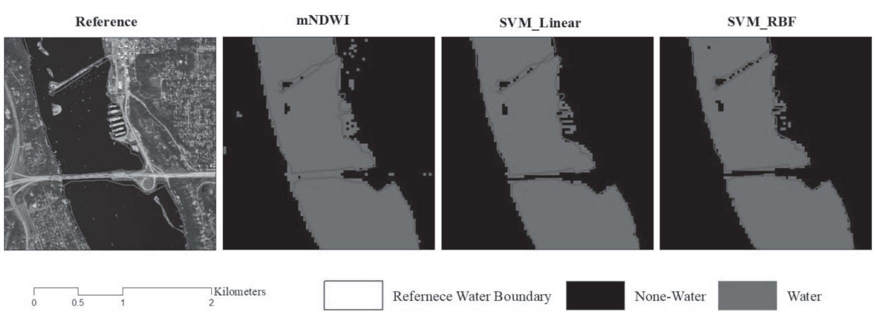

Figure 5.—Comparison of three classifiers to detect bridge over the river.

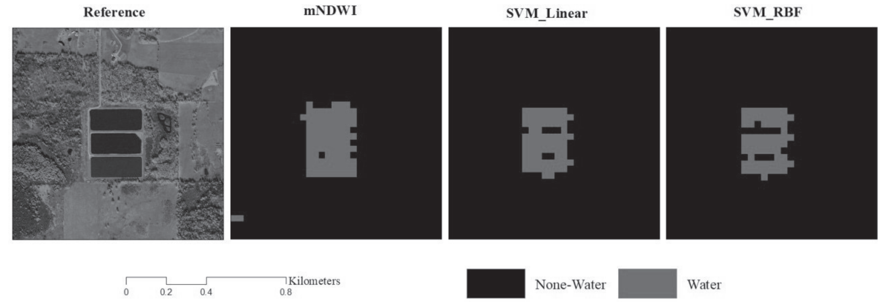

Figure 6.—Comparison of three classifiers to detect three adjacent reservoirs as separate features.

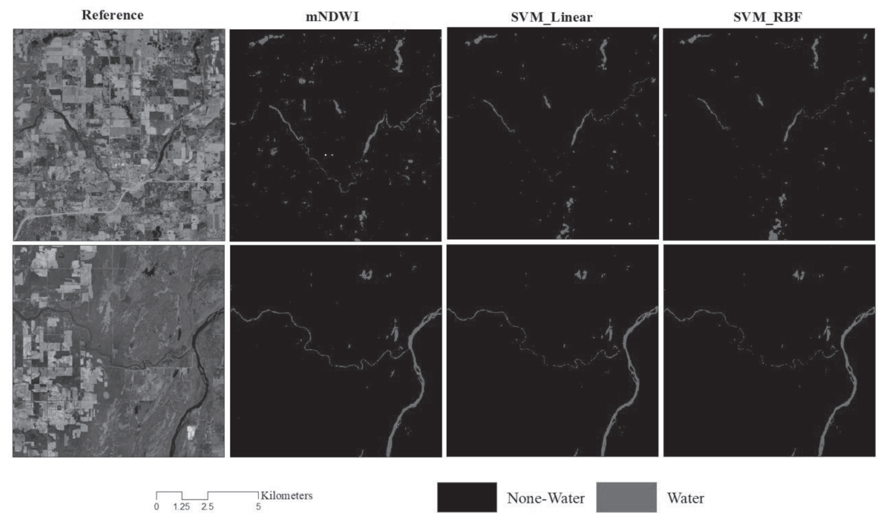

Figure 7.—Comparison of three classifiers to detect narrow streams of water body in the St. Croix watershed area.

Quantitative Results

The classification accuracy is evaluated by error matrix, total error (error of omission and error of commission), overall accuracy, Kappa coefficient, and McNemar's chi-square test. Tables 2 and 3 show overall accuracy and Kappa coefficient results from the mNDWI method and SVM Linear and SVM RBF approaches. The quantitative results show that water index and SVM methods have a similar overall accuracy of nearly 98% (Table 2). mNDWI performed marginally better (0.51%) than the SVM classifiers in overall accuracy.

Table 2. Summary of accuracy assessment results of mNDWI and SVM Models.

	mNDWI	SVM Linear	SVM RBF
Overall Accuracy (%)	98.49	97.98	97.98
Kappa Coefficient	0.96	0.96	0.96

Table 3. Confusion matrices of mNDWI, SVM linear and RBF.

Method		Water	Non-Water	User's Accuracy
mNDWI	Water	96	0	100%
	Non-Water	3	100	97%
	Producer's Accuracy	97%	100%	99%
SVM Linear	Water	95	0	100%
	Non-Water	4	100	96%
	Producer's Accuracy	96%	100%	98%
SVM RBF	Water	95	0	100%
	Non-Water	4	100	96%
	Producer's Accuracy	96%	100%	98%

Comparing omission error (water pixels classified as non-water pixels) between the three classifiers show that all three produced an omission error of 0% (Table 3), which means all the reference non-water pixels are classified correctly. With reference to commission error (non-water pixels classified as water pixels), the results show that the mNDWI method classified 3% of reference water pixels as non-water, while SVM approaches (both linear and RBF kernels) classified 4% of water pixels from reference points incorrectly as non-water pixels.

To assess the statistically significant differences between the three classified maps, the study also calculated McNemar's chi-square test. This test is instrumental in identifying the best model among the mNDWI, SVM Linear, and SVM RBF, as the differences in overall accuracy is merely 0.51%. The McNemar's test result shows that the classification performance was not equal. In fact, mNDWI performed significantly better than both SVM linear (= 60.0161, $p < 0.05$) and SVM RBF (= 72.3049, $p < 0.05$).

Comparison of Background Noise

In order to compare the classification accuracy of water, different background noises are compared (Figures 8 and 9). A closer visual inspection of the background noises shows that SVM models extracted water from urban and wetland background noise much better than the mNDWI model. Two examples of built area in St. Croix watershed area are shown in Figure 8. In both examples, mNDWI misclassified low albedo built-up areas as water ,while SVM classifiers extracted water comparatively better in this background noise. Figure 9 shows water pixels in wetland background. The results from three classifiers indicate that mNDWI misclassified wetlands as water pixels, while SVM classifiers extracted water from a wetland more accurately.

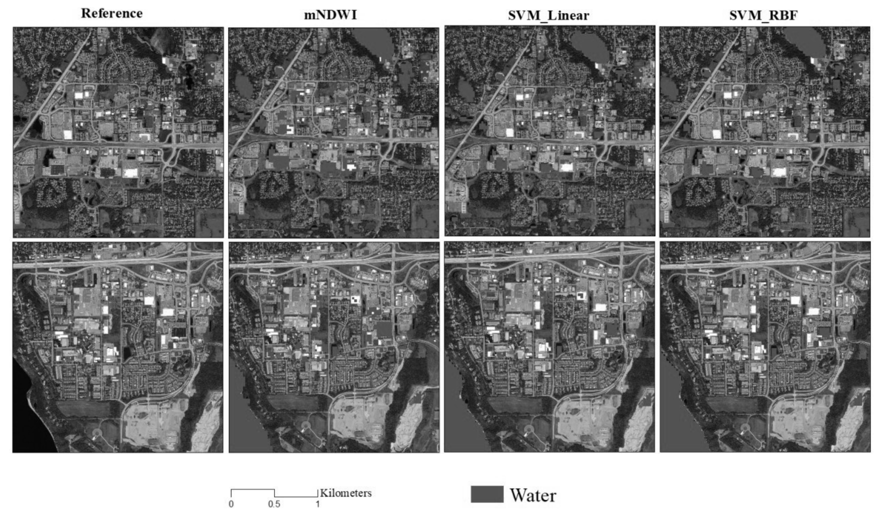

Figure 8.—Comparison of three classifiers to detect water in urban/developed area.

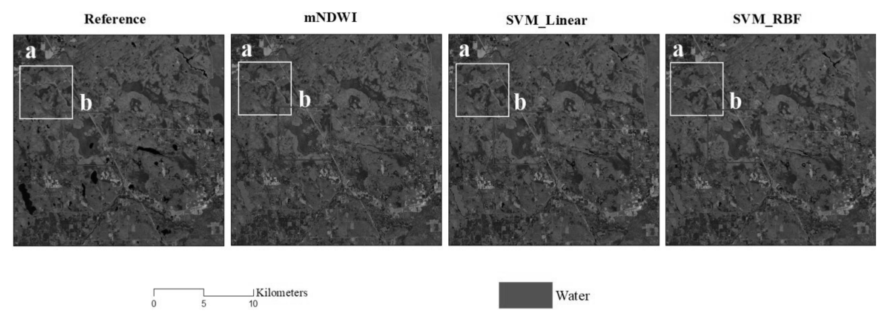

Figure 9.—Comparison of three classifiers misclassifying wetlands as water. Two wetlands are marked as a and b.

Discussion

The St. Croix Watershed Area, in Wisconsin and Minnesota, USA, was selected as a test site for this research. The study area is an ideal test site for comparing different water extraction methods, as there are massive amounts of open surface water area varying in depth of water (deep or shallow water), shape of water boundaries (well-defined lake boundaries, wide rivers, narrow streams), and type of water (pure water or containing vegetation or sediments). Additionally, the study site is a very heterogeneous landscape presenting different land uses and land-cover types. The heterogeneous landscape also means that the region provides a large number of low-albedo land surfaces that are often confused in water extraction such as wetlands with varying amount of grass, shrub and woody cover, built areas, cloud shadows, and forested areas. These background noises and the heterogeneous landscape have made this watershed a very challenging case study for water extraction. Yet, this same challenge of the study site provides an ideal test site to compare between the more traditional and mathematically simpler index-based water extraction method of mNDWI with a more contemporary and computationally complex statistical machine-learning-based algorithm such as the SVM.

Accuracy of water extraction depends on the range of background noises (non-water surface) the research is trying to address; as such, much of the research on water extraction has focused on one or two background noises and developing algorithms that best address those one or two background noises. The water index-based methods are more commonly used because of its simplicity, automated approach, rapidity in application, and less data dependency compared to more complex classification-based water extraction methods. Generally, the threshold values used in these methods are fixed, but it can be challenging in the case of environmental noises such as shadow, forest, clouds, and build-up/urban areas. Among the water indices, mNDWI was developed to address low albedo built area confusion with water bodies (Xu 1996). Studies have also shown that mNDWI performs much better than other index-based methods such as NDWI, AWEI, and NDMI in extracting water from a heterogeneous landscape with multiple background noises (Ji et al. 2009; Li et al. 2013; Feisha et al. 2014; Yang et al. 2015; Fisher et al. 2016; Adhikari 2019). Thus, it is not surprising that mNDWI performed well in extracting water in the heterogeneous landscape of the St. Croix watershed area with an overall accuracy of 98.49% and a kappa coefficient of 0.95. The statistical assessment of classification accuracy performance showed that SVM did not offer an improvement over mNDWI in terms of overall accuracy and Kappa coefficient. The slightly higher overall accuracy of mNDWI in comparison to SVM's overall accuracy (97.98%) is also on par with other similar studies that compared water indices and ML algorithms for water extraction with built areas as background noise (Xu 2007; Sarp and Ozcelik 2017).

Nevertheless, visual inspection of water maps demonstrated that SVM models extracted water from certain sites better than mNDWI in this study site. The sites where SVM Linear and RBF extracted water better than mNDWI are located mostly in the central and northeastern part of the St. Croix watershed area, where there is a dominance of wetland land cover. Wetlands are difficult to separate, as the spectral responses of wetlands can be very similar to open water surfaces, depending on the percentage and type of vegetative cover in the wetland. Thus, the deliberate training data from wetland areas as non-water pixels in an SVM classifier might have allowed for more accurate water extraction in the northeastern part of the study area. The visual inspections also show that SVM models extracted water more accurately than mNDWI in locations that are in close proximity to built-up areas such as bridges, boat launching ramps, man-made reservoirs, and buildings in the southern part of St. Croix watershed area, even though mNDWI was devised to address the built area noise in water extraction mapping. Sanchez et al. (2018) found that SVM performed better in extracting reservoirs, as compared to mNDWI. The present research results resonate with other previous researches that found SVM to maintain spatial characteristics of isolated features such as reservoirs, bridges, and roads better than other algorithms (Huang and Zhang 2009; Mountrakis et al. 2010; Poursanidis et al. 2015). Thus, SVM might be a preferable model over mNDWI in areas where fragmented and isolated built-up areas are the background noise.

Overall, this research concludes that SVM models would be great for areas that are very heterogeneous, with a preponderance of built and wetland land-covers with isolated and fragmented water spaces such as reservoirs and bridges. Yet, the slightly higher accuracy of the quantitative results of mNDWI show that a simple, water-index-based method can produce rapid and reproducible water maps for regional- and global-scale mapping. Additionally, this research shows that the performance of ML algorithms such as SVM are best suited for locations where precise water mapping might be required, and where training data collection and expert knowledge of the study site to validate the training data are available. The contradictory results of the quantitative analysis with the visual interpretations could also be the result of a pixel-based accuracy assessment, a popular approach for classification validation (Ye et al. 2018). Pontius and Millones (2011) have argued against an accuracy assessment based on the Kappa coefficient that are derived from a confusion matrix. Polygon-based sampling for accuracy assessment, a less common approach, might address the contradictory quantitative and qualitative results better (Ye et al. 2018).

Conclusion

The present study focused on open surface water detection using Landsat TM satellite data, with the St. Croix watershed area as the test site. The St. Croix watershed area provided an ideal site for testing the robustness of a mathematically simpler water index mNDWI with a computationally complex machine-learning algorithm SVM Linear and RBF. The study site of the St. Croix watershed area is an ideal test site, as it provided a large, heterogeneous landscape with many low-albedo background noises. Three water maps were generated from mNDWI, linear SVM, and RBF SVM. To statistically assess the results, error matrices were calculated for each of these water maps, providing overall accuracy and kappa coefficient. McNemar's chi-square test was calculated to check whether the differences in accuracy of the three maps were statistically significant. The quantitative results show that the index method (mNDWI) and classifiers (SVM) produced similar overall accuracies, with slightly better performance for mNDWI. McNemar's chi-square test confirmed that MNDWI was a better method than SVM classifiers. Visual inspection of the images show contradictory results where the SVM classifiers extracted water more accurately than mNDWI in close proximity to built-up areas and wetlands. The quantitative and qualitative results show that a SVM classifier may not provide better performance accuracy of mNDWI, but it can be an improvement over mNDWI to detect open surface water in a landscape with wetland and built area as the dominant background noise. We can conclude that the mNDWI might be best used when rapid and reproducible maps are needed for global- and regional-scale water mapping, as it is algorithmically simple, computationally easy, requires less ancillary data, and does not need expert knowledge about the landscape. In contrast, SVM might be a better approach when precision mapping is needed for a very heterogeneous landscape with urban and wetland as the background noise.

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Media Coverage and Rebuilding in Two Neighborhoods in the Aftermath of the 1989 Loma Prieta Earthquake

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Abstract

This mixed-methods study examined two neighborhoods in San Francisco with similar earthquake-induced ground failure history—the Marina District and the South of Market Area (SoMa)—in the aftermath of the 1989 Loma Prieta Earthquake. The research explored differences in their recovery processes, including the potential impact of uneven coverage in newspaper media, and different pre-earthquake socioeconomic conditions and building types. Despite findings that the Marina was mentioned more frequently in news media coverage than SoMa, disproportionate to the ratio of damaged buildings between the two regions, socioeconomic processes of rebuilding may better explain how the geography of these neighborhoods shaped the earthquake recovery experience.
Keywords: earthquake, disaster, media, Loma Prieta, rebuilding

Introduction

Images of the San Francisco Bay Area's Marina District burning permeated the air waves and made front-page headlines in the days and weeks that followed the magnitude 6.9 earthquake on 17 October 1989 (Bardet et al. 1992). The earthquake itself originated seventy miles south in the Santa Cruz Mountains, causing a wide swath of destruction up and down the San Francisco and Monterey Bay Areas. In total, sixty-four people were killed and $10 billion USD (in 1989 dollars) worth of damage was inflicted on the region in the span of roughly thirty seconds (Steinbrugge and Roth 1994).

The Marina and South of Market districts (SoMa) experienced particularly extensive damage during Loma Prieta because of ground failure and liquefaction. In the Marina District, seventy-four buildings were destroyed and damages were estimated at $55,233,241 USD (in 1989 dollars); in SoMa, twenty-five buildings were destroyed and damages were estimated at $36,893,325 USD (in 1989 dollars) (Harris and Egan 1992; Taylor et al. 1993). The Marina District and SoMa neighborhoods make for a compelling comparison because while their underlying soils shared similar liquefaction potential and both neighborhoods experienced significant structural damage in the 1989 quake (Dyl 2009), the two neighborhoods had significantly different socioeconomic compositions.

The Marina District was (and remains) an upscale, picturesque neighborhood of elegant architecture and exclusive streets (Bauman 1997). SoMa was heavily industrial and commercial, with residential niches of mixed income households, and experienced a surge of development during the dot-com boom of the 1990s (Bauman 1997; Gin and Taylor 2010). The median home value in the Marina was over $500,000 USD in the 1990 census, and the population below poverty level was just under 5 percent (US Census Bureau 1990). In SoMa, the median home value was $192,700 and the poverty level was 18.7 percent, which was 6 percent higher than the San Francisco City and County average at that time (US Census Bureau 1990). The Marina had more owner-occupied buildings than SoMa, although both neighborhoods had more renters than owners (US Census Bureau 1990). The Marina, covering 0.6 square miles, housed 9,775 people in 1990, making up 1.4 percent of the San Francisco City and County population. SoMa covered 1.5 square miles and contained 11,770 people, 1.6 percent of the San Francisco population. The Marina was populated by mostly middle- and upper-income white professionals, while SoMa housed a diversity of ethnic backgrounds from various layers of economic strata (Bauman 1997; US Census Bureau 2010). Identifying potential underlying contributors to the different rebuilding patterns of these two neighborhoods is the central subject of this study.

