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Soundscape Mapping: Spatial Variability of Sound at Furman University

Alec Schindler, Introduction to Geographic Information Systems (GIS), Fall 2016

Introduction

Sound is an important and often undervalued resource. Many organisms depend upon sound and vocal communication in order to carry out everyday functions for survival. These functions include reproduction, foraging and prey detection, predator avoidance, group cohesion, and habitat selection. Looking at the soundscape as a whole is therefore very important in order to properly understand ecological processes and functions (Pijanowski et al. 2011). However, anthropogenic (human caused) noise disturbances often disrupt animal communication through frequency overlap, referred to as acoustic masking (Barber et al. 2009). Looking at the entire soundscape and studying its spatial variability can often give us important information about the health of the ecosystem. However, most previous studies only measure sound intensity, and are therefore limited in their depiction of the soundscape (Hong & Jeon 2014). Another tool for mapping soundscapes is SPreAD-GIS. This tool models sound propagation in an area. However, previous studies have only used it to evaluate the effects of noise pollution, but not applied it towards depicting the soundscape as a whole (Read & Mann 2012). I mapped the soundscape of Furman University's campus using sound intensity as well as many different soundscape indices in order to see how sound varied spatially and how landscape characteristics such as land cover and anthropogenic disturbances affected the soundscape. I used a combined approach of interpolating actual recording values and SPreAD-GIS modeling.

Methods

I used SM2+ automated recording units to record sound at 30 random locations across Furman University's campus. The recorders were set to record for 1 minute, on the hour for every hour in a 48-hour period, for a total of 48, 1-minute recordings per site. The site recordings took place between August and November 2016. I then used the soundecology package in R to calculate anthrophony, biophony, acoustic complexity index, acoustic diversity index, and acoustic evenness index for each recording. Anthrophony, or human-created sound, is the intensity of sound in the 0-2000 Hz frequency range. Biophony, or nonhuman biological sound, is the intensity of sound in the 2000-8000 Hz frequency range. Acoustic complexity is the variation in intensity of sound. Acoustic diversity is calculated by dividing the spectrogram into bins and taking the proportion of the signals in each bin above a threshold, and applying the Shannon index of diversity to these bins. Acoustic evenness is calculated the same way as acoustic diversity, but the Gini index of evenness is applied instead of the Shannon Index. I averaged the values of each of these soundscape indices per site in order to come up with an overall value for each index for each site. I joined a table of the resulting data to a shape file of Furman's campus boundary. I then interpolated the results across the entire campus using the spline interpolation method in order to get a continuous dataset of soundscape index values. I then created a map from the resulting raster file of the spatial variation of each soundscape index across the Furman University campus. I then used values from my recordings, land cover and elevation of the recording sites, and weather conditions from the time of my recordings to calculate sound propagation using the SPreAD-GIS toolbox in ArcMap. I added all the resulting raster files together to create one raster containing the entire baseline noise propagation, and one containing the noise propagation difference from background noise. I compared the soundscape maps to the noise propagation maps, a land cover map, and to the street locations to see if any of these factors affected the soundscape.