Although there is discussion around what exactly exemplifies recovery, for the purposes of this study, rebuilding is taken as a major indicator of recovery, and is the main factor considered here (Chang 2010; Tierney and Oliver-Smith 2012). The Marina was repaired rapidly and in nearly identical form to its pre-earthquake state (Arnold 1993; Bauman 1997). Reconstruction was geared toward replacing damaged structures with new structures that served the same purpose of providing housing, and even involved transforming previously low-rent units into condominiums. The costs were met mostly by residents themselves, with government aid intended to help homeowners with bureaucratic processes (Bauman 1997).

SoMa, however, did not quickly return to its previous state. After the quake, the city did not encourage replacing lost low-income apartments in the same way they did in the Marina (Bauman 1997). The cost of rebuilding in SoMa was borne largely by government and NGO assistance and volunteers (Bauman 1997). The earthquake presented an opportunity to work toward needed redevelopment goals in SoMa, as evidenced by the growth and

work of the South of Market Redevelopment Area, initially established to aid recovery, later supporting improvement in housing and neighborhood services (Office of Community Investment and Infrastructure n.d.).

In addition to the socioeconomic and building-type differences in these two regions, media coverage varied dramatically. After the 1989 Loma Prieta event, media coverage focused on the Marina District, while less coverage was given to the more ethnically diverse East Bay and Santa Cruz, even though these areas were equally devastated (Dyl 2009; Rogers et al. 1990; Rodrigue, Rovai, and Place 1997). Research has suggested that differences in media coverage have been related to differences in recovery time and community response, and has possibly been linked to economic and cultural differences (Rodrigue 1993; Rodrigue, Rovai, and Place 1997; Rovai 1994). Repetitive images of earthquake damage in certain locations shown by the media has coincided with public perceptions that damage was most severe in these locations (Rovai 1992; Rodrigue, Rovai, and Place 1997). Additionally, Rodrigue, Rovai, and Place (1997) described "filters" through which information provided by the media must pass. These filters may involve news reporters receiving official communications that they must then turn into a news story, adding discursive layers to the information that may shape the resulting impressions on the audience (Davis and French 2008). It is quite possible that the Marina represented a more popular story for the media than SoMa in the quake's aftermath.

The fact that the media is a highly commercialized industry that depends in part on sensationalism to draw in and keep customers to maintain a steady base of support may help explain why the aesthetically dramatic burning Victorian structures in the Marina were utilized (Ali 2013). These images may have served as a disaster reporting "hook," which are often composed of a compelling visual image such as a memorable landscape or a site of dramatic fatalities to draw in viewers and readers (Dynmon and Boscoe 1996). The media's actions may have unintentionally generated a bias toward the Marina District.

The 1992 North Coast Earthquake in California also exemplified a media bias toward certain regions (Rovai 1994). Rovai (1994) argued that the media's attention was focused on picturesque, tourist-oriented Ferndale rather than lower per-capita income Rio Dell, as evidenced by significantly higher visibility in newspaper articles and photographs. Rovai (1994) concluded that socioeconomic factors existing prior to the earthquake contributed to differential rates of recovery, and that financial resources were clearly more available and accessible to Ferndale residents than to Rio Dell residents. Though the populations in the 1992 North Coast earthquake and the 1989 Loma Prieta Earthquakes were quite different, Rovai's (1994) study exemplifies the potential impact of unintentional media biases on recovery.

The three main sources of information for media outlets in the aftermath of Loma Prieta were the national newswire, network television broadcasts, and witness accounts, all of which suffered from misinformation, inadequate estimations, and preconceived views in the immediate chaos that followed the event (Rogers et al. 1990). At the time of the Loma Prieta Earthquake, media outlets of all kinds were concentrated in San Francisco to cover the 1989 Major League Baseball World Series. The fire that broke out in the Marina District made it the first region to gain media attention, and the images captured of that event greatly influenced impressions of damage as a result (Bolin 1990). Rogers et al. (1990) reported on a visit to the San Francisco Bay Area the day after the earthquake and took stock of the casualties and damage reported by radio, television, and newspaper outlets. Some of these reports specifically mentioned impassable intersections, which Rogers and his team found very much passable. Recently published "best practices" stress the importance of thoughtful, ethical reporting in order to help reduce errors and negative impacts on communities in the midst of disasters, alluding to the tremendous potential impact of inaccurate reporting (Ewart and McLean 2018).

The goal is not to critique the media, but instead to illuminate its possible role in disaster recovery within these two neighborhoods following the 1989 earthquake by answering the following question: Was there a difference in newspaper coverage of the Marina and SoMa neighborhoods following the 1989 Loma Prieta Earthquake, and if so, did this impact recovery? As models for the current study I draw on Rodrigue's research on media coverage following the 1994 Northridge Earthquake (1993; 1997; Rodrigue and Rovai 1998; Rodrigue et al. 2004) as well as Rovai's research on community response to the 1992 North Coast Earthquake (Rodrigue and Rovai 1998; 1994) and modify the scope of their methodology and approaches to fit the confines of this study.

Tabulating newspaper mentions of the Marina District and SoMa indicated that the Marina District was mentioned more frequently in the *San Francisco Examiner* and the *San Francisco Chronicle* than the SoMa neighborhood during the three months following the Loma Prieta Earthquake. By triangulating this quantitative information with a geohistorical analysis of both neighborhoods' pre-existing socioeconomic dimensions and post-earthquake reports, the different pathways to recovery are more clearly elucidated. The results of this mixed-methods approach suggest that, although possibly expressing bias in media coverage of the Marina over SoMa, pre-earthquake socioeconomic conditions and building type were likely dominant factors in determining the patterns of rebuilding.

Materials and Methods

This research utilized a mixed-methods approach, combining quantitative and qualitative data to provide a more multifaceted perspective on recovery from the quake in these two neighborhoods. By triangulating the quantitative newspaper mentions with assessments of the neighborhoods both before and after the earthquake, a more nuanced scenario emerges (Salkind 2010).

First, newspaper mentions of Marina District damage and SoMa damage were tabulated for the three months following the 1989 Loma Prieta Earthquake. The *San Francisco Chronicle* and the *San Francisco Examiner* were the primary sources for newspaper media data, given that they were the primary morning and evening edition newspapers (Table 1). Sections included in this tabulation included news, business, community, and science sections, and I eliminated sports, entertainment, and editorials. Only full text articles were included with a title indicating subject matter related to the earthquake. The newspaper media data collected covered both residential and commercial recovery in both neighborhoods, so the interpretations made based on this data do not distinguish whether the article mentioned a residence or a commercial building. Because of the time and technology involved, television media was not used in this study.

Table 1: Number of mentions of SoMa and/or Marina neighborhoods during the three months after the Loma Prieta Earthquake in the *San Francisco Chronicle* and/or *San Francisco Examiner*, 10/18/89–1/18/90.

	Chronicle		***Examiner***	
	SoMa	**Marina**	**SoMa**	**Marina**
October	35	206	30	184
November	18	95	20	55
December	8	15	10	19
January	0	7	7	5
Total	61	323	67	263

The data from the first three months of coverage after the 1989 earthquake in the two primary San Francisco newspapers indicates that the Marina District was mentioned more frequently than SoMa. However, without socioeconomic data, the newspaper mentions provide an incomplete view of the event and its aftermath.

In addition to tabulating newspaper mentions, this analysis included a close reading of reports published in the quake's aftermath that described damage and recovery patterns in order to formulate a pre- and post-quake picture of the two neighborhoods. Reports to the government on the quake included analyses of pre-quake socioeconomic conditions in these two neighborhoods, and issues encountered in the post-quake environment. Incorporating these qualitative studies on post-earthquake recovery contexts and processes provided potential explanatory reasons for why the newspaper coverage was uneven. These data are described in the Discussion section below.

Discussion

While the Marina had three times as many damaged structures and a slightly higher cost of damage than SoMa (Harris and Egan 1992; Taylor et al. 1993), the Marina was mentioned more than four times more often in these newspapers. This indicates that media representation in the Marina was *not* directly proportional to that of its damage, and that it did receive disproportionately more coverage in these newspapers than SoMa.

That the Marina was mentioned more frequently than SoMa could have been related to damage differences and the spectacular visuals that accompanied it, but also socioeconomic differences. Because of distinct socioeconomic circumstances existing in each neighborhood *before* the quake, recovery may have occurred more rapidly in the Marina than in SoMa *regardless* of media coverage. The Marina was mostly residential with a high-end commercial district, while SoMa was mixed industrial and commercial with some small residential enclaves (Bauman 1997). This difference may have had an effect on the speed of recovery because commercial buildings have a different route to reconstruction than residences do, with wood-frame buildings tending to be repaired more quickly, and also are more likely to be residential (Al-Nammari and Lindell 2009). On average, repaired residential wood-frame multifamily buildings were occupied roughly two years after Loma Prieta (Comerio and Blecher 2010). Recovery in the Marina District also may have been facilitated by the fact that Marina residents fit the model of an anticipated disaster victim, that of a middle-class homeowner (Comerio, Landis, and Rofe 1994). The recovery processes in the Marina District

and SoMa likely differed in part because of their socioeconomic makeup, but also because of the type of buildings located in the two neighborhoods.

Importantly, SoMa had a higher percentage of renters rather than owner-occupiers compared to the Marina. In fact, almost seventy percent of San Francisco's low-income, single-room occupancy (SRO) hotel rooms in residential hotels were lost in SoMa alone during the quake (Bolin 1990). Many owners found it cost-prohibitive to replace their damaged hotel with a new hotel serving the same purpose and population (Comerio 1998). Low-income housing is the most difficult to replace, as agencies that work with low-income populations and build low-income residences were already working in a near-crisis mode during normal conditions (Greene 1991). Further, there was a requirement that those requesting housing assistance from FEMA have stable housing prior to the quake, leaving SRO residents unable to rely on this resource upon which regular homeowners and renters could rely (Comerio 1998). Not only were displaced SoMa residents, typically renters or shelter residents, unable to make rebuilding decisions on their own, they were often coming from a position of instability (Comerio 1998).

The differences between recovery patterns in these two neighborhoods falls in line with other studies that have found pre-disaster socioeconomic status an important factor in disaster recovery (Fothergill and Peek 2004; Masozera, Bailey, and Kerchner 2007). Grants, loans, and donations are used in emergency situations to bring one's situation back up to where it was prior to the emergency, not above and beyond. Although media coverage is associated with increased charitable giving, even if resources toward recovery were allotted based on newspaper media representation, it is nearly impossible to say whether these additional financial resources can offset pre-earthquake financial circumstances (Brown and Minty 2006).

Concluding Remarks

The purpose of this study was to identify the interplay of media coverage and socioeconomic status in recovery from the Loma Prieta Earthquake, as evidenced by building reconstruction. As the findings and discussion indicate, the media is just one cog in the larger socioeconomic machine; the complex interplay of competing and coexisting socioeconomic, environmental, and political factors that impacted disaster recovery in San Francisco may be fruitful for future research in this area, particularly in the field of environment justice. With increasing awareness of the interplay of socioeconomic and environmental vulnerability, perhaps there will be more recognition of the higher relative vulnerability of certain neighborhoods to disaster that will avail them to increased attention, newspaper media or otherwise, that may perhaps result in speedier and more efficient recovery.

Future research might incorporate television media coverage in addition to newspaper coverage. Details on the tax structure in San Francisco at the time of the 1989 earthquake might also shed further light on this subject in future research. In addition, a frame analysis of the textual and visual content of newspapers might provide more contextual evidence for how earthquake impacts were described, further detailing the media's impact on recovery.

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Determining Heat Island Response to Varying Land Cover Changes Between 2004 and 2017 Within the City of Reno, Nevada

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Abstract

The objective of this research was to investigate the role of land cover changes through time in influencing spatial variability of the surface urban heat island of the metropolitan area of Reno-Sparks, Nevada. Thermal imagery from Landsat 7 ETM+ sensor was gathered for a period between 2004 and 2017. Using parcel data, the time series of Landsat data was sampled for areas that had undergone development during that time. A set of generalized linear models was conducted to determine expected temperature change with land cover class. It was found that recently developed regions within Reno-Sparks are 0.6°C warmer on average than the undeveloped desert grasses and sage. When wetlands/irrigated greenery were converted, it resulted in an increase of over 2°C. This research has shown that the Reno-Sparks surface urban heat island has undergone local, but measurable, growth in the past fourteen years.

Introduction

The Urban Heat Island (UHI) phenomenon describes a situation in which urban cores and developed areas exhibit higher surface and air temperatures than surrounding non-developed regions. This gradient in temperatures is caused by several factors; first and foremost it is induced by the transition of latent heat flux into sensible heat via the transformation of vegetative and soil surfaces to the lower albedo materials that are commonly found amongst city centers (Imhoff et al. 2010). Secondly, human-made materials such as asphalt and concrete absorb high amounts of solar radiation and release a percentage of it later in the day as sensible heat (Bokaie et al. 2016). Finally, the introduction of high-rises and skyscrapers can inhibit prevailing wind patterns and prevent more even temperature gradients (Bokaie et al. 2016).

The intensity and impact of the UHI are of significant interest as the world's population is rapidly urbanizing, with as many as fifty-four percent of the global population residing in cities as of 2014, with estimates of around two-thirds of the world's population dwelling in cities by 2050 (United Nations 2014). An extensive proportion of the human population will be subjected to artificially increased temperatures that may be as high as or higher than 8°C above the surrounding regions (Imhoff et al. 2010). High spatial resolution data from the Airborne Thermal and Land Applications Sensor (ATLAS) shows surface temperature in microclimate extremes within a city to be as high as 60°C (Wang and Quattrochi 2007). The negative effects of such conditions include increased air pollution (Estoque et al. 2017), increased power consumption that may strain power grids (Azevedo et al. 2016), and increased severity of summertime heat waves, which claim thousands of lives in an average year (Mirzaei and Haghighat 2010). More rarely, prolonged or severe heat waves in populated regions can push death tolls into the tens of thousands (Robine et al. 2007). All of these consequences will be aggravated by larger-scale climate changes and continued migration into city centers (Jones et al. 2015).

Research shows the exact magnitude of UHI impacts to be more complex than a simple relationship to population growth as originally postulated by Oke (1973). While the general positive correlation of temperatures and population holds (Oke 1973), the temperature does not retain a set value above the surrounding areas. The temperature gradient is more pronounced depending on season and time of day (Wang and Quattrochi 2007). Atmospheric stability also plays a role in the day-to-day magnitude of the UHI phenomenon (Wang and Quattrochi 2007).

Space-borne remote-sensing systems are capable of analyzing UHI effects with a wide range of spatial and temporal scales when funding for a dedicated sensor and/or aerial missions is unavailable. These systems provide more complete coverage than station-based measurements. Data from many systems such as Landsat are free, and their thermal bands are proving to be of great use for studying UHI signals (Imhoff et al. 2010; Bokaie et al. 2016; Estoque et al. 2017). There are drawbacks, including but not limited to systematic errors in gain (Aniello et al. 1994) and distortions due to atmospheric conditions, both of which can be accounted for with pre-processing (Bokaie et al. 2016). Urban Heat Island and Surface Urban Heat Island signals may

be influenced by building height variability that exists within cities due to changes in shading throughout the day (Small and Zappa 2017). Deep street canyons show the same surface temperature as densely vegetated areas such as city parks during the afternoon hours (Small and Zappa 2017).

UHI research centered on larger cities (e.g., Phoenix and Las Vegas) utilized remote sensing techniques; lacking are similar studies on small to mid-sized cities. (Cayan and Douglas 1984; Xian and Crane 2006; Ramaurthy and Sangobanwo 2016). A case in point is the Reno-Sparks metropolitan area with its estimated population of more than 400,000 (Washoe County Consensus Forecast 2016). From the 1960s onward, a growing discrepancy exists between the minimum temperature records at the Reno/Tahoe International Airport and Tahoe, California (Ardnt and Redmond 2004). Comparisons with other rural stations show further contrast in temperatures and continuing UHI-driven warming in the intensely developed regions of Reno-Sparks (Hatchett et al. 2016).

Washoe County has undergone a large population expansion in the past several decades (Forstall 1996) that includes conversion of agricultural and wetlands in the south and east parts of the valley to developed lands. This may lead to an even hotter Reno-Sparks, as healthy vegetation plays an important role in mitigating the effects of the UHI (Akbari et al. 2001; Rahman et al. 2017). The Reno-Sparks area, the largest developed area within Washoe County, is categorized as mid-latitude steppe on the Köppen Climate Classification System, with a wide-swinging temperature range between seasons (Houghton et al. 1975). Precipitation is variable every year, as the Reno-Sparks Metropolitan area lies in the Sierra Nevadas' rain shadow. However, resting on the immediate leeward side of the rain shadow with an average elevation of 1,338 meters for the valley floor (U.S. Geological Survey 2006), the region still receives higher amounts of rainfall/snowfall than do lower basins to the east (Hatchett et al. 2016). Although the cities reside in a dry environment, the Truckee River flows through the area, creating an oasis for vegetation. Plants appropriate incoming shortwave solar insolation for food use and prevent the transformation into sensible heat (Rahman et al. 2017). Water uptake by vegetation also plays a role as a conduit for transpiration, which is a considerable heat sink (Gillner et al. 2015).

Current projections show the Reno-Sparks area gaining 100,000 additional inhabitants by the year 2036 (Washoe County Consensus Forecast 2016), and many Planned Unit Developments (PUDs) to house these individuals are slated for prime green space (Northern Nevada Regional Growth Study

2015); the summertime temperatures in the valley may start to negatively impact sensitive species in the urban environment (Mason et al. 2017).