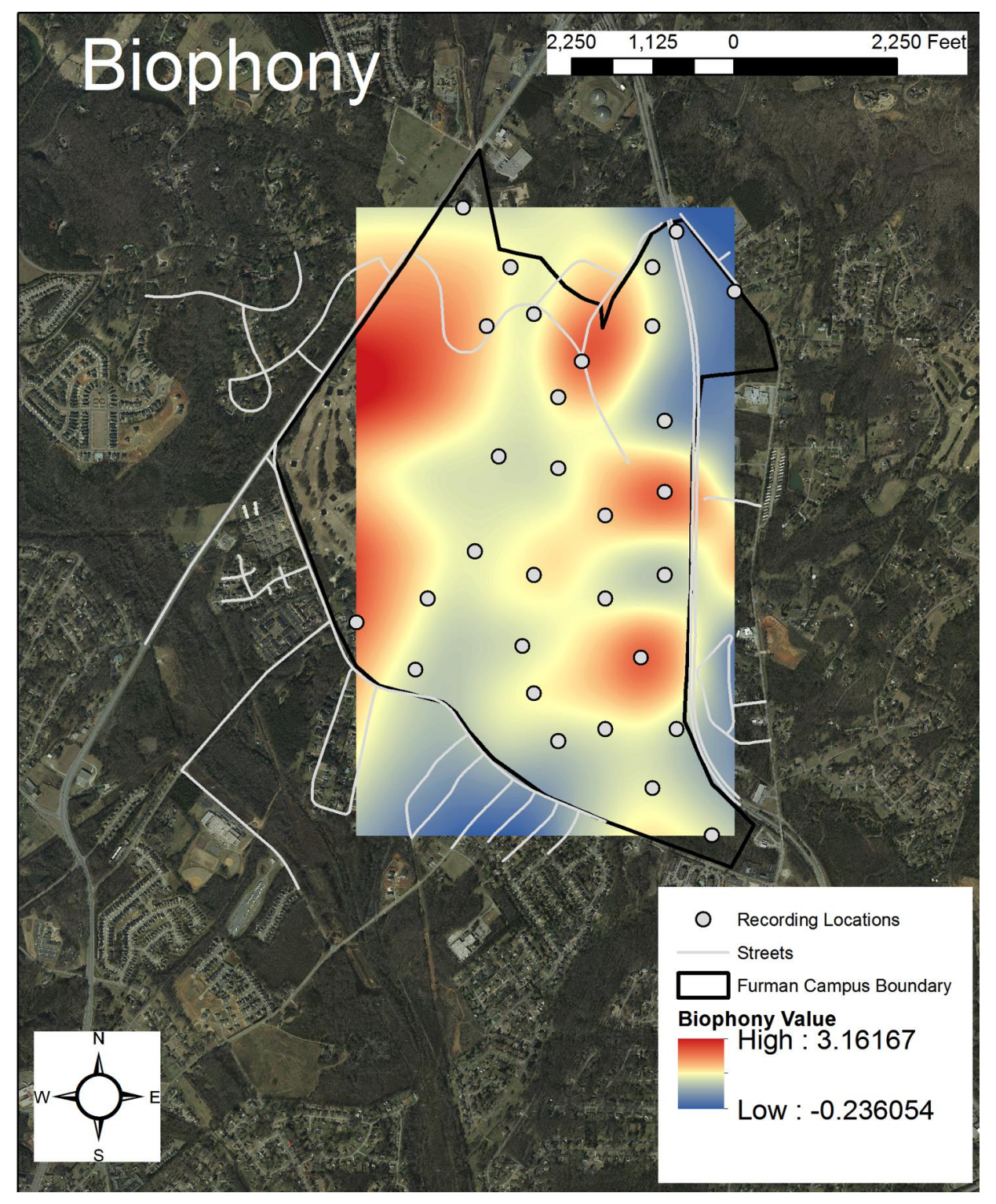