This project analyzes alterations of land surface temperature in the urban environment of Reno-Sparks, using freely available imagery collected by the Landsat 7 Satellite's ETM+ (Enhanced Thematic Mapper Plus) sensor's thermal band. These data are the effective skin temperature or land surface temperature of all surfaces in the Landsat scene, which may be comprised of asphalt, vegetation, or building roof. This study did not make use of atmospheric corrections, as only relative temperature differences are being compared; absolute surface temperature was not required (Small and Zappa 2017).

In particular, this research addresses whether or not recent development of the region's desert landscape has made any quantifiable impact on the local surface urban heat island. Secondarily, the effect that irrigated and natural green space has, and how it acts, upon the local UHI signal is examined. Being able to detect fine-scale nuances in UHI impacts using freely available data should also allow a wider variety of growing urban areas to do simple assessments and create zoning plans for better future outcomes where artificial microclimate alterations are minimized.

Methods

The area of interest (Figure 1), is approximately 68,500 acres, filling the majority of the Truckee Meadows Valley and including the urban centers of both Reno and Sparks as well as the bulk of their developed townships. It also contains important features such as the Reno-Tahoe International Airport, as well as multiple large sections of crop land and natural wetlands.

Landsat 7's thermal band (Band 6) covers the window from 10.4 to 12.5 micrometers and has a native spatial resolution of sixty meters (U.S. Geological Survey -A 2018). The U.S. Geological Survey, however, resamples this band to thirty meters within its standard level-1 product to match the spatial resolution of the other sensors' bands using the Landsat Product Generation System (U.S. Geological Survey - B 2018). With this spatial resolution, distinct city morphologies can easily be detected and major landmarks such as dense city cores and airport runways are apparent (Figure 2). An issue with resolving individual buildings is that there are some examples of structures appearing to read between 10°C and -35°C within the city boundaries. This variation is most likely due to the emissivity of the building's metal roofs (Morton 2018). Some metals, especially highly reflective ones, have low emissivity

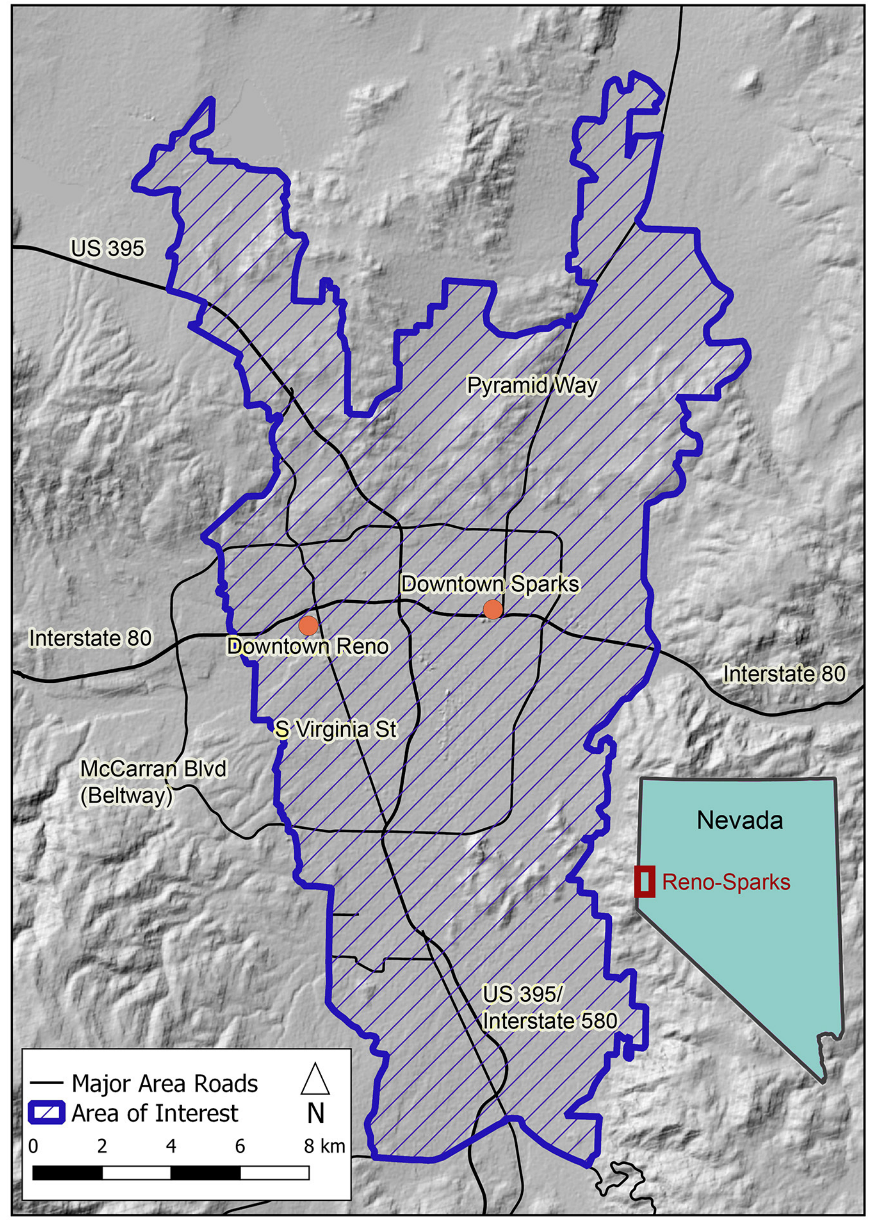

Figure 1.—Map of Reno-Sparks Urban AOI.

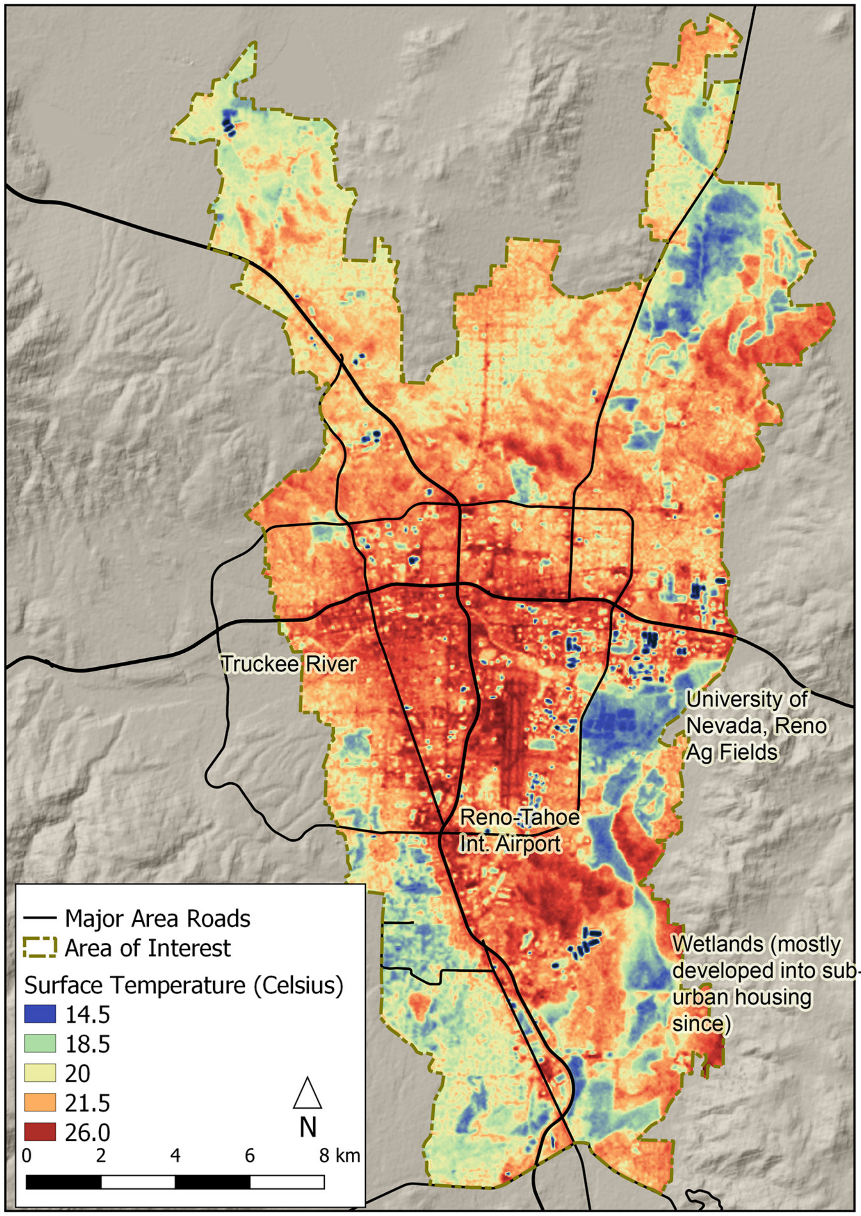

Figure 2.—Example of at-satellite surface temperature map: July 17, 2005). A direct comparison between an automated surface observing station located at Reno-Tahoe International Airport (toward the center of the area of interest polygon) and the underlying pixel show approximate temperatures of 27.8°C (air temperature for closest measurement to Landsat 7 flyover) and 24.0°C, respectively.

coefficients at temperatures below 100°C (Smithells 1976). Landsat's sensor, with its limited thermal window, simply reads this as being cold without the input of additional information.

Nighttime images are sometimes used in studies, as the heat island's signal shows the sharpest contrast after the peak heating of the day as human-made materials continue to release sensible heat, whereas the surrounding desert environment has cooled (Xian and Crane 2006). Hatchett et al. (2016) further enforces this for the Reno-Sparks high-desert environment, as the stronger growth trend in the UHI signal is seen historically in the minimum temperatures during the summer months.

Imagery used in the study spanned a duration of fourteen years (between 2004 and 2017) of Landsat 7 thermal images. The scene (Row: 211/Path 139) has the Reno-Sparks Metropolitan area in the northern center of the image. As heat island behavior shows the strongest signal in June, July, and August for the Reno-Sparks region (Hatchett et al. 2016), only nocturnal images in, and immediately around, meteorological summertime (the hottest months in the annual temperature cycle in the Northern Hemisphere) were chosen. This set of images was then visually filtered for clouds, with any that contained clouds above the area of interest being rejected, leaving a total of sixty usable images.

All images were georeferenced using major road intersections and prominent building edges as controls (Yuan and Bauer 2007). The raster data were then projected to Universal Transverse Mercator Coordinate system, Zone 11 North, Datum of World Geodetic System of 1984, and then clipped to a smaller spatial area for statistical analysis using the bilinear interpolation approximation method. As the mountains around the valley were not of interest, the clipping footprint was the main body U.S. Census Bureau's 2016 urban boundary that lay within the valley (U. S. Census Bureau 2017). This polygon was additionally convenient, as the majority of it fell within the small band in the center of the scenes that was not impacted by the scan line corrector fault present on Landsat 7 since 2003.

Land surface temperatures were calculated by following the procedure in the Landsat 7 Science Data Users Handbook (Goddard Space Flight Center 2018). The first step was converting the digital number product directly downloaded from Earth Explorer (U. S. Geological Survey-C 2018) to Spectral Radiance, done via Equation 1.

Equation 1: Digital Numbers to Spectral Radiance

$$\frac{(Lmax_{\lambda} - Lmin_{\lambda})}{(QCALmax - QCALmin)} * (QCAL - QCALmin) + Lmin_{\lambda}$$

Where:

- Lλ = Spectral Radiance at the sensor's aperture (watts/m2*ster*μm)
- QCAL = The quantized calibrated pixel value in DN
- QCALmin = The minimum quantized calibrated pixel value (corresponding to Lminλ) in DN
- QCALmax = The maximum quantized calibrated pixel value (corresponding to Lmaxλ) in DN
- Lminλ = The spectral radiance that is scaled to QCALmin (watts/m2*ster*μm)
- Lmaxλ = The spectral radiance that is scaled to QCALmax (watts/m2*ster*μm)

The second step was to convert spectral radiance to at-satellite surface temperature in Kelvin using an estimation of Planck's Law of electromagnetic radiation emission via Equation 2 (Yuan and Bauer 2007; Chander and Markham 2003; Goddard Space Flight Center 2018).

Equation 2: Spectral Radiance to at-satellite Temperature

$$T = \frac{K2}{ln\left(\frac{K1}{L_{\lambda}} + 1\right)}$$

Where:

- T = Surface Temperature in Kelvin
- K1 = Calibration Constant 1 (From scenes' MTL document)
- K2 = Calibration Constant 2 (From scenes' MTL document)
- Lλ = Spectral Radiance at the sensor's aperture (watts/m2*ster*μm)

To negate the potential of sampling a falsely cold value due to emittance metal roofs, histograms were calculated for all scenes, and values beyond four standard deviations were removed. This value removed the unrealistically cold pixels around the buildings in question, but did not eliminate the lower values seen along waterways or in low-lying fields.

Land cover classifications for this study are defined by the 2001 National Land Cover Database (2001 NLCD) (Homer et al. 2007). Once projected to the same coordinate system as all Landsat images and clipped to the area of interest, they were reclassified into two categories: dry and green (Figure 3). Dry consisted of classes 31 (barren land), 52 (shrub/scrub), and 71 (grassland/herbaceous), with scrublands comprising 72.9% of the undeveloped environment. These three classes represent the standard high-desert environment in which the Reno and Sparks urban cores have grown. Green was a conglomeration of classes 21 (developed open space), 81 (pasture/hay), 82 (cultivated crops), and 95 (emergent herbaceous wetlands). These four classes represent large grass areas around public facilities, city parks, and human-irrigated fields in the region.

The land use dataset covering the entire study area included individual parcels with year built/modified, developed by the Truckee Meadow Regional Planning Agency (Truckee Meadows Regional Planning Agency 2017) and was used to determine areas that had been developed during the study period (Figure 4). This map shows properties that were constructed between 2004 and 2017 and used to determine green built and dry built. The area developed totaled approximately 23.2 km^2 or 5,733 acres (Figure 5). Parcels that had been built in 2001 through 2004 were masked out of the 2001 NLCD, as Landsat has few nighttime flyovers of the Reno-Sparks region during that time frame. Changes in land cover class between 2001 and 2004 were accounted for by referencing this dataset.

The processed Landsat images were grouped by year, and at-satellite temperature was averaged on a pixel-by-pixel basis, as the parcel data was only described to the year level. This also helped to account for meteorological variations for each year. This yearly average temperature value was converted into a spatial data table with columns of whether the pixel was developed or unaltered and whether it was originally dry land cover or green. This created four classes with associated temperatures: dry built, green built, dry unbuilt, and green unbuilt for each year.

All years were combined into a single spatial data table (Figure 6), and then a stratified random sample with a size of 300 per class, per year, was conducted on the records in this dataset (Figure 7). This resulted in a total of 1,200 per year and a grand total of 15,600. As hundreds of thousands of records existed within the main spatial data table, it was deemed that 300 should be able to capture the variation of each of the four classes at a high confidence level without increasing the chance of a convergence of proba-

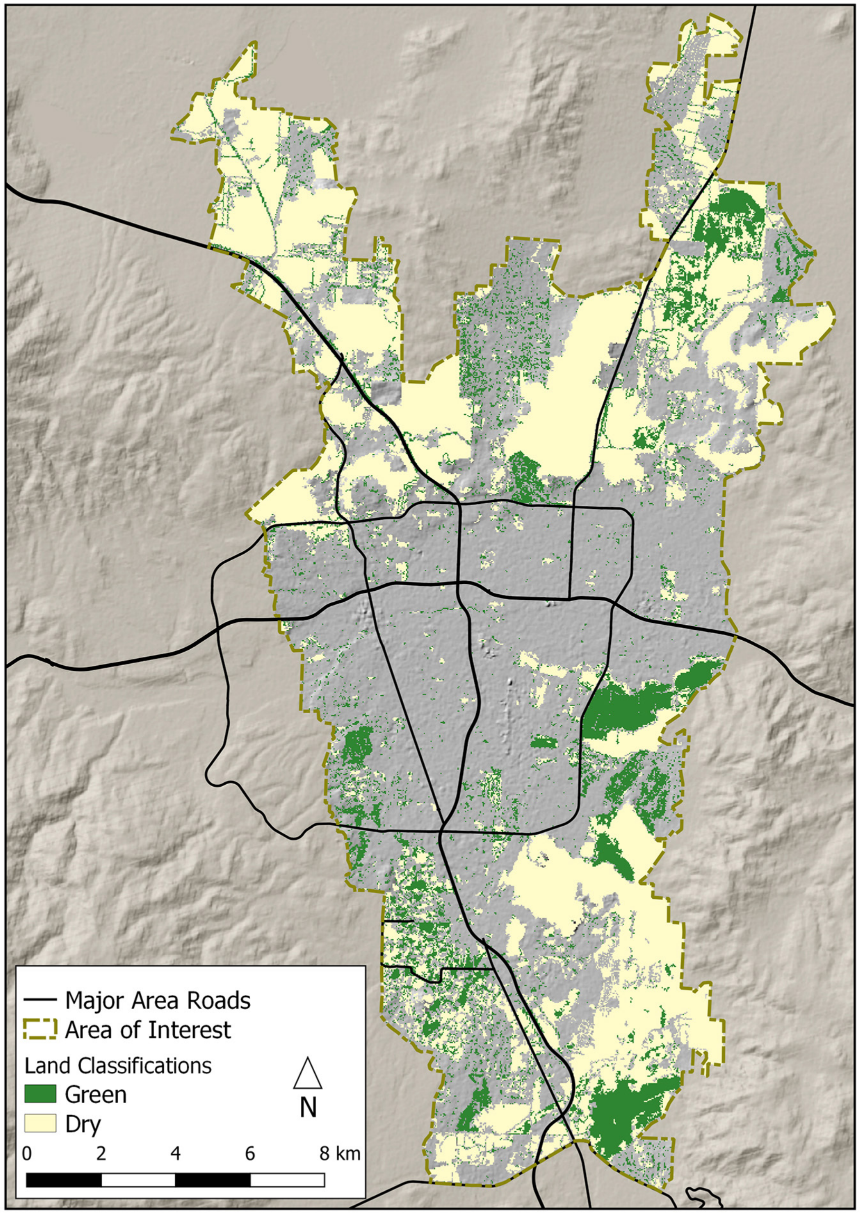

Figure 3.—Dry and Green Classified regions in the study area AOI.

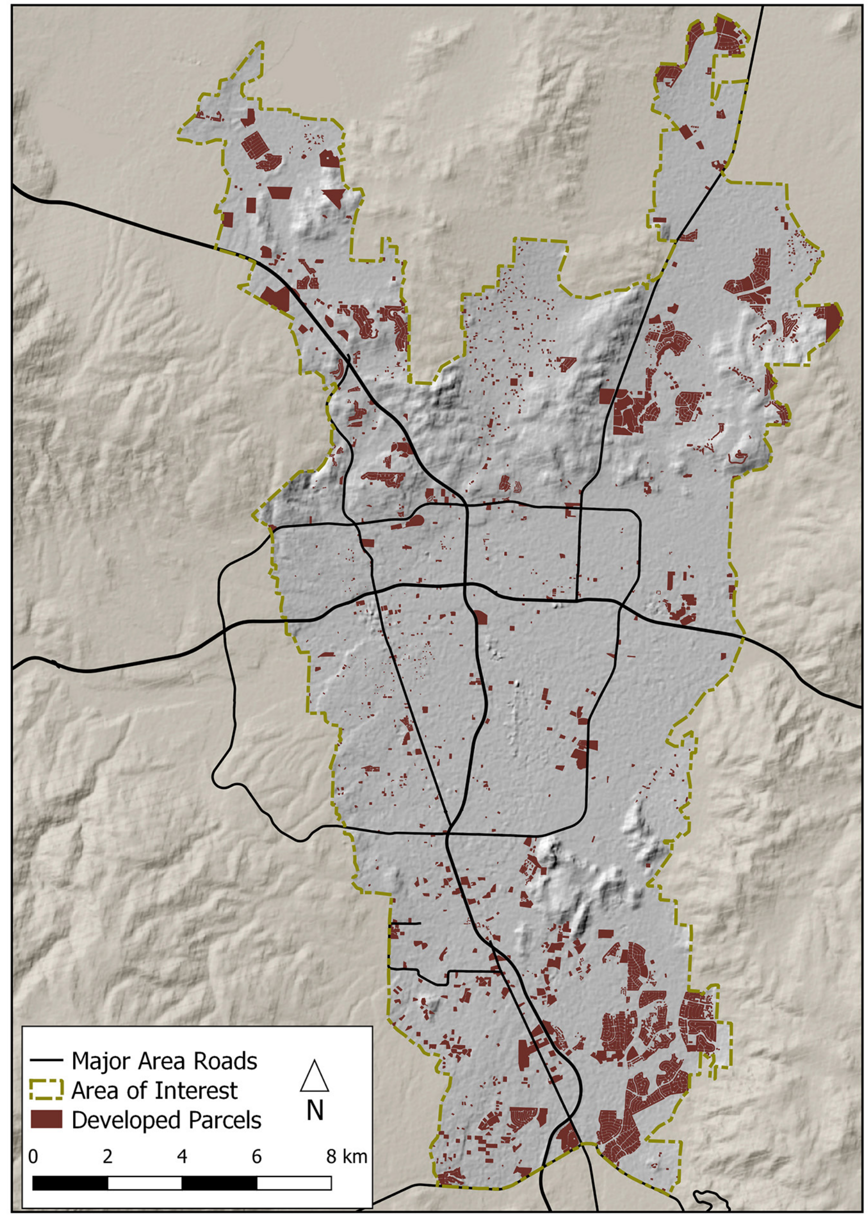

Figure 4.—Parcels that had undergone development between the years of 2004 and 2017 in the AOI.

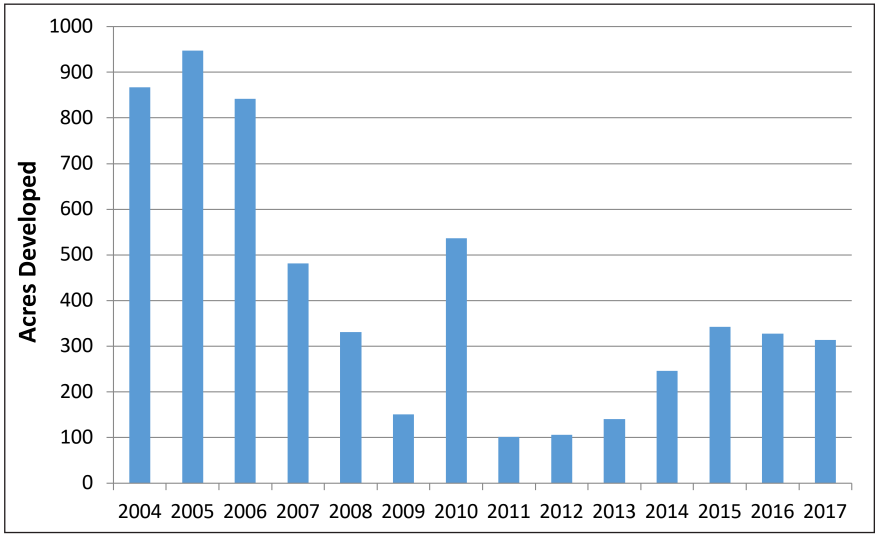

Figure 5.—Bar chart of approximate acreage built per year.

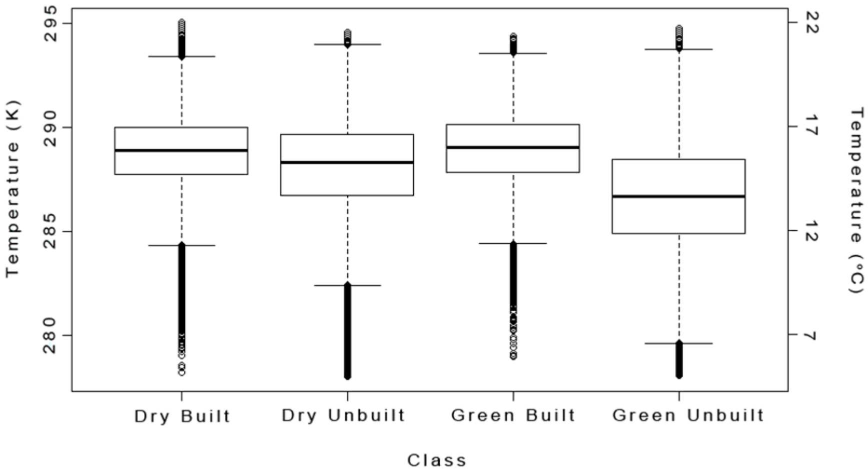

Figure 6.—Boxplot of all data for all years, categorized by Land Cover Class.

bilities (Cochran 1977; Israel 1992; Fischer 2010). A Cross-Validation was completed to assess the effectiveness of the model. A total of ten random iterations were completed with the same sample parameters on the population of the spatial points data frame.

A set of general linear models were fit to the sampled data. Models included a null model with "Temperature only," another with the predictor variable of "Land Cover Class," a third with the temporal changes between each

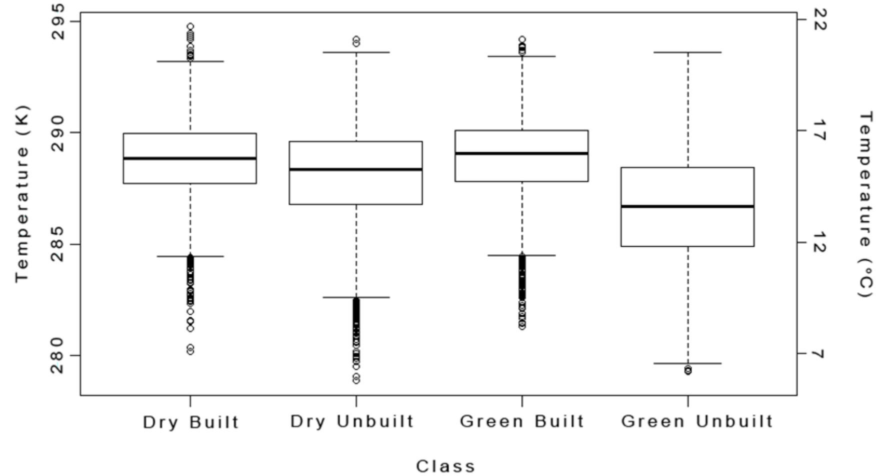

Figure 7.—Boxplot of all samples for all years, categorized by Land Cover Class.

"Year," and fourth and finally a model with an interaction between the terms "Land Cover Class" and "Year." Akaike's Information Criterion (AIC) was chosen as the determinant of the relatively best fit model (Akaike 1974). A pair-wise comparison was completed to evaluate results of the Generalized Linear Model. This contrast test is known as Tukey's Honestly Significant Difference Test, and summarizes statistical relationships (Tukey 1949). An analysis of variance F-Test that was also conducted on the main effects showed significant differences between the land cover classes (F-Statistic of 1,390.8) ($P < 0.001$).

Results

The model with "Year" interaction with "Land Cover Class" had the lowest AIC estimate (Table 1). This proves "Land Cover Class" explains most of the temperature variance, but the model can be reasonably improved upon by adding the year to year variability in temperature. The generalized linear model showed a surface temperature for the area of interest of 288.68 K or 15.53°C (Table 2) with an R-squared of 0.40. Cross-validation had a mean correlation coefficient of 0.623 (standard deviation of 0.008) compared to the model's 0.624.

Table 1. AIC Table

	Intercept	degrees freedom	AIC	delta	weight
Land Cover Class * Year	288.7	53	62,437.0	0.0	1
Year	288	14	65,610.6	3,173.6	0
Land Cover Class	288.8	5	66,682.1	4,375.1	0
Null (Temperature)	288.1	2	69,392.4	6,955.4	0

Table 2. Generalized Linear Model output

*Note: Estimate is in Kelvin. Signif Codes are as follows: 0 ‘***’ , 0.001 ‘**’, 0.5 ‘*’, 0.1 ‘.’

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)	signif. code
Intercept	288.675	0.102	2834.658	< 2e -16	***
Dry Unbuilt	-0.635	0.144	-4.412	1.03e - 05	***
Green Built	0.087	0.144	0.604	0.5458	
Green Unbuilt	-2.237	0.144	-15.53	< 2e -16	***
year 2005	0.262	0.144	1.816	0.0694	.
year 2006	1.722	0.144	11.956	< 2e -16	***
year 2007	-0.379	0.144	-2.632	0.0085	**
year 2008	-0.670	0.144	-4.832	1.37e - 06	***
year 2009	0.893	0.144	6.201	5.77e -10	***
year 2010	-2.037	0.144	-14.146	< 2e -16	***
year 2011	0.060	0.144	0.419	0.6751	
year 2012	1.190	0.144	8.263	< 2e -16	***
year 2013	-0.902	0.144	-6.263	3.88e -10	***
year 2014	-0.564	0.144	-3.918	8.98e - 05	***
year 2016	0.200	0.144	1.390	0.1645	
year 2017	1.612	0.144	11.192	< 2e -16	***
Dry Unbuilt : Year 2005	-0.326	0.204	-1.602	0.1092	
Green Built : Year 2005	0.060	0.204	0.296	0.7675	
Green Unbuilt : Year 2005	-0.105	0.204	-0.516	0.6062	
Dry Unbuilt : Year 2006	0.107	0.204	0.525	0.5997	
Green Built : Year 2006	-0.295	0.204	-1.449	0.1474	
Green Unbuilt : Year 2006	-0.051	0.204	-0.253	0.8002	
Dry Unbuilt : Year 2007	-0.086	0.204	-0.420	0.6746	
Green Built : Year 2007	-0.076	0.204	-0.374	0.7085	
Green Unbuilt : Year 2007	0.081	0.204	0.399	0.6902	
Dry Unbuilt : Year 2008	-0.198	0.204	-0.974	0.3300	
Green Built : Year 2008	-0.460	0.204	-2.260	0.0238	*
Green Unbuilt : Year 2008	-0.029	0.204	-0.142	0.8870	
Dry Unbuilt : Year 2009	-0.235	0.204	-1.152	0.2492	
Green Built : Year 2009	-0.105	0.204	-0.517	0.6050	
Green Unbuilt : Year 2009	0.301	0.204	1.475	0.1401	
Dry Unbuilt : Year 2010	-0.225	0.204	-1.104	0.2695	
Green Built : Year 2010	-0.021	0.204	-0.101	0.9198	
Green Unbuilt : Year 2010	0.195	0.204	0.960	0.3372	
Dry Unbuilt : Year 2011	0.398	0.204	1.953	0.0509	.
Green Built : Year 2011	0.065	0.204	0.321	0.7483	
Green Unbuilt : Year 2011	-0.102	0.204	-0.505	0.6132	
Dry Unbuilt : Year 2012	-0.110	0.204	-0.539	0.5898	
Green Built : Year 2012	0.242	0.204	1.193	0.2329	
Green Unbuilt : Year 2012	0.226	0.204	1.109	0.2673	
Dry Unbuilt : Year 2013	-0.171	0.204	-0.842	0.3998	
Green Built : Year 2013	0.144	0.204	0.710	0.4778	
Green Unbuilt : Year 2013	0.380	0.204	1.868	0.0617	.
Dry Unbuilt : Year 2014	-0.451	0.204	-2.218	0.0265	*
Green Built : Year 2014	0.130	0.204	0.642	0.5209	
Green Unbuilt : Year 2014	0.281	0.204	1.381	0.1674	
Dry Unbuilt : Year 2016	0.381	0.204	1.869	0.0616	.
Green Built : Year 2016	0.156	0.204	0.768	0.4426	
Green Unbuilt : Year 2016	0.155	0.204	0.761	0.4467	
Dry Unbuilt : Year 2017	0.220	0.204	1.081	0.2799	
Green Built : Year 2017	0.031	0.204	0.149	0.8814	
Green Unbuilt : Year 2017	0.321	0.204	1.576	0.1150	

Areas that originated as the green unbuilt class constructed during the study period showed no significant change between the expected pre-developed temperature (a difference of 0.087°C). The surrounding dry unbuilt class within the area of interest had a cooler temperature than the model's expected value, with a change of -0.64°C ($P < 0.001$). The green built landscape was approximately 2.24°C cooler than the intercept of the null model ($P < 0.001$). The GLM output shows a significant difference between many of the years, further compounding that one or two years of temperature data may not fully describe an area's, region's, or city's thermal regimes. Tukey's Test also identified a significant difference between all land cover classes except for green built versus dry built (Table 3).

Table 3. Tukey's Honest Significant Difference
Note: Estimate is in Kelvin/degrees Celsius. Signif Codes are as follows: 0 '*' , 0.001 '**', 0.5 '*', 0.1 '.'*

Class Contrast	Estimate	Std. Error	z value	Pr (>|z|)	Signif. code
Dry Unbuilt - Dry Built	-0.635	0.14402	-4.412	< 1e - 04	***
Green Built - Dry Built	0.087	0.14402	0.604	0.931	
Green Unbuilt - Dry Built	-2.237	0.14402	-15.530	< 1e - 04	***
Green Built - Dry UnBuilt	0.722	0.14402	5.016	< 1e - 04	***
Green Unbuilt - Dry UnBuilt	-1.601	0.14402	-11.118	< 1e - 04	***
Green Unbuilt - Green Built	-2.324	0.14402	-16.134	< 1e - 04	***

Discussion

The nighttime surface thermal environment is altered by development, and to a much greater degree if the land developed was originally green built. Of an original 91.0 km^2 of dry unbuilt within the area of interest, a total of approximately 18.2 km^2 was developed between 2004 and 2017. Of an original 29.5 km^2 of green unbuilt within the study zone, approximately 4.6 km^2 was developed. I use approximate numbers because a parcel may have been carved out of a larger section and declared by the county as developed in a certain year, but the construction of the entire footprint of a parcel may not have occurred within that exact year. Some parcels were also slated for development as lower-density suburban housing. Areas featuring mixed pixels as yards and other personal greenspace have an increasing trend in the American West (Yabiku et al. 2008). Many parcels did not undergo a 100 percent change from one landcover class to a new one. Most suburban homes, for example, are designed with a front and/or back yard, and thus are not a true 100 percent change of class from green unbuilt or dry unbuilt. As a result, a broad area's true temperature change is not the same as would be seen with a much smaller, more homogeneous cover. However, value changes of one and two degrees Celsius when developed are not unexpected for the Southwestern United States (Cayan and Douglas 1984).

While the National Land Cover Database is freely available and a versatile product, it does have some inaccuracies, as can be expected with any remotely sensed product (Wickham et al. 2010). Additional inaccuracy also may have been introduced by the area's wetlands' water content changing over time (Pavri and Aber 2004). Both of these previous factors would have impacted how well the original NLCD classes matched what was truly in the valley, and therefore how well this research's four classes (dry unbuilt, dry built, green unbuilt, green built) would have performed in representing the actual land cover.

Development during the study period does not seem to override the influences of the local climate or topography to any observable degree, as direct comparisons of the total area of interest's surface thermal signal over the study period did not return any significant trends. This means that while undeveloped regions in the area of interest showed a significant increase in surface temperature after being developed, the climatology for Reno-Sparks as a whole does not seem to have been impacted for the duration of 2004 through 2017.