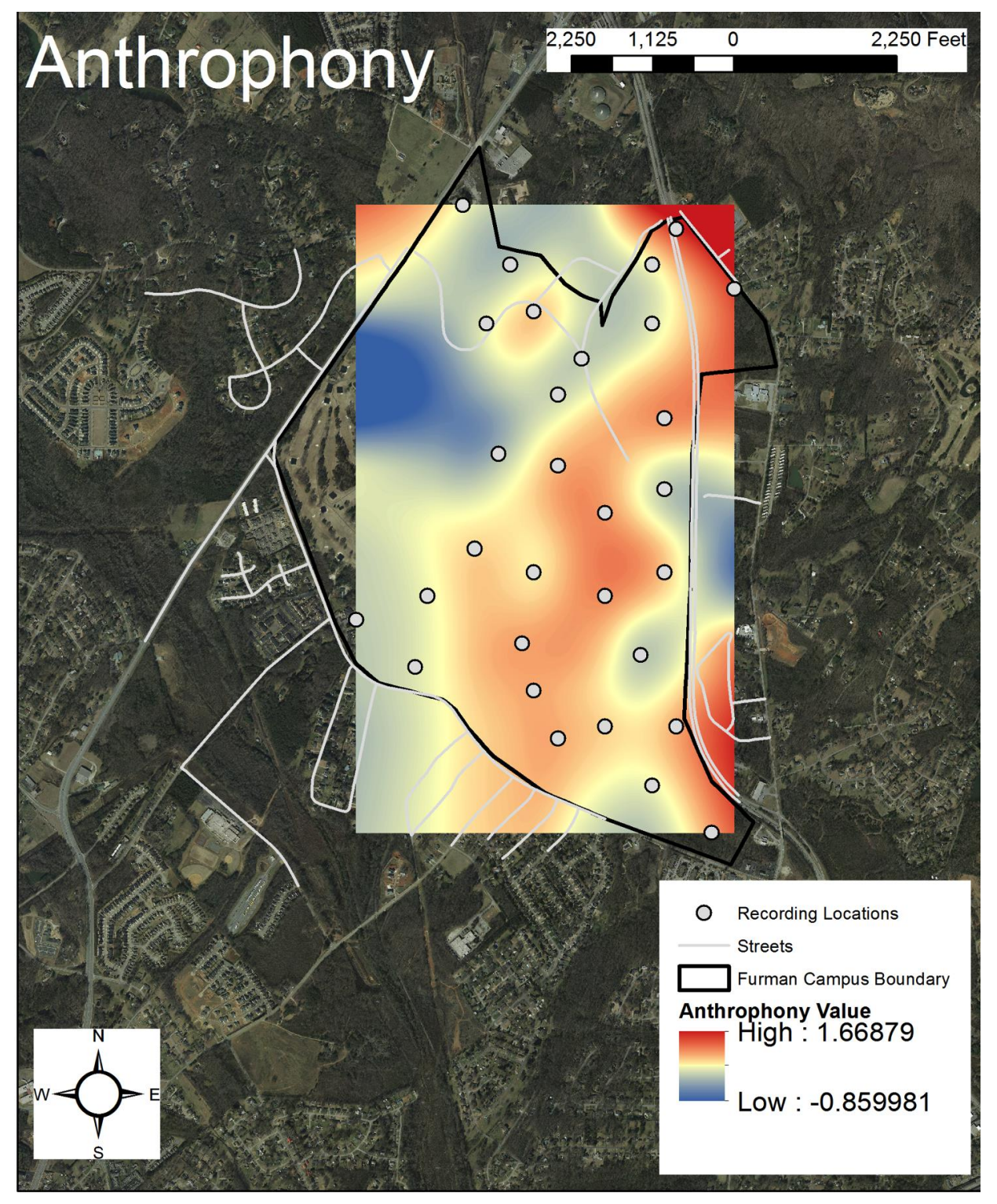


Figure 4 (above): This map shows the average biophony value from each recoding location. Values are interpolated across Furman University's campus using the spline method.

Figure 5 (below): This map shows the average anthrophony value from each recoding location. Values are interpolated across Furman University's campus using the spline method.



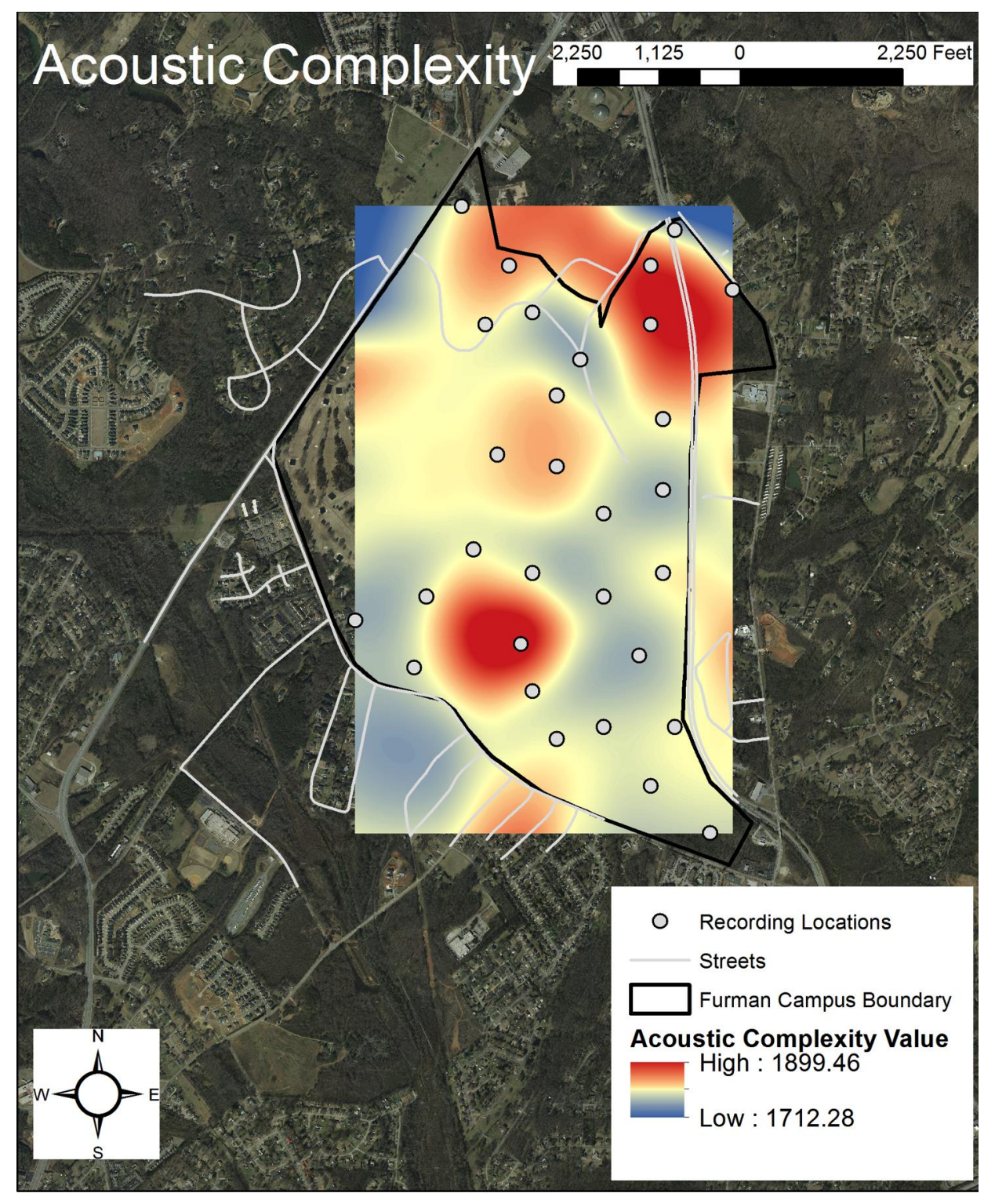
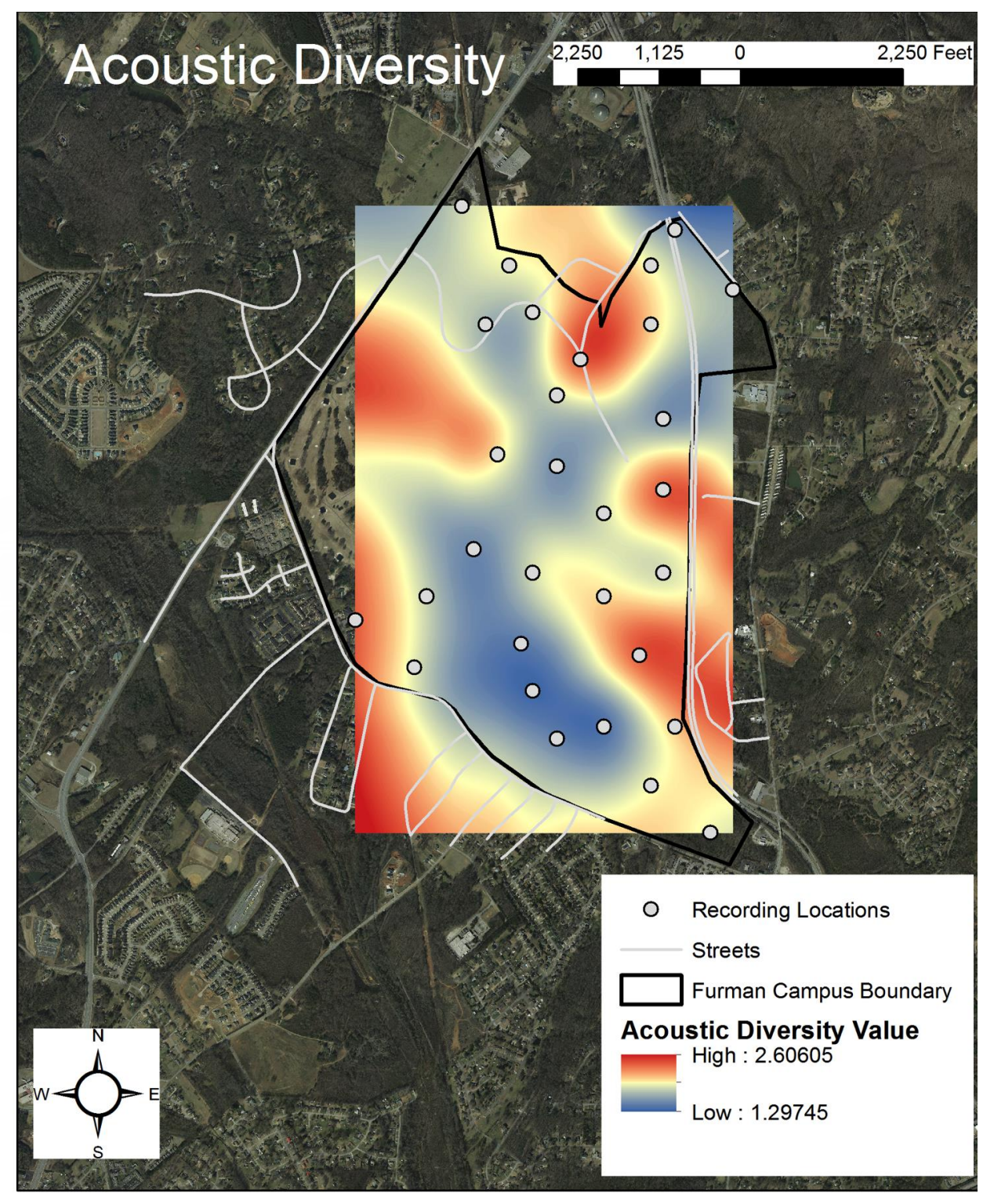