Some years were warmer or colder/wetter or drier than others. Landsat passes over only once every sixteen days, severely limiting the sample size of each year and the ability to correct for abnormal years and conditions. This is especially important in a steppe environment, where small differences in available moisture can be a large driver of vegetative health and density (Moore et al. 2015). The yearly variations in temperature and precipitation trends made a quantifiable, citywide change in the surface urban heat island's signal difficult to detect, due to the city's relatively small size and location nestled between multiple mountain ranges.

A positive shift in temperature of 0.6°C to the native landscape steppe cover, 8.2 percent of the entire area of interest's footprint, was clearly seen. The paving over of green space was the more noteworthy driver of change, with a 2.2°C temperature increase. However, only 4.6 km^2 of green space was built during the past fourteen years. This is less than 1.7 percent of the total area of interest, or a total of 15.6 percent of green space present in the area of interest. Reno-Sparks' growth was encumbered during multiple years of the research's imagery period, due to the National Recession in 2008 (Truckee Meadows Regional Planning Agency 2017). There was no significant difference between developed land originating as either green unbuilt or dry unbuilt.

While expansion into green space in Reno-Sparks was negligible for the years between 2004 and 2017, subdivisions are currently being constructed into the area's wetlands. Current plans also show numerous additional units slated for the next few years expanding into the valley's southeast wetlands and agricultural lands, as well as into alluvial catch basins along the mountain fronts (Truckee Meadows Regional Planning Agency 2017). If development follows current plans, it can be expected that the Reno-Sparks UHI will continue to expand and possibly show even stronger signals through the next decades, as development covers a higher fraction of greenspace than it did since 2004.

Conclusions

In this research, a series of sixty Landsat 7 thermal images covering fourteen years of development in the Reno-Sparks metropolitan area were analyzed. Spaces that had been developed from natural desert grasses and sage (dry unbuilt) showed a surface temperature increase of 0.6°C. Portions that had been developed from green unbuilt, be it natural or human-made green space, showed a 2.2°C increase in surface temperature. Since these areas of change account for 18.2 and 4.6 km^2 respectively, Reno-Sparks' UHI signal has measurably increased since the turn of the millennium.

Not all development is equal, and future work could be done to account for varying degrees of impervious surfaces throughout Reno-Sparks. Suburban versus more intensely developed areas such as industrial or highly urbanized zones could be individually categorized, and planners/policy makers will be able to better allot for the potential change in surface heat retention to result in less contribution to the UHI.

Due to income disparities, the development of green spaces in urban landscapes is inequitable. This disproportion is seen in the percentage of green space within a given neighborhood, with a significant positive gradient in green space following economic classes in southwestern U.S. metropolitan areas (Jenerette et al. 2013). This owes to the wealthier classes generally living in lower density areas, thus dwelling upon larger lots and being more likely to have access to the resources to landscape/manage them as well (Clarke et al. 2013). Socioeconomic data for Reno-Sparks could determine to what extent income divergence exposes its citizens to UHI impacts, and whether or not future planned regions of the valley perpetuate this.

The UHI phenomena will continue to be a feature of the global landscape, exacerbated by the world's growing population, by the trend of urbanization of this population, and by meteorological extremes/climate change (IPCC 2014).In order to mitigate this human-created issue, we must first understand it and its unique fingerprint within every city. This type of data was a premium before the 1970s and therefore was unavailable to many. With the advancements of remote sensing, it is now available at no cost. Landsat thermal data is available for the majority of the Earth's surface, and looks to be so in the future with the recent Landsat 8 and upcoming Landsat 9 (to be launched in the end of 2020); it is hoped that this research can provide a template for future studies. With remote sensing and ever-advancing technologies, UHIs can be studied in a greater temporal and spatial resolution in many small and growing cities throughout the world.

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Voices of Cully: Experiencing the Home amid Gentrification

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Abstract

The Cully neighborhood is situated in the northeast quadrant of Portland, Oregon. It is a 2.75-square-mile plot of land and home to roughly 13,000 people. In addition to being one of the most diverse neighborhoods in Portland, it is the most densely populated, with the smallest amount of parkland per capita. Over the past two decades, home value has increased 203 percent in Cully, compared to a 90 percent citywide increase. We interviewed residents of the Cully neighborhood to explore their relationship to home amidst conditions of gentrification. Gentrification literature and mainstream media coverage most often focus on neighborhood-scale socioeconomic processes of gentrification, ignoring the home as the space where gentrification is experienced first and most intimately. This article takes steps toward analyzing the scalar impacts of gentrification, moving beyond and below a neighborhood-scale analysis to consider the ways in which gentrification impacts residents inside their homes—homes which, we argue, can take on both sanctuary and imprisoning qualities. Just as gentrification will look different depending on researchers' and/or policymakers' conceptualizations, so too will anti-gentrification interventions. Developing place-specific anti-gentrification solutions entails listening to the voices of experience, the voices of residents.

Gentrification Beyond the Neighborhood, Within the Home

In Brooklyn, New York, and in other well-known gentrifying neighborhoods in the United States, reports of rising rents and forced evictions, the influx of hipsters and bike lanes, and the replacement of locally owned corner stores with microbreweries and coffee shops dominate gentrification-related media coverage (Bodenner 2015, 2016; Kaysen 2016; Semeuls 2016; Wainwright 2016; Jennings 2019; King 2020). In 2016, *The New York Times* published interviews with a dozen young native New Yorkers, revealing that while some welcomed the new amenities accompanying the gentrifying class and others lamented a perceived loss of community, not one was able to afford an apartment in his or her childhood neighborhood (Kaysen 2016). *The Atlantic* similarly reported that in the Ballard neighborhood of Seattle, Washington, old-growth-fir houses were being torn down and replaced by "slap-dash concrete, high-capacity condo/retail complexes" (Bodenner 2015). This was done as a part of the city council's attempt to develop urban villages as a means of preventing sprawl.

Such stories of gentrification are not limited to the United States. Media coverage of the phenomenon is echoed in European countries as well. For example, *The New York Times* reported in 2017 that the arrival of 60,000 people over the previous year in Berlin had resulted in overcrowding, competition over housing, and an increase in "leases canceled for the slightest triviality" (Wilder 2017). In response, local grassroots coalitions had taken to the streets in protest, carrying signs proclaiming "We're all staying" and "Say no to crowding." City authorities responded by introducing rent caps, a partial ban on vacation rentals, development-free zones, and increased social housing subsidies. Such interventions attempting to preserve the livability of a neighborhood are commonly enacted to mitigate the negative impacts of gentrification.

In Portland, Oregon, as reported in *The Atlantic*, "African Americans who were once a majority in Northeast neighborhoods have been displaced to 'the numbers,' which is what Portlanders call the low-income-far-off neighborhoods" (Semuels 2016). Portland is just one city that has recently been put on the map for its increasing youth culture and associated amenities (Fowler & Derrick 2018). The cases of Brooklyn, Seattle, Berlin, and Portland exemplify both the conventional understanding of gentrification as well as a fulsome discourse of those reporting the phenomenon. According to the dominant narrative, a neighborhood undergoes rapid transformation, pointedly serving a young, upper-income, creative class, and displaces long-term residents as well as the long-standing cultural fabric of the neighborhood. Although the print media consistently allude to housing, by highlighting the displacement of residents and the demolition of old homes for the construction of newer and shinier units, the ways in which residents experience gentrification *inside* their homes have been ignored.

Examination that ignores the home is not limited to the print media. Academic scholarship follows a similar tendency toward conceptualizing gentrification with an exclusive spatial framing of the neighborhood. Academic literature may offer a more nuanced and place-specific examination of gentrification, but it nonetheless excludes the home. A prime example is provided in geographer Loretta Lees' (2000) review article. Lees urges the attention to varying geographies of gentrification by introducing two contradictory experiences of the phenomenon. The *emancipatory city* thesis demonstrates that, for some who would be considered gentrifiers, the city is experienced as a liberating space. For example, according to Forest (1995), the gay community in Los Angeles was able to explore and affirm its identity through the gentrification of West Hollywood. This thesis is implicit in literature focusing on the gentrifiers themselves and their forms of agency. The *revanchist city* thesis, however, considers "the privileging of middle class desires and the effects of the advancing gentrification 'frontier' on other class fractions" (Lees 2000, 399). The *revanchist* thesis is well represented in the aforementioned reports by *The New York Times* and *The Atlantic*.

According to Lees (2000), there is not *a* gentrification, but *multiple* gentrifications (see also Lees et al. 2008). Although these theses implore greater place specificity in gentrification debates and attention to how places are constructed, the spatial scale of analysis is, again, too often limited to the neighborhood. Gentrification is differentiated from case to case, but analysis among the cases remains at the neighborhood scale. The home remains overlooked as the space where gentrification is experienced most intimately.

Excluding an examination of how gentrification is experienced within the home contributes to universalizing the concept of gentrification as a single neighborhood-scale process. This universalizing tendency relates in no small part to the economistic thinking in gentrification studies. Scholars have thus far been interested in identifying the forces that propel rapid and class-targeted development (Glass 1964; Smith 1996; Smith 1982; Redfern 2003; Kennedy & Leonard 2001; Lees et al. 2008). As a result, gentrification continues to be conceptualized as a neighborhood-scale economic transformation, as it first was by Ruth Glass in 1964. As she observed in inner London, "One by one, many of the working class quarters have been invaded by the middle class…once this process of 'gentrification' starts in a district it goes on rapidly until all or most of the working class occupiers are displaced and the whole social character of the district is changed" (Glass 1964, xvii). To be sure, gentrification comprises neighborhood-level economic restructurings worth examining. However, a "district" or a neighborhood is comprised of individual *homes*. And *homes* are where the lives of the urban poor and working class take place.

In the rare case the home is brought into the interrogations of gentrification, it is cast as either a place where people live happily or a space from which people are displaced, a Manichean-like practice of representation that flattens actual lived experience. Yet the home is experienced as a complex space, one that interacts and changes in concert with a multiplicity of external processes. Dominant gentrification discourses, however, fall short in imagining the home as a space that is subject to change. Rather, the home is most generally implicated as a passive piece in a larger, neighborhood-wide process.

The purpose of this article is to contribute to gentrification scholarship by examining how people experience the home as a result of gentrification. We do this by conducting in-depth, semi-structured interviews with long-term residents inside their homes, located within the rapidly gentrifying neighborhood of Cully, in northeast Portland. By analyzing their perceptions and feelings of their homes amid gentrification, we show how experiences inside the home reflect broader political-economic processes and social restructurings; notions of the home as impervious to external forces do not stand. Conceptualizing the home as both *emancipatory* and as *confining*, we illustrate the ways in which the home is a mediated space, rather than a static one. Forces outside the home shape experiences inside the home, creating a space that acts as both a sanctuary and a prison.

Background, Methodological Pivoting

The Cully neighborhood is situated in the northeast quadrant of Portland, Oregon. It is a 2.75-square-mile plot of land and home to roughly 13,000 people (see Figure 1). It is the most densely populated neighborhood in Portland and has the smallest amount of parkland per capita. Families with children occupy 32.6 percent of households, compared to 26.4 percent citywide (City of Portland Bureau of Planning 2008, 7–8). Cully is also more ethnically and racially diverse than the city as a whole (see Figure 2). The Cully neighborhood in particular is home to a large number of aging and elderly, with residents aged 55–59 and 60–64 increasing 52.6 percent and 57 percent, respectively, between the years of 2000 and 2010 (US Census 2010). Over the past two decades, home value has increased 203 percent in Cully, compared to a 90 percent citywide increase. These conditions make Cully ripe for rapid population change, following a well-known pattern witnessed in the adjacent Alberta and Mississippi neighborhoods, which are notorious frontiers of gentrification Portland.

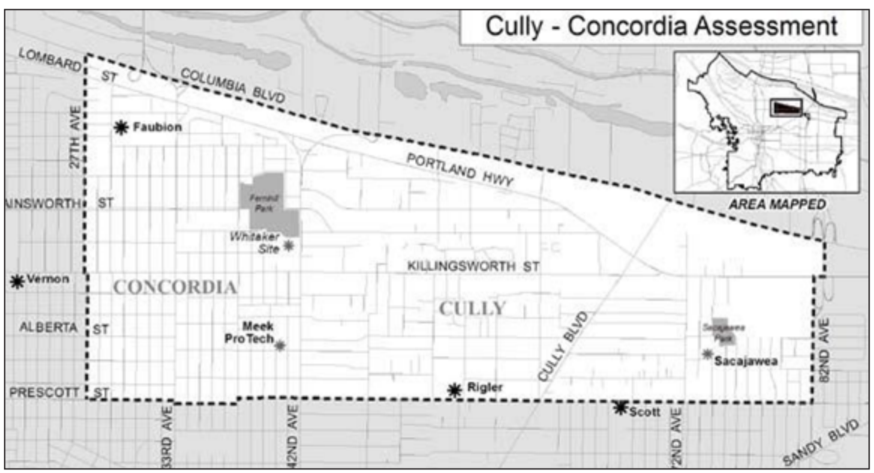

Figure 1.—Map of Cully study area (City of Portland Bureau of Planning 2008).

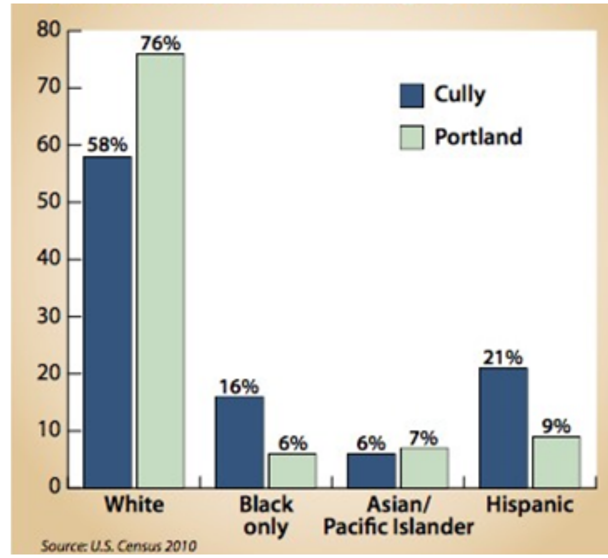

Figure 2.—Cully Racial Demographic (US Census 2010).

With the original goal of gathering narrative data about homeowners' experiences living in Cully, we conducted semi-structured interviews with nine long-term residents. Race, age, and family and home sizes varied among the participants, but all shared the economic distinction of being low income (see Table 1). The interview schedule opened with questions about the individuals' family, including questions such as "Where are you from? Where are your parents from?" and then turned toward questions about the individuals' experience living in Cully, including "How long have you lived in the neighborhood? Have you seen Cully change since moving here? Do you feel as though you can get what you need from the businesses in Cully without leaving the neighborhood?" Final questions prompted the individual to comment on the spatiality of his or her social networks, including questions such as "Do you feel connected to your neighbors? Do you participate in community organizations in/outside of Cully?" Interviews lasted between half an hour and two hours and were conducted in the residents' homes. All interviews concluded with an open summon for stories about living in Portland and/or the Cully neighborhood and thoughts on the interview that had just transpired.

Table 1. Demographics of Participating Homeowners

Participant Demographics	
Percentage of Minority Participants (African American or American Indian)	44%
Percentage of Participants Age 55+	78%
Percentage of Disabled Participants	56%
Average Years in Cully	10+
Average Household Size	3
Average Household Income	$23,337

In the course of conducting interviews, we noticed a certain phenomenon: While our questioning was designed to elicit commentary on changes within the Cully neighborhood, thereby replicating the default analytical scale identified in the opening of this article, respondents, when given the opportunity to explore more emotive concerns, preferred to talk about their homes. While most were aware of the changes occurring in their neighborhood, we found that participants redirected conversation to their personal experiences of the home, for example, expressing pride of homeownership, alluding to stresses associated with maintaining the home, and/or voicing feelings of being trapped by their homes. In line with our Participatory Action Research (PAR) methodological framework,[1] we recognized the need to adjust our interview schedule, pivoting to further explore experiences of the home. Rather than maintaining a rigid focus on perceptions of neighborhood-scale change, we encouraged participants to guide the conversations themselves.

Residents' testimonies, as we explore in greater depth below, highlight tensions between experiences of the home as a source of pride and the home as a source of confinement. Though contradictory, these experiences of home, for our participants, are true and legitimate. In fact, the contradiction follows a certain logic: Amid conditions of gentrification, the Cully residents sought greater sanctuary in their homes; greater attachments to home were accompanied by heightened feelings of entrapment. These testimonies, whether or not residents were cognizant of their contradictions, complicate Edenic portrayals of the home.

1 Participatory Action Research (PAR) focuses on the needs and desires of research participants. PAR empowers autonomy and self-determination by placing the opinions, ideas, and experiences of those being researched in high esteem, and bringing "citizens and local knowledges directly into the exchange" (Fischer 2000, 171).

Perhaps experiencing the home as simultaneously emancipatory and confining is a common phenomenon. However, as our investigation suggests, gentrification serves to exacerbate and exaggerate these would-be contradictory experiences. We redirect the conversation away from a neighborhood-scale analysis to the homeowner and the way he or she experiences gentrification inside of the home, to highlight the temporality and local specificity of the gentrification process and to argue that any single generalizable theory—or even a polarized two (i.e., supply and demand theses of gentrification)—is insufficient.

Addressing the Lacuna in the Room: Conceptualizing the Home

"For our house is our corner of the world."
—Gaston Bachelard, *Poetics of Space* (1958)

While the home has been largely excluded from public and academic discourses on gentrification, early thinking on the home is provided by mid-twentieth-century humanist geographers. These scholars depict the home as separate from the outside world, as a protected space that remains untouched by external neighborhood, citywide, statewide, and even nationwide forces. For example, Bachelard, in his classic *Poetics of Space* (1958), conceptualizes the home as a "primal space that acts as first world or first universe that then frames our understanding of the spaces outside" (quoted in Creswell 2014, 39). This perspective excludes consideration of the influence of outside spaces and phenomena on human experience inside the home. In this manner, the home is understood as an *ideal* space.