Figure 6 (above): This map shows the average acoustic complexity value from each recoding location. Values are interpolated across Furman University's campus using the spline method.

Figure 7 (below): This map shows the average acoustic diversity value from each recoding location. Values are interpolated across Furman University's campus using the spline method.



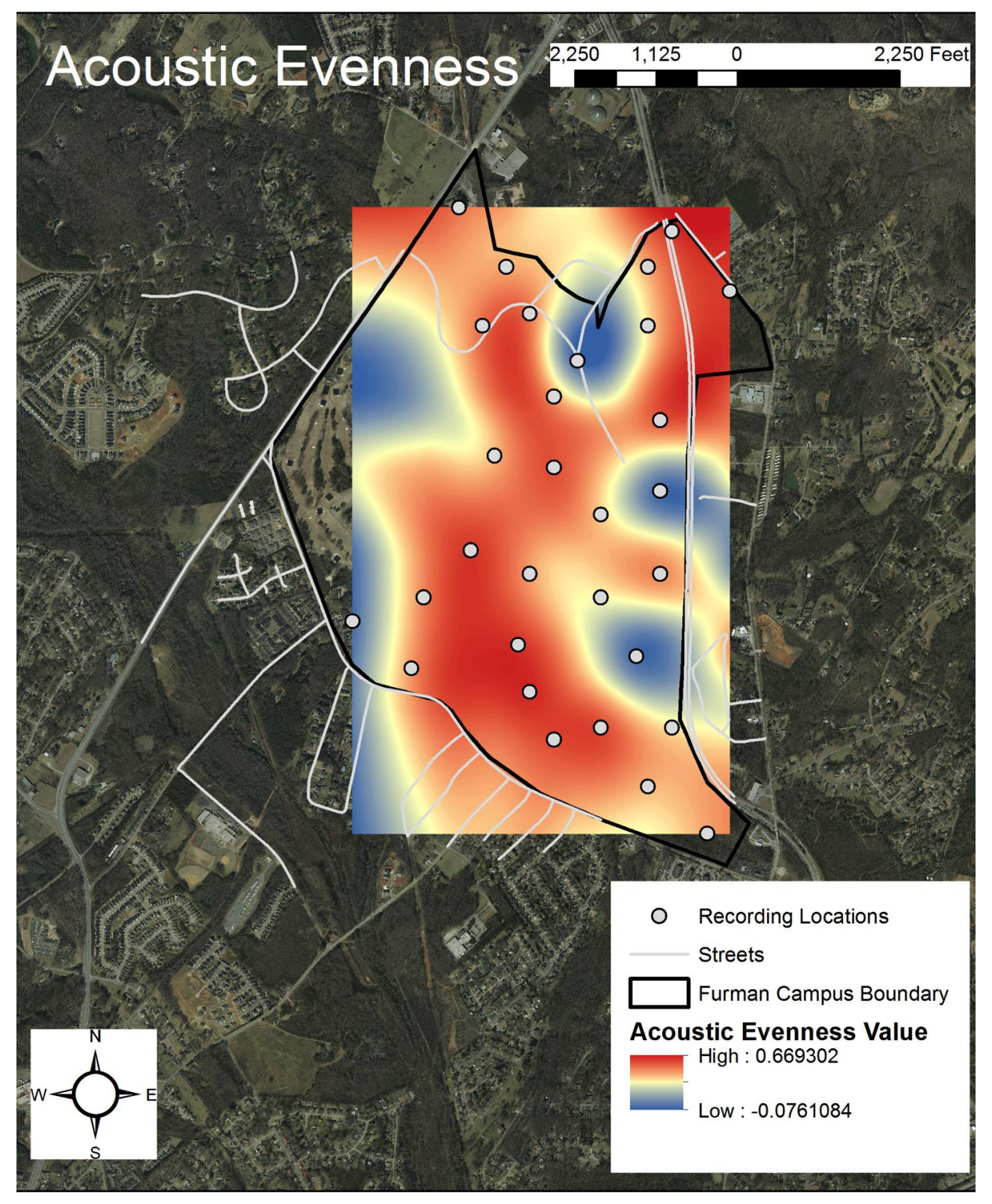


Figure 8 (above): This map shows the average acoustic evenness value from each recoding location. Values are interpolated across Furman University's campus using the spline method.

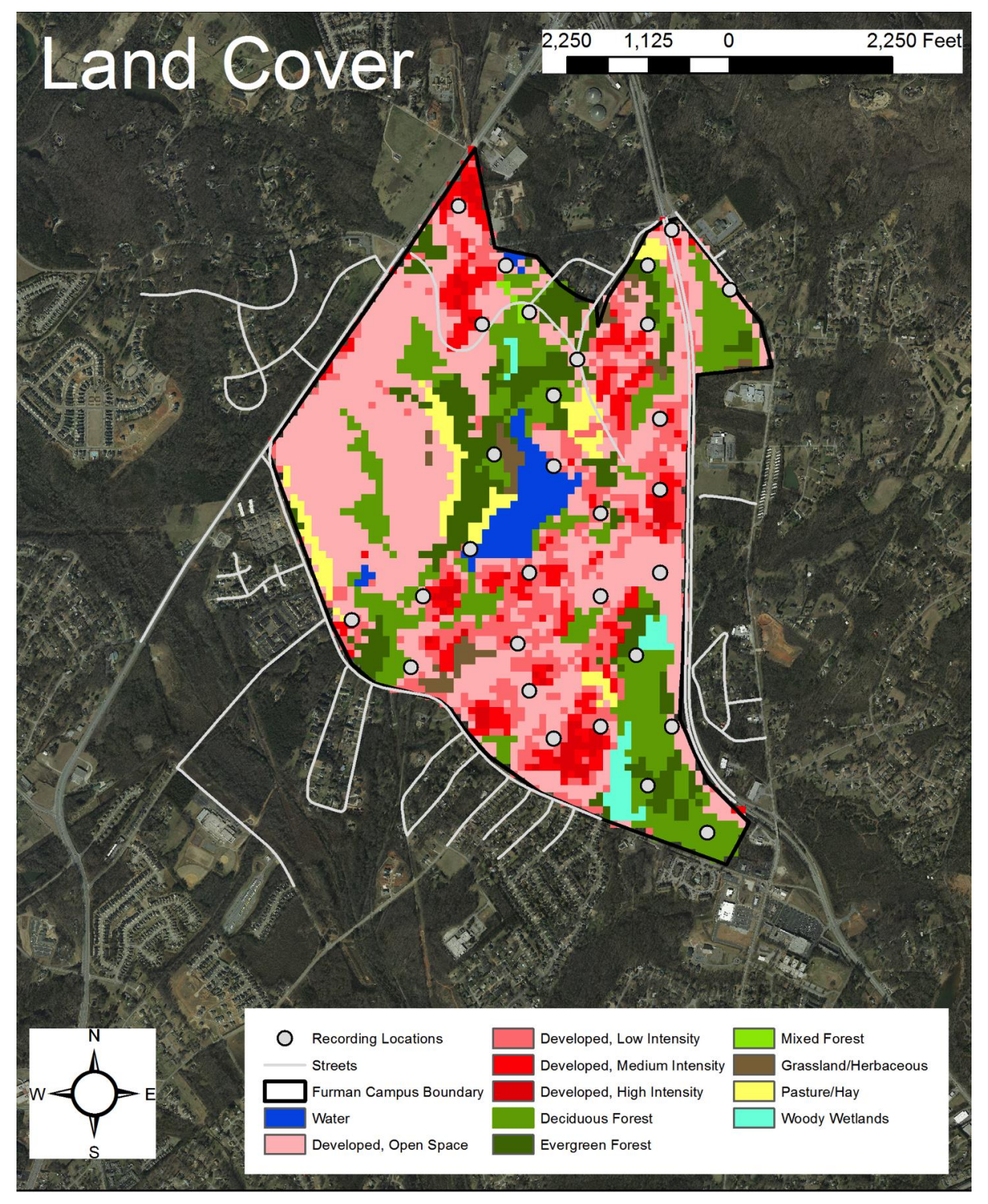


Figure 1: This map shows the types of land cover on Furman University's campus.