This interpretation came under critique by late-twentieth-century feminist geographers, who argued that experiences of home are conditioned by class, gender, and broader social regimes. Gillian Rose asserted that for many women, the home is not a space of safety but rather one of "drudgery, abuse and neglect" (1993, 56). Adverse experiences of the home are created, and exonerated, by outside social-economic forces that create and legitimize institutional inequalities. The home is reinterpreted as a space of *confinement*, far from the emancipatory realm imagined by Bachelard. Building on early feminist critiques of the home, bell hooks (1990) claims the home as a place of *resistance*. Having grown up in a racially segregated society, hooks experienced home as a space of freedom from outside oppression, a place where "people are relatively free to forge their own identities" (quoted in Creswell 2014, 41). Such experience contributes to the home acting as a protective space, where the resident is free from outside prejudice and other restrictions.

Feminist and other critical geographers diverge on how the home is experienced. However, their collective critique of the home as an idealized space, as put originally forth by Bachelard and other humanists, betrays notions of the home as a discrete space, of walls that are impenetrable from outside forces operating at multiple spatial scales. In toto, the post-humanist arguments compel us to imagine the home as highly subjective and changing over time. It is not static.

Home as Sanctuary

"The hermit is alone before God. His hut, therefore, is just the opposite of a monastery. And there radiates about this centralized solitude a universe of mediation and prayer, a universe outside the universe. The hut can receive none of the riches 'of this world." It possesses the felicity of extreme poverty; indeed, it is one of the glories of poverty; as destitution increases it gives us access to absolute refuge."
—Gaston Bachelard, *Poetics of Space* (1958)

Guiding this evaluation of home as sanctuary is Romanian Philosopher Mircea Eliade, who has long been considered "something of an axis mundi" (Biles 2007, 294) among scholars of sacred space. Eliade (1959) posits, "Every construction or fabrication has the cosmogony as paradigmatic model" (45); i.e., the creation of the world, whereby the universe unfolds from a center, is the archetype for every human gesture and thus every human settlement. A cosmic symbolism is enacted by the structure of a sanctuary.

In this section, we imagine the home as a primary space—the center—much like Eliad's sanctuary. The home acts as a sanctuary by both literally and metaphorically protecting its occupants from the outside world. We identify three ways the home acts as a sanctuary. First, by dint of its physical structure, the walls of the home shield occupying humans from outside elements and create a sense of safety and refuge. Second, the home acts as a sanctuary by facilitating freedom of expression and fostering familiarity with possessions that are contained within, creating a certain liberation-through-privacy to enact our identities. And, third, the home acts as a sanctuary by granting financial security as well as the projected image of stability.

Privacy and Protection

The home protects its occupants by creating a physical barrier between them and the outside world. The location and physical appearance of a property can furthermore establish or hinder the sense of safety. A majority of homeowners we interviewed referred less specifically to the physical protection of the house and more to the feeling of security cultivated by the Cully neighborhood.

Five of the nine participants named quietness as their primary reason for liking the neighborhood. Several responses alluded to the calmness of Cully: "Well, it's quiet except on the fourth of July of course," "It's not a high traffic street… It's pretty quiet," and "I like being off the road, and, you know, it's quiet back here for the most part." Others responded less specifically, typified in the following reference to comfortability:

> When we picked this house, one of the highlights was that in the backyard we have really nice trees, and being next to the schoolyard and a church over here. It just felt really nice and comfortable and we haven't regretted it since we moved in.

Testimonies point to a shared reverence for the rural feel of Cully, its open spaces, old-growth trees: "I love the old growth trees, the lushness of the vegetation," "It's really green so the trees, I like that," and "We have redone the backyard since we bought the house but at the time my husband, before we had kids and everything, fancied himself an urban farmer so he wanted a lot of space."

A sense of security is generated by these physical conditions, as seen in the following exchange:

> Interviewer: "Why do you like living in Cully?"
>
> Respondent: "The peace and the quiet and, I'd say, the privacy…because, I mean, there's not too many people getting into your business. We don't really have to worry too much about break-ins or getting ripped off or stuff like that. It's pretty safe, it's a pretty safe neighborhood."

Three residents, all with children or grandchildren, mentioned the proximity to parks as a reason for liking Cully. Frequent references to the greenness of Cully exemplify the ways in which aesthetics cultivate feelings of (in) security. For instance, with varying opinions, four residents brought up the poor road conditions in the neighborhood. Two residents identified a lack of sidewalks and poor walkability as contributors to their primary distaste about the neighborhood. In contrast, one resident wanted to "leave the potholes alone because they slow down the cars," and another said she was "happy we don't have sidewalks because it decreases the foot traffic in our neighborhood." Though residents' beliefs about what enriches Cully's livability varies, they share an understanding that a neighborhood's physicality has the ability to cultivate or hinder livability.

Cully residents value the home as a protective space for its location within the neighborhood. One resident contrasted Cully with other Portland neighborhoods: "You know, if I were in Southeast I wouldn't feel that way, no way, but here I feel safe." The home acts as a sanctuary by creating physical boundaries between the occupant and the outside world. But walls are permeable. Outside conditions shape inside conditions. Cully residents feel safe inside their homes because, as indicated in interviews, they perceive the surrounding neighborhood to be safe. And perceptions of safety hinge on neighborhood aesthetics.

Possessions

The home allows space to forge identity without the risk of outside judgment. Possessions inside and outside the home reflect the occupant's identity back onto them, as well as serving as everyday reminders of the freedom to alter their space as they choose. This dialectical relationship is witnessed in the following statements: "I can pretty much do whatever I want to my home. Every tree that is on this place, I planted. Every shrub that is on this place, I planted," and "I've planted like nine trees on my own property."

The residents whose spaces were most adorned with possessions tended to spend the most time in their homes for lack of transportation or disability-related limitations. The same resident who expressed pride in having planted every tree and every shrub on his property had nearly three thousand DVDs stacked from floor to ceiling in his main sitting room: "I'm running out of room. People have joked with me 'Why don't you start renting them out?'"

Another resident who rarely left his home had mirrors strewn about the living-room floor, which he explained were for a mirror wall he was building in the back of the house. His house was decorated with antiques he had found at estate sales throughout the years. In contrast, residents with greater mobility tended to keep cleaner spaces and have fewer possessions inside the house.

Household pets were another indicator of residents' sense of rootedness. Obvious affection toward animals emphasized how possessions allow an individual to construct his or her personalized sanctuaries. One resident fostered dogs as a hobby and spent twenty minutes discussing the process of fostering and training the animals she housed. Another resident's cat, which he called Sweetie, spent a majority of the interview on his lap. He expressed that his veterinarian expenses were a distinct source of shame for him. Another resident spoke to his dog, which hobbled around, crying: "Hello, sweetie pie, what's your trouble? What's the matter baby?" He joked that neither of them were aging very well.

Financial

The home protects its owner as an investment, sustaining in the wake of external transformations. Many residents noted the ways in which Cully had changed since their arrival, which ranged from ten to twenty-nine years prior. Despite—or perhaps in light of—the recognition of vulnerability to displacement, residents felt extreme pride of home ownership. The home reveals itself as a fundamentally protective space and as the origin of its occupant's sense of stability. One resident who lived in and maintained his mother's house remarked, "People need a place to live, you know? It's just part of the human existence." Residents felt pride in their decision to buy a home: The purchase was regarded as a step forward both personally and financially. Take, for instance, the following statement: "I got it in my mind that I wanted to buy a house because I was 50 and didn't have any investments"; "I felt that it gave me more freedom than an apartment; I also discovered that it cost less than having an apartment"; "It's cheaper than renting… I thought it was a practical idea at the time…instead of just throwing your money into something where then you leave and have nothing, it seemed to make more sense"; and "I was getting tired of getting disrespected by my landlord…and one dreary Saturday afternoon I happened to be looking through the nickel ads and one had this address."

The purchase of a home promised a new life, the creation of new memories. The home becomes associated with memories, acting as a backdrop for the occupant's life. Bachelard's assertion that the home "is one of the greatest powers of integration for the thoughts, memories and dreams of mankind" (1958, 6) is witnessed in the statement, "My kids were raised here, my husband did a lot of work on it and it's my life." Further exemplification is provided in another exchange:

> Respondent: "Owning a home gives me more freedom, more comfort."
>
> Interviewer: "Do you still feel that way?"

> Respondent: "Oh yes, yes indeed, I have fought diligently to stay here. Last year they kept trying to put me into different kinds of homes for the elderly and I don't want that. I would prefer staying here until the final day comes, if that's at all possible."

The homeowner's relationship with the home becomes more intense over time. Whether meaning is forged by relationships that tie down an occupant to the space or the home grows as a liberating space, attachments increase over time, never lessen.

Home as Prison

The following analysis of home as prison is based on the Foucaultian idea that "*humane" conditions of confinement are nonetheless conditions of confinement* (Foucault 1995). A great deal of prison research has been dedicated to conceptualizing human beings as psychologically imprisoned by society (Crewe 2015; Ievins & Crewe 2015; Green 2016; Pratt & Miao 2017). For example, the infamous Stanford Prison Experiment (Haney et al. 1973 cited in Turner 2006, 41) found that "ordinary people assigned to the roles of prisoner and guard would naturally and automatically accept and enact these roles." The individual as a prisoner is socially determined (Turner 2006). Thompson elaborates on the findings of Haney et al. (1973), asserting "Prisons and punishment are performative. They construct *special sites*, appeal to certain audiences, involve ritualized acts and entertain or appall" (Thompson 2004, 57, emphasis added). This body of prison scholarship implicates the home as a "special site" for the performative aspects of discipline and punishment (Foucault 1995). While much research has yet to be done on the social determinism enacted by and within the home, our analysis here begins the discussion. We explore the home as a material manifestation of identity. Conceptualization of the home as a prison points to the ways in which a home, or a cell, is personalized space embedded in broader systems and physical structures of confinement.

The home acts as a confining space (1) by way of ideological attachment and (2) the burdens associated with owning a physical structure as a financial investment. In some capacity, evidence of the home as a sanctuary also stands as evidence of the home as a prison. First, the walls that establish privacy and protection also act as barriers to the outside world and foster physical and emotional isolation. Second, the possessions inside and outside the home that establish familiarity and represent expression also act as an increasing financial burden on the homeowner; similar to the home itself, maintaining accumulated possessions fosters attachment to the home. Finally, the physical and financial burden of owning a home in a gentrifying neighborhood limits the homeowner's mobility. Increasing property values make it difficult for the resident to compete with neighboring properties, and thus restrict their ability to sell the home.

Isolation

Isolation occurs due to a perceived lack of neighborhood cohesion and a lack of neighborhood resources. One resident discussed at length the ways in which her experience growing up differed from her experience of living in Cully today:

> When I grew up the neighborhood was taught [that] everybody looked out for you. On a day like today you would see kids all up and down the streets and you just don't see that anymore. For one reason, it's not safe. For another reason, a lot of people don't encourage their kids to go out because they just don't feel good about it.

Contrasting the past with the less-favorable present is common for residents of gentrifying neighborhoods, well established in media reports and academic literature on gentrification (Lees 2000; Lees et al. 2008; Baram 2018). Literature and media reports indict the home as a space where people retreat in lieu of spending time with neighbors, but ignores this pattern as a potential source of isolation. Feelings of isolation are exacerbated by lacking neighborhood cohesion, exemplified by the following exchange:

> Interviewer: "Do you feel connected to your neighbors?"
>
> Respondent: "No. I don't know them from a hole in the wall…no one has ever made the gesture of coming to see me or talk to me or whatever, and I have really not been in shape to do it."

Multiple residents identified poor mobility as the reason for their disconnection from the neighborhood. Mobility is limited for a number of reasons, including financial and time restraints associated with maintaining a home. In the following exchange, a resident explained why he was unable to participate in neighborhood decision-making:

> Interviewer: "Do you ever attend neighborhood association meetings?"
>
> Respondent: "I can barely keep my yard cut, I just don't have time."

Financial stresses force residents to prioritize the maintenance of their home over other financial obligations: "Property values are high and I have such a hard time keeping this home and I have no life, I can't afford an automobile—my van has been sitting here needing a new transmission for three years." Obligations such as replacing a transmission, attending neighborhood association meetings, or paying vet bills end up on the back burner.

The lack of and/or poor access to transportation cultivate isolation for elderly and disabled homeowners. In the following discussion, one resident alludes to the relationship between transportation and maintaining interpersonal relationships:

> Respondent: "Transportation is my biggest problem, I can't ride the bus because it's too painful. I have to go through Ride Connection, which requires a four-day in-advance request… I could utilize them more but isolation is a problem for me."
>
> Respondent: "Both my sisters are living in the area."
>
> Interviewer: "Do you see them?"
>
> Respondent: "No I don't see any of them—mostly because of the transportation issue. If you notice on the list there, I also have vertigo, which makes it very difficult to go places."

Vulnerable residents are often dependent on others for completing basic tasks, such as going to the grocery store or to medical appointments. Those without strong support networks fight to get their basic needs met and often struggle to leave the house. Reliance on others fosters dependence and forces residents with limited mobility to adjust their habits to suit their caretakers' timelines: "I have someone who is willing to take me to Winco, I go once a month and buy my entire months worth [of groceries]."

One resident talked explicitly about his reliance on others for being able to participate in life outside of the home, saying, "Lets face it, I am dependent, I am really dependent, I am dependent on my disability income, I am dependent on resources, I am dependent on the kindness of other strangers."

In gentrifying neighborhoods, resources for folks with limited mobility are lacking due to the influx of young, able-bodied, financially stable renters and buyers. Consequently, long-term, vulnerable residents spend a majority of their time inside their homes and most any interaction with the outside world still takes place from inside. One homeowner reflects on his physical limitations and isolation, saying, "Depression is a problem… I work hard at my thinking." This same resident said the David Romprey warm line was his primary contact with others. The hotline provides a space where people can call "just to talk… They are trained to affirm and validate one's experiences and viewpoints and feelings and thoughts… They don't help, they just listen."

For homeowners with financial and/or physical limitations, the home acts as a space of confinement. The same walls that foster a sense of privacy and protection also act as material and emotional barriers from the outside world. For some, the home is itself the cause of isolation, while for others, the home is simply a space where isolation is experienced most intimately.

Possessions

Possessions inside and outside the home foster familiarity, ensuring comfort for the occupant. But these same possessions require physical and financial maintenance. Residents, particularly those who have become less able-bodied over time, expressed the burden of maintaining their personal assets: "I used to have flower beds out front. I had three of them and I finally got to a point where I just couldn't take care of them anymore. I used to have an electric train running through my backyard and I finally had to give it up last year because I couldn't take care of it either."

Possessions are an extension of the homeowner's identity. An inability to maintain one's possessions thus creates negative feelings that the homeowner may direct at the home space in its entirety rather than the individual possession. The home transforms from a space of relaxation to one of tension when adornments become a source of stress rather than expression:

> Furniture is highly overrated, I would be happy in a tiny house the size of my kitchen… All I need is a place for my bike, to put my guitar and pretty much that's it except the basic essentials of life—something to cook with, something to wash with but mostly I live in that space anyway. I don't really use the rest of the house, it's just a place to accumulate junk and to try to get rid of the junk and you know the yard is huge; it's a double lot so that's a lot of work. I pretty much hate being a homeowner.

Possessions hindered the homeowner quoted above from selling her house and leaving the neighborhood. She continued,

> That's just a big chore to sell a house, and so that's a big deterrent. It's kind of an overwhelming proposition to move… It's just too much work to be a homeowner, especially on a lot this size… You can't just shove the whole lot into a landfill and any kind of flat surface in the house is just covered in a week.

While residents boasted about their neighborhood's improving aesthetics, they simultaneously expressed anxiety over maintaining their properties. Residents feel responsible for maintaining their property's physical appearance in part due to the internalization of perceived new neighborhood aesthetics. Those who were more physically able kept up their properties themselves, but did so out of fear of losing their place in the neighborhood. One resident said his home was "Definitely a lot of upkeep, and I'm the only one doing it so you know, can't be getting lazy. Yeah, if I don't do it, it won't get done. I'm very dependent on here so…"

On the other hand, those who lacked the financial and physical means of maintaining their properties relied on sparse neighborhood resources:

> You know, I've remodeled two homes, but I can't mow the lawn now. I can't do housework. There just aren't resources for poor people to get help for those things…in terms of household work and yard work… Very, very few and you have to be like a third of the median income or less than that.

Another resident expressed concern over the consequences of being unable to maintain his property:

> I just want to have my house in order and clean and I can't do that anymore and I can't get the help to do that and I can't do yard work anymore. It's just getting harder to maintain my home and I don't want to end up in a concrete floor studio apartment in an extra care facility, but that's where I'm headed to be honest.

The inability to maintain personal possessions inside and outside the home transforms the home from a space of comfort and familiarity to one of discomfort. For others, the possessions that cultivate refuge, also contribute to feelings of confinement by supplying the occupant with stimulation that might otherwise be found outside the home. Consider, for example, the resident who had three thousand DVDs and received up to seven magazines a day. Possessions have the power to convert the home from a financial investment to a financial burden, limiting residents' ability to build equity and wealth more generally. Possessions are difficult to divorce from the home because they are an extension of the homeowner's identity. They can become distinctly burdensome because they exist in the resident's living room and impact the occupant more frequently and intimately than the house as a structural whole.

Financial

The home as a financial investment requires continual maintenance or otherwise diminishes in value over time, transforming from a wealth-building entity into a wealth-building impediment. This is clear in the following Cully resident's statement: "I've been house broke ever since I moved into this house." For homeowners in gentrifying neighborhoods, increasing property values and competition over housing accelerates this transformation. The home becomes an increasingly imprisoning asset over time when proper maintenance is untenable.

Cully residents considered buying a home to be a step in the direction of financial and personal stability. Homeowners reflected on their feelings at the time of the purchase, saying, "I felt that it gave me more freedom" and "It's cheaper than renting… I thought it was a practical idea at the time." One resident who said, "I got it in my mind that I wanted to buy a house because I was 50 and didn't have any investments" reflected on feeling disillusioned by the idea of homeownership:

> It was based on faulty thinking, you know this idea that people who own homes are more stable and have a life… and uh, also that it was an investment. It's not an investment… You can't touch the equity. I just knew nothing about financial security or personal finance and what made a responsible person. I just never had those.

Other residents echoed the sentiment of feeling trapped by home ownership. Still, keeping their homes despite new socioeconomic pressures associated with the processes of gentrification, was regarded as a point of pride. The resident quoted above reflected on a time during which he lived on fifteen percent of his net income and frequently visited food banks: "It was hell, pure unadulterated hell, but I saved the house. It was all I could do." Another resident discussed her life after losing her husband in 1999: "After I lost my husband, I really haven't done much of anything which may not be a good thing, but that's just the way I am. I mean I have enough energy to work and try to maintain my house and that's about all I can do."

Residents become confined by the home because it is their primary and often only investment. As a result, homeowners work desperately to save the investment, which becomes increasingly strenuous as the surrounding neighborhood gentrifies. The resident who once lived off of fifteen percent of his net income said he was considering moving into the shed in his backyard and renting out the main house "just to be able to live… just to be able to stay."

As a neighborhood gentrifies, competition over housing increases and long-term homeowners experience the financial burden of maintaining their property value. Homeowners are often forcefully displaced and newer, more expensive units replace their homes. Cully residents understand this process, as exemplified in the following testament:

> There is mold in some houses and that qualifies you to tear the house down. For example there's one lady, she lives on the corner in a 15,000 square foot lot, well her house has mold in the basement so it can be torn down and they'll build five homes there or fifteen townhomes, and that's a problem all over the city—homes being destroyed. Four hundred in the last ten years have been torn down, I heard that number last week."

The replacement of affordable housing with expensive units affects both the financial landscape and the social fabric of the neighborhood. This jeopardizes the ability for some to stay in place, as explained by this long-term home owner:

> Property taxes in this neighborhood are already about $4,000 dollars a year. And to me, if I have $700,000 to buy a home, they may come in and make demands for improvements that the people here now aren't comfortable with. For instance, they want sidewalks. Well, I'm happy we don't have sidewalks because it decreases the foot traffic in our neighborhood... So, you know, we just really cringe when we see that potentially happen.

Alternatively, homeowners experience forced *non-displacement* because their house cannot compete with the current housing market. They are unable to sell:

> Interviewer: "How long do you intend to stay in Cully?"
>
> Respondent: "Rest of my life. I don't have any choice. This house made 30,000 last year, just being here. Did you know Portland is the number one city in the country for the rate of property value increase?"

Vulnerable homeowners in gentrifying neighborhoods are often confronted with the decision to either hold onto a losing investment or be foreclosed upon:

> I don't plan on going anywhere, as long as I can keep my house. I'm trying to work with Wells Fargo, so they can do something with my mortgage because it's just way too high. I don't want to sell it or anything, I don't have any plans on going anywhere but if I can't continue to afford it, shoot, I might be in foreclosure.

In either case, the home, which was initially purchased under the aegis of freedom and security, imprisons the homeowner.

Maintaining the value of a home requires either direct or indirect upkeep by the homeowner. In the case that the homeowner is physically unable to perform the maintenance—consider the replacement of a roof or any other large-scale project—they must have the means of hiring someone else to do the work. For vulnerable populations, who are often low-income and/or physically disabled, maintaining the physical integrity of the house becomes onerous, if not impossible. Cully residents are becoming increasingly confined to their homes by a competitive housing market and, as a result, living in unhealthy and unsafe conditions to be able to stay in the neighborhood.

Concluding Discussion

Journalists and scholars alike have overlooked, and perhaps looked away from, how gentrification is experienced in the home. To address this lacuna, we conducted interviews exploring Cully residents' relationships to home and how those relationships are shaped by conditions of gentrification. The scalar shift in focus, bringing the home to fore, carries with it important implications for the way policymakers and academics understand and develop anti-gentrification interventions.

Our introduction of the home into gentrification literature iterates and expands on Lees' (1994, 2000; see also Lees et al. 2008) geographies of gentrification. To combat the harmful impacts of gentrification, as she asserts, the process must be understood as place-specific, as having varying scalar impacts, and as a process that impacts individuals and individual households in radically different ways. The home offers a compelling unit for analysis because experiences inside the home mirror and are mediated by broader economic and social restructurings. Conceptualizing the home as both a sanctuary and a prison encourages us to imagine gentrification as *both* emancipatory and revanchist, as a phenomenon that must be addressed based on the affected population's unique characteristics. Our examination of residents' experience of the home furthermore contributes to feminist geographers' critiques of humanistic interpretations of home.

Although journalists and scholars alike recognize the impacts of gentrification on the housing market, their analyses ignore the way gentrification is experienced inside the home. The home has been represented either as a space where people live happily or one from which people are displaced. But it is overlooked as a space that is in and of itself vulnerable to change. As a result, anti-gentrification strategies have tended to identify the neighborhood as the primary scale of intervention—implementing rent caps, increasing social housing subsidies, and non-development zones to restrict the influx of upper-income occupants—and the experiences of homeowners have been excluded from the debate. This examination of the home as a changing and transformative realm serves to redirect the focus of gentrification theorization away from neighborhoods and onto homeowners.

Mitigating displacement is an important anti-gentrification strategy. However, proposing non-displacement as a stand-alone intervention is insufficient. Without distinguishing between disparate types of displacement (i.e., renters vs. homeowners), the equally damaging phenomenon whereby long-term residents become confined to their homes—an involuntary non-displacement of sorts—is ignored.

Conversations with Cully residents indicate that building and/or preserving healthy neighborhoods is more complicated than building parks, putting in bike paths, or zoning the perfect ratio of commercial and residential land. It requires a compassionate and thoughtful investigation into the needs of the neighborhood's most vulnerable members, because gentrification manifests differently and is not simply an issue of preserving affordable housing. It is a phenomenon that reaches beyond and below the neighborhood scale, affecting the day-to-day lives of individual residents. Too long has gentrification been conceived primarily as a singular economic process whereby low-income people are displaced due to the onslaught of development. Too often have quantitative approaches been used to adumbrate the lives of residents. Resisting social harms associated with gentrification means humanizing those who are being harmed, and the place to start is in the home, their primary dwelling.

Our hope is that these research findings have captured the complexities of one gentrification while providing some additional language and/or frameworks to discuss them. A neighborhood is a messy coalescence of families and friends and social groups, all experiencing gentrification differently because they experience life differently.

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BOOK REVIEW

Mining the Borderlands: Industry, Capital, and the Emergence of Engineers in the Southwest Territories, 1855–1910

Sarah E. M. Grossman. Reno and Las Vegas: University of Nevada Press, 2018. 175 pp. $45 hardcover (ISBN 978-1-943859-83-2)

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Many hundreds of books have been written about the fascinating subject of mining in the American Southwest. Sarah E. M. Grossman's *Mining the Borderlands* takes a distinctive approach by focusing on the history of mining engineers in Arizona in the United States and the state of Sonora in northern Mexico. With this focus she reveals not only an underappreciated aspect of American mining, but also describes issues pertaining to the penetration of capitalism into the Southwestern frontier.

The book is the result of Grossman's 2012 history dissertation at the University of New Mexico and is divided into six chapters plus an introduction, conclusion, bibliography, and eight illustrations and two maps (as well as a photograph of an historical map). The University of Nevada Press has done an excellent job of layout and printing, making an attractive and short book that will appeal to both the specialist and the afficionado and student of Southwestern history and mining history. The book will hold interest for geographers, not only for its regional aspect, but because the mining industry and mining engineers helped shape economic, political, and cultural factors in the region as well as having a serious and problematic environmental impact. And geographers will no doubt recall that Alexander von Humboldt started out as a mining engineer, receiving his education at the Royal Saxon Academy of Mining in Freiburg, Germany, the same institution where many of the first mining engineers discussed in Grossman's book also studied.

The American Southwest was, during the period under investigation (1855–1910), a remote frontier, from the perspective of capitalists and investors on the East Coast of the United States. But despite this remote location from the centers of investment capital, the mining industry in the region flourished because of a cadre of mining engineers who formed a technocratic class with mining expertise. These mining engineers served as intermediaries between capital and labor and shared aspects of each. Mining engineers were a mobile class that moved from mine to mine as circumstances warranted, which meant that they might have lived in other parts of the country such as Michigan and California before ending up in the Southwest borderlands. (Wallace Stegner's classic novel *Angle of Repose* relates the life of one such mining engineer.) These mining engineers helped expand the American economy into these border regions and helped incorporate them into the overall economy, serving as (often unwitting) agents of economic hegemony.

Mining was, and still is, a high-risk, capital-intensive industry. Investors wanted assurance that they were investing in something profitable, and mining engineers were positioned to provide that assurance. As technocratic experts, they and their reports could reassure investors in a way that mine owners, brokers, and bankers could not. After all, mining engineers knew all about mines and their potential output and profitability, or so investors believed. As mining shifted from placer mining to hydraulic mining and then to underground mining, a greater level of expertise was required, and thus mining engineers became more crucial to the industry as it sought to attract investment capital. The Southwest borderlands were rich in gold, silver, copper, and other metals, but it was copper that eventually became king, largely because of the development of electricity and the electric grid, which required copper wiring, and which penetrated into almost all aspects of manufacturing, lighting and heating, transportation, and indeed most aspects of people's lives. Grossman's selection of the United States-Mexico border region in the late-nineteenth and early-twentieth centuries thus allows her to focus on both the rise in importance of copper and the trans-border aspect of the industry.

The book's first chapter examines the early days (mid-nineteenth century) in the Arizona-Sonora borderlands, focusing especially on the Santa Rita Mine, one of the region's first major mines. Using this example, the author explores how mining engineers first became important as a way to reassure skittish investors, with the industry promoting their educations at prestigious mining schools (especially at the Royal Saxon Academy of Mining in Freiburg, then considered the world's leading educational institution for mining engineering). If a graduate of this leading center said that a mine would be profitable, investors tended to believe that it would. In this sense, as experts certified by mining academies, mining engineers were able to insinuate themselves as crucial players in the mining industry.

Chapter two further explores the importance of a formal education at a mining academy and the eventual establishment and growth of mining programs at such universities as Harvard, Yale, the University of California at Berkeley, and the University of Nevada, among many others. Americans realized the need to create their own centers of mining education, building on the structure and training of the Freiburg school. The growth of these American mining engineering programs increased the professionalism of the mining field, and soon degrees and certification from such programs were essential for a career as a mining engineer. But in addition to being credentialed from a mining program, mining engineers needed to demonstrate field experience, which in any case most mining students were eager to do. This brought them in contact with mine laborers, as mining engineers shared the same life in remote mining camps. Most mining programs provided this form of experiential learning as part of their requirements. Most programs also adapted to the increasing professionalism of the times by eliminating such earlier requirements as Latin, other languages, and botany, updating the curriculum to reflect the new applied engineering focus.

Chapter three looks at the topic of masculinity in the mining industry, and the need for mining engineers to prove themselves not only as engineers, but also as men (as nearly all of them were), demonstrating the ability to conform to the norms of masculinity of the times, and adopting appropriate clothing, headgear, and footwear that reflected their rugged and outdoor adventure-oriented self-perception. Chapter four is a case study of the Copper Queen Mine in Bisbee, Arizona, and the importance of mine prospectuses and reports, the writing of which gave mining engineers considerable power and influence with investors. Their honest assessments of mines could bring mining engineers into conflicts with mine owners, who naturally wanted to put the best possible spin on their mine and its potential to reward investors, and mining engineers were expected to share in the rosy vision that mine owners had of a mine's future. Grossman explores the writing of mine reports in some depth, examining the use of rhetoric and perspective, and what she calls the "performance of objectivity."

The book's final two chapters look at the evolving role of the mining engineering profession, in which the profession became more democratic with the increase in the number of university mining programs (with many of these at public land-grant institutions in the western United States). In the mid-nineteenth century, most mining engineers came from elite East Coast backgrounds and had the wherewithal to study at the prestigious Royal Saxon Academy of Mines in Europe, but in the early-twentieth century, mining engineers often came from less elite backgrounds and from western mining states. The book concludes by emphasizing the significant role the mining engineers played in the development and capitalist penetration of the Southwest borderlands, incorporating this region into the larger American economy, and how, in tandem, the mining industry became more technocratic and rationalized as it continued to extract metals from the soil of the borderlands.

The book contains few errors, but geographers will pick up on things that an historian might not, such as when on page 8 the author refers to the Gadsden Purchase as "a large swath of land in present-day Arizona south of Tucson," when in fact Tucson, far from being to the north of the Gadsden Purchase, is just about in the middle of it. And the community of Cucurpe in Sonora, where the San Francisco Mine was located, is spelled as "Cucerpe" on the map on page 24. Geographers might also be disappointed by the scarcity of maps in the book, with only two (other than one in an historical photo), and those quite small and simple. These minor points, however, do not detract from Grossman's achievement, which has shined light on the important role that mining engineers played in the Southwest borderlands, as agents who helped facilitate the development of this region and its incorporation into the American economy. The book will be enjoyable and informative reading for all geographers and anyone else interested in the Southwest borderlands and in the growth of the mining industry.

Commentary: Black Lives Matter

Mike DeVivo
Grand Rapids Community College

As a veteran, educator, and citizen, it is with great sadness and grave concern that I write these words, for not only do African Americans continue to be threatened by bullies in law enforcement positions, our head of state endangers those peacefully exercising their First Amendment rights in support of the victims of police brutality. Like many of you, I am dismayed and outraged. Although it is normally not apropos for faculty in higher education to express viewpoints beyond private conversations concerning political leaders, the current crisis in leadership, and my expertise in leadership scholarship, as well as my leadership experience and geographical research, necessitates this statement. I would be remiss if I did not do so.

It is past time to recognize the oppression that African Americans have endured, and working together to ameliorate this injustice is an imperative. I know many of you carry these same beliefs. A recent University of Michigan study reported that whereas about 39 in 100,000 white men and boys can expect to die at the hands of police officers, approximately 100 in 100,000 black men and boys are killed by police. In essence, black males are about 2.5 times more likely to be killed by police during their lifetimes than white males.

A measurable increase in the level of violence levied toward African Americans has occurred over the past four years. Before the 2016 election, many "Black Lives Matter" protesters faced physical and verbal abuse delivered by Trump supporters, and during the last quarter of 2016, the FBI reported a 25 percent increase in hate crimes. In December of that year, Ku Klux Klan groups planned Trump victory parades. In a recent report, the Southern Poverty Law Center showed that between 2017 and 2019, a 55 percent increase in white nationalist hate groups took place. For sure, white hate-mongers have found license during the current presidential administration to threaten, inflict harm on, and kill people of color. This could have been predicted, given events surrounding the 2016 campaign.

Among many disturbing incidents, one that took place in March 2016 stands out. At a rally for the leading Republican presidential contender, Virginia State University student Sierra Thomas shouted "Black lives matter!" As Donald Trump yelled into his microphone, "Get out!" Ms. Thomas became one of the many protesters who faced the wrath of his supporters. She recounted her experience for the *Washington Post*. Please be aware that her account spares no harsh words levied against her.

> Look them in the eyes. Show no fear. Remember why you're here. Oh - that must be the police touching me.
>
> I turned around, all the while yelling, "BLACK LIVES MATTER!" I couldn't stop saying it.
>
> Trump looked my way and yelled into the mic: "Get out!" The people I'd been sitting and talking with cheered with the rest of the crowd as police came over.
>
> Three officers grabbed me, and I heard cheering from all around. Maybe in other circumstances, I might have been afraid. But right then, I wasn't. I didn't have time to worry, and I most certainly couldn't show it. I blocked everything out and kept chanting.
>
> I raised my fist back in the air. "BLACK LIVES MATTER!"
>
> A middle-aged white man in the crowd yelled at me: "Get your little ass out of here! Go home, n**ger!"

Tyranny is begotten from hatred and division sown, and it is no secret that the current administration fuels the kind of conflict that is modeled by authoritarian leaders elsewhere across the globe. In his criticism of the recent ambush against peaceful protesters demonstrating legally in front of the White House, former Secretary of Defense James Mattis remarked,

> Donald Trump is the first president in my lifetime who does not try to unite the American people—does not even pretend to try. Instead he tries to divide us. We are witnessing the consequences of three years of this deliberate effort. We are witnessing the consequences of three years without mature leadership. We can unite without him, drawing on the strengths inherent in our civil society. This will not be easy, as the past few days have shown, but we owe it to our fellow citizens; to past generations that bled to defend our promise; and to our children.

The words of General Mattis are striking, and the road we must follow is difficult, for it is a long and plodding effort to exact much-needed change. Yet, we are all tasked with uniting in this common cause, and we must do more than simply generate awareness of racism and injustice. Indeed, the onus is upon each of us to work toward making constructive changes toward advancing justice and equality for the black community. Ponder ways to make a difference, show no tolerance for injustice, and consider making a contribution to your local NAACP branch. Let us all join together in this fight. Black Lives Matter!

A friend of California Geography and a regular participant at CGS conferences for many years, Mike DeVivo has often brought his students from Michigan, who frequently presented papers at the annual meetings on the geography of social injustice. He is Professor of Geography at Grand Rapids Community College and author of Leadership in American Academic Geography: The Twentieth Century.

Commentary: Why the Transatlantic?

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Spanning forty-one million square miles of the earth's surface and connecting four continents, the Atlantic Ocean houses the origins of our current global culture. Within its depths lie legacies of nightmarish atrocities, traces of great human ambitions, and the echoes of enlightened ideas. Traverses back and forth across this giant pool, the epicenter of the so-called "Age of Exploration," resulted in unprecedented exchanges of humans, ideas and ideologies, goods and gods, technologies and diseases. The manifold consequences of these transatlantic interactions reverberate with us today. As evidence, one need look no further than the Black Lives Matter movement, which emphatically reminds us that the current economies in the Americas are founded on the labor of enslaved Africans. Financial interlinkages across the Atlantic, founded and strengthened through waves of European colonization and imperialism, continue to structure the global economy in ways that uphold the dominance of countries in Western Europe and North America over societies in Africa, the Caribbean, and Middle and South America. New and hybrid cultural forms, from food to fashion and music, arose from transatlantic interactions, subsequently becoming global culture. In short, study of the transatlantic as a *historic geographic region* can lead to critical insight into complex social and cultural dynamics that we grapple with today.

The purpose of this essay is to offer a glimpse at the Transatlantic World's history, shedding light on events that birthed our modern society, which in turn might help us to understand the specters of disease, civil turmoil, racism, and economic downturn confronting us today. These are not unprecedented events. Humanity continues to grapple with these problems, seemingly captive to historical processes that gave rise to the Transatlantic World. Insight into the transatlantic—including how we might think about it as a geographic region—may help stimulate some of the forward progress we could use at this point in history.

The term *transatlantic* is ostensibly redundant in a world where Atlantic studies exist. Kenyon Zimmer, in his essay "Transatlantic History: Locating and Naming an Emergent Field," defines transatlantic history as an umbrella which includes Atlantic studies but has no chronological end point" (Zimmer 2013, 3). However, the traditional notions of the Atlantic, a space of new and unprecedented interactions, ascribe the notorious year of 1492 as its beginning. After setting sail from Palos de Fronterra, Spain, Christopher Columbus made first contact with the Taino tribe in today's San Salvador. This initial interaction and the events that followed created a system that exchanged ideas, people, and commodities across the Atlantic Ocean. These exchanges led to revolutions, the establishment of new states, and the rise of capitalism as the world's dominant economic system.

Europe's emergence from out of the so-called "Dark Age" coincided with the construction of this Atlantic system. Furthermore, the Europeans' ability to exploit the resources in the New World allowed them to dominate their rivals to the east. European empires formed through colonies across the Atlantic, dominating and oppressing populations to such extent that it laid the foundation for transformative revolutions. Nevertheless, the constant throughout the new interactions and accompanying change was the transatlantic slave trade, whose legacies still haunt the Transatlantic World.

The labor and practices of Africa and its people act as the foundation for the transatlantic. Africans, however, were not the first choice of labor for the Europeans. The first groups enslaved were the Native peoples of the New World. This practice ended after Bartolome de las Casas, a friar and early abolitionist, penned *A Short Account of the Destruction of the Indies* in 1522. This seminal work exposed the Spanish exploitation of the Natives as well as made the argument that they be treated as subjects in need of civilizing. De las Casas primarily based his argument, targeted at the papacy, on the fact that most of the indigenous Americans were converts to Catholicism. This, in effect, halted attempts to enslave indigenous Americans, although the exploitation of their land and their slaughter remained constants.

Before the transatlantic slave trade, Europeans viewed sub-Saharan Africa with a combination of fear and mystery. The idea of anti-Black racism existed in Western Europe before the slave trade commenced. One group of English voyagers described sub-Saharan Africans as "beastly savage people, wilde men and brutish black people" (quoted in Davis 2006, 52). Furthermore, West Africa's climate was similar to the tropical environment found in the Caribbean. To enterprising Europeans of the era, African slaves seemed like the solution to their production dilemma. Thus, the transatlantic slave trade began. With its origins tied to racist thought, its implementation led to the rise of Western Europe and cultivated an enduring perception of Africa, its people, and its descendants spread across the world.

Although forced to migrate during the middle passage, enslaved Africans held on to their beliefs and culture. Slaves were predominantly brought from West Africa and believed in the vodun, "forces or powers that made themselves known through means of supernatural; revelations" (Sweet 2011, 409). Over time, these notions mixed with the ideas of native religions and Catholicism to form the contemporary voodoo religion. Furthermore, in these West African communities, "healing was the most viable means of addressing the misuses of power." Thus, healers held tremendous power in their communities. Often a rival lord sold healers into slavery because they possessed the ability to challenge their own power. This practice ensured that such traditions survived into the New World.

Africans also carried with them cultivation practices. The climates of the Caribbean and West Africa were similar, and "some white planters seemed to have known that they could greatly benefit from the skills of African-born slaves who were familiar with the flora and fauna of semitropical coastal regions" (Sweet 2011, 409). Furthermore, during the pioneering period, some Africans "showed whites how to develop a lowland cattle industry and helped plan as well as construct dikes to control the irrigation of low-lying rice fields" (Davis 2006, 137). These techniques proved paramount to early colonists in North America who already dealt with difficult terrain and justifiably hostile native populations.

In most instances in which a population has its history erased due to enslavement, large swaths of cultures are lost. European slave masters most often were intent on the erasure of African traditions. The annihilation of memory itself, in effect, was the aim. A population that lacks knowledge of its history is easier to manipulate, and is thus more susceptible to exploitation as free or cheap labor for burgeoning empires. Fortunately, large portions of African customs rely on the oral tradition. Therefore, healers were able to maintain stories about the vodun, which, even amid the horrors of slavery, they were able to pass along to the next generation.

The transatlantic transfer of cultural traits and traditions is even more apparent in music and dance. Many African rituals call for specific drums and dance movement to summon the will of a deity. The drum rhythms in particular spread throughout the Caribbean. As they passed from one generation to the next, they assumed new local variations, but even in hybrid expression their essence remained intact. One instance of this is the rise of Jamaican dance-hall music, which originated from African drumbeats. Jamaican immigrants usually went to one of two places. Some went to England, a common practice due to Jamaica's place in the British Commonwealth. There they laid the foundation for skinhead culture. Others took their dance-hall music and emigrated to the United States, specifically New York. In New York, dance-hall music blended with disco, the popular music of the time. This combination, along with new music technology, led to the creation of hip-hop, first in the Bronx, then spreading among other black urban populations in the U.S., then to suburbs and infilling throughout the country, in time diffusing throughout the world. Today, hip-hop, a legacy of the transatlantic, is *the* worldwide musical expression of urban youth. In spite of the forces of commodification, hip-hop still acts as a voice of resistance.

The free labor generated by the transatlantic slave trade led to the increased production of goods, giving rise to unprecedented mass production. The British Empire's adoption of capitalism allowed for them to thrive in the Transatlantic World. While the Spanish and Portuguese began their decline as leading empires, Britain rose as both an economic and a military power. In *An Inquiry into the Nature and Causes of the Wealth of Nations,* Adam Smith documented the situation within the British Empire. After the book's publication in 1776, Smith's advocacy of free-market capitalism diffused throughout the Atlantic World and inspired others to follow. It is no coincidence that Alexander Hamilton, the first U.S. Secretary of the Treasury, designed an economic system that eerily mirrored that of Britain.

Nearly three centuries after Columbus arrived in the New World, thirteen of the British Empire's twenty-six colonies declared independence. Two pieces of the narrative of the American Revolution that too often are overlooked must be considered here. The first is that a result of compromise in the newly formed government led to the assertion that a male slave counted as three-fifths of a man. This compromise not only ended the debate about slavery temporarily, but the three-fifths compromise also changed the public perception of the slave. The masses no longer encountered a person when dealing with a slave; legally, the slave was no longer a full person. The long-term ramifications are still felt, as public perception dehumanized slaves and extended the view that their descendants were morally indecent, less human than people of European descent. Here lies a key origin of America's modern racist views.

The irony of the situation leads to the second point of importance for the American Revolution. At the precipice of revolution in Boston, Massachusetts, on March 5, 1770, British soldiers sent to maintain peace after social unrest due to the Stamp Act entered into an altercation with the mob. Six

British soldiers opened fire on the crowd. Crispus Attucks was the first person to lose his life in this incident, which was later dubbed the "Boston Massacre." Attucks, who took two bullets to the chest, was a black man. News of the event and the clearing of the six policing soldiers involved sparked outrage across the thirteen colonies. Their defense attorney, John Adams, future U.S. president, ensured victory. Again, consider that irony: an unarmed black man's killing by authorities sparked the first of the Atlantic revolutions.

Echoes of Crispus Attucks' death reverberated through the Atlantic and made their way to France, where the *ancien regime* was ripe for a revolutionary overthrow. An incompetent leader sat on the throne. Debt was accruing due to foreign war. Enlightenment ideals equipped minds prepared to move the world away from the entrenched rule of nobility and toward a world of democratic governance. Contemporary educated people are probably aware of the French Revolution and its place in feeding the subsequent rise of democracy as the most legitimate form of governance. However, most overlook the direct tie of the French Revolution to both phases of the Haitian Revolution, due in large part to France's lack of acknowledgment of slaves in the colonial empire. When the National Assembly formed, their ratification of the Declaration of the Rights of Man and the Citizen declared all men of France citizens.

The events in Paris eventually traversed the Atlantic to the Caribbean and settled in Saint Domingue, one-half of Hispaniola. This French possession, with its large production of coffee and sugar, not only was the most lucrative colony in the French Empire, but it also housed the most rigid caste system, with wealthy plantation owners at the top and slaves at the bottom. On the island also lived a caste of free blacks, descended from wealthy plantation owners who maintained a higher place in the system over poor whites. News of the revolution affected the classes differently. For the free blacks, who at first were denied citizenship along racial lines, wealth and importance were key in securing inclusion in the citizenry. Poor whites became antagonistic against their fellow French citizens. Slaves, however, were most impacted. Widely perceived as non-human and of inferior intelligence, slaves were deemed less than a person. The irony is that this perception caused most slave owners to speak openly about the happenings in France in front of their slaves, who were most definitely listening. They understood that, according to the Declaration of the Rights of Man, they should be free. This, coupled with rumors that Louis XVI had abolished slavery, gave rise to open insurrection. The population of the island was ninety-five percent slaves. On August 22, 1791, they rebelled. From their French masters the slaves understood notions of freedom. But they also “had known rape, torture, degradation, and, at the slightest provocation, death. They returned in kind” (James 1938, 88).

With the perception of the slave as subhuman and the French Revolution entering a dictator phase, the newly established republic would come under fire. Napoleon Bonaparte found himself fighting multiple wars across Europe, running short on supplies and thus needing money. Free labor was the easiest way to make his empire profitable. Attempting to restore order on the island, he sent troops to Saint Domingue, thereby pushing the Haitian Revolution into its second phase. The former slaves had already succeeded in their fight for freedom; now they fought for independence. After successfully rebuffing Napoleon’s forces, the formerly enslaved revolutionaries renamed the island Haiti, as it had been called prior to Columbus’ setting foot there more than three hundred years earlier. Unwilling to recognize Haitian independence, European powers refused to enter trade agreements with the island. Before its fight for freedom, Haiti supplied most of the tobacco and sugar circulating the Atlantic region. The boycott of Haiti was fueled by reactionary fears of fueling similar uprisings in other lands dominated by western imperialism, yet “to neglect the racial factor as merely incidental is an error” (James 1938, 283).

The foregoing sketch of two revolutions suggests that three preceding centuries of exchange and interaction had given rise to what can be understood as a Transatlantic World: a new region not based on notions of physical separation, political borders, or cultural homogeneity, but rather one arising from new mobilities and unprecedented subjugation, the pursuit of new economic opportunities, political domination and resistance, cultural heterogeneity and hybridity. The revolutions came toward the close of the eighteenth century, marking an end to the first era of the Transatlantic World. The nineteenth century ushered in a new era. One form of revolution ended, but another began. The working classes on both sides of the Atlantic began taking pride in their status as laborers, new insights blossomed on the notion of the enslaved. Shared cultures of the northern half of the Atlantic started to eye the southern hemisphere’s attachment to the slave trade as problematic, and thus abolitionist ideas began traversing the Atlantic. By 1888, slavery was abolished in the Transatlantic World through legislation, warfare, and cultural shifts. In the wake of Atlantic abolitionism came the formation of new states, such as Sierra Leone and Liberia, a response to the ever-changing landscape of the transatlantic that initiated a process of descendants of Africans attempting to settle in their ancestral land.

The Transatlantic World arose via a set of processes that perpetuates cycles that have repeated themselves since Christopher Columbus—that infamous Spanish-backed Genoese explorer—arrived in present-day Hispaniola. Today, much like then, a government is desperate for opportunities to broaden its economic horizons and allows an enterprising individual with advanced technology to usher in a new age of exploration. Might the critical inquiry of the Transatlantic World as a historical geographic region provide insight into how new post-continental regions might emerge, the promises and pitfalls their emergence might hold? Today, in echoes of earlier Atlantic revolutions, open rebellion seeks to overthrow racist systems of oppression and economic exploitation. How are currents and contours of Black Lives Matter and other social justice movements part of the transatlantic legacy, and how might today’s rebels learn from earlier Atlantic uprisings? Remaining oblivious to dynamics and forces that gave rise to the Transatlantic World as a historical geographic region, we are likely to sit by as the cycles of subjugation and insurrection repeat themselves.

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Ahmed T. Foggie is a lecturer at Humboldt State University in the Department of Geography, Environment, and Spatial Analysis. Before joining the faculty in spring 2020, he attended the University of Texas at Arlington, where he received a master’s degree in history. His area of focus is the Transatlantic World and its influence on modern culture. Drawing on his specialization, Foggie is designing a new course titled The Transatlantic World, which he is scheduled to teach in the spring of 2021. Approaching the Transatlantic as a historic region that has played a significant role in the formation of contemporary global society, the course will include the digital humanities.

Geographic Chronicles

March 10, 2020

Dear California geographers and friends,

Guided by an abundance of caution about the current outbreak of COVID-19 in the Bay Area, the California Geographical Society board has made the decision to cancel this year's conference, scheduled April 17-19 in Oakland. This decision was made both for the health and safety of attendees and the financial health of the CGS as an organization.

We are sorry to report this decision, as the annual conference is a highlight of our year, and an event we and so many other California geographers eagerly look forward to each spring. We hope you will understand and support our decision.

Our intention is to hold the 2021 conference in Oakland, and we are working with the venue to maintain current arrangements for next year.

For those who have already registered, we will refund your registration fees. Please contact Tiffany Seeley at cgsconferencereg@gmail.com to process your refund. Alternatively, you may donate your registration fees to the CGS to help us absorb some of the costs incurred by cancelling this event.

We are tentatively looking into hosting 2-3 informal regional mixers across the state to provide an opportunity for our members to meet together this year despite the cancellation of the conference. If you have any suggestions on where or when we could host these events, please don't hesitate to contact us

Kind regards,
Matthew Derrick (President)
Jenn Kusler (Vice President)
Zia Salim (Co-Treasurer)
Jodi Titus (Co-Treasurer, Past President)
Scott Crosier (Past President)
Stephen Koletty (Board Member)
Alison McNally (Board Member)
Tiffany Seeley (Board Member)
Ryan Koyanagi (SoCal Student Rep)
Ryan Miller (NorCal Student Rep)

June 6, 2020

Dear colleagues,

The governing board of the California Geographical Society (CGS) joins others in calling for a dismantling of racist structures and practices in this country. The killing of George Floyd, Ahmaud Arbery, Breonna Taylor, and countless other Black Americans is a consequence of the much larger backdrop of structural racism that upholds historical and current inequities. We issue this statement of solidarity with the acute awareness that the discipline of geography and our own organization have not dedicated enough effort to dismantle these structures within our own spheres of influence. We are committing ourselves to antiracism and will begin defining concrete steps of action at a special meeting later this month. We invite your participation and input.

Sincerely,
Matthew Derrick
CGS president
CGS governing board members

June 17, 2020

Dear colleagues,

On June 13, 2020, following its public statement of commitment to antiracism a week earlier, the governing board of the California Geographical Society (CGS) held a special meeting, open to the public, to begin an ongoing process of examining who we are as an organization and begin identifying concrete action we can undertake to match our stated commitment to antiracism.

With most of the board in attendance, along with many members of the broader CGS community, we held what we think was an open, honest discussion about our organization and discipline, in particularly asking the question of why we—as a membership body and more pointedly as a governing body—so poorly reflect the diversity found more broadly in California.

In previous public communication, we promised that our words would be paired with action. Coming out this Saturday's meeting, first, we agreed that this is only the start of an ongoing process—a portion of each board meeting will be devoted to reflection and assessment of our commitment to antiracism.

Second, we identified several points of action with synergistic ties to our annual conference, including the following:

- Being more intentional in selecting conference cities/sites in a manner that expands our scope to be more inclusive of people and groups who traditionally have not been made to feel welcome to geographic and other professional conferences. This step includes active community outreach and fostering local partnerships.
- Creating of a formal mentorship/cohort program for undergraduate students of color.
- Forming of a new conference award for "Research in Social and Environmental Justice."
- Devoting travel awards for undergraduate students of color.
- Organizing at panel discussions on social justice and equity in California geography.
- Holding a book club (via Zoom), inviting the full CGS membership to collectively examine antiracist scholarship, culminating in a panel presentation/discussion at the spring conference.

Third, we identified the follow action items to take place outside our annual meeting:

- Conducting a census on diversity of CGS membership, learning, authorship in *California Geographer*, who we are inviting to speak at conferences, etc.
- Forming a committee on equity in California geography.
- Developing a communication structure to coordinate with geography faculty at the community college, CSU, and UC levels on addressing issues related to social justice and antiracism within our discipline.

These are among the action items we intend to pursue moving forward. We invite your feedback and continued involved with the CGS as we move forward with action to match our stated commitment to antiracism.

Sincerely,
Matthew Derrick
CGS president
CGS governing board members