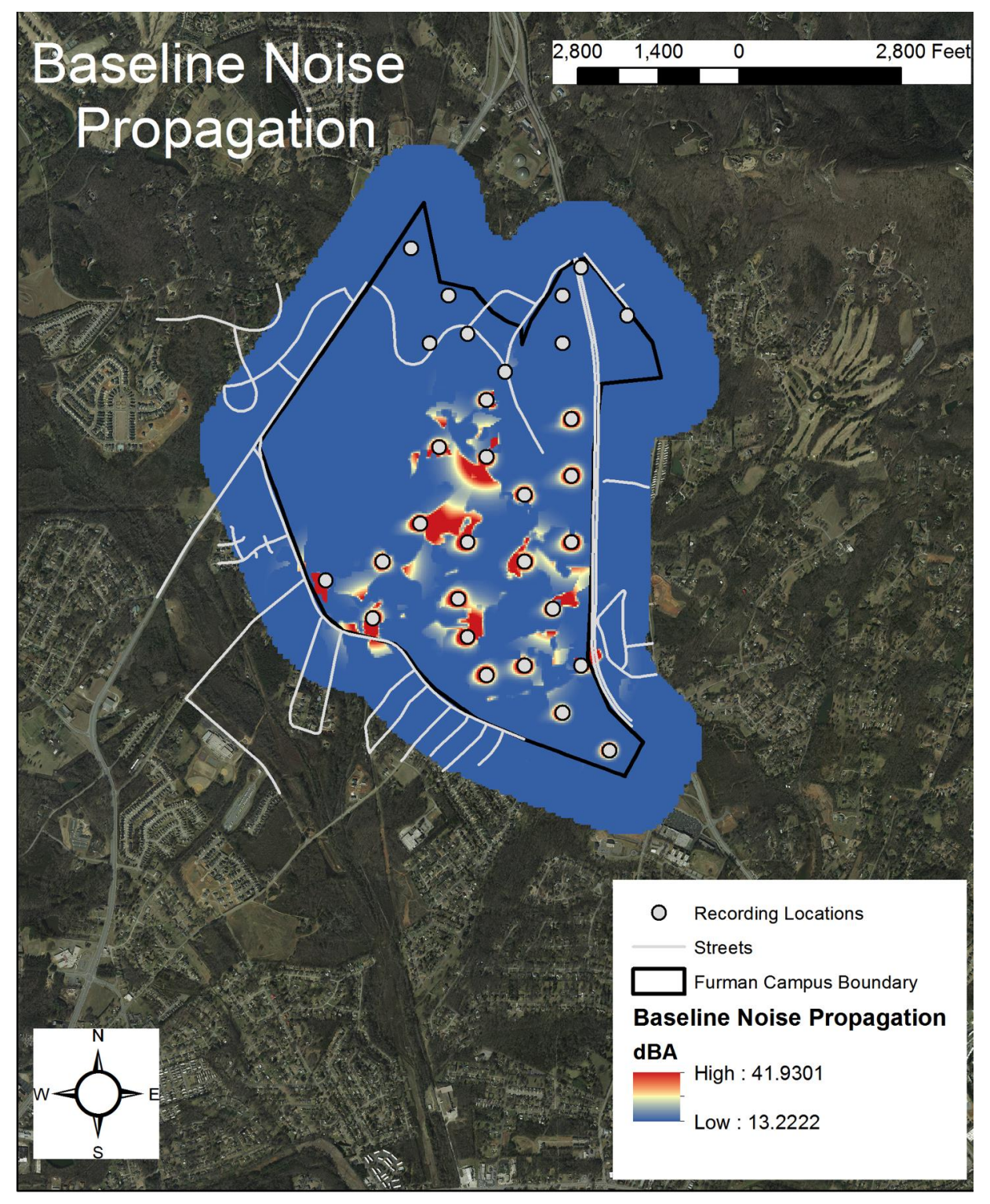


Figure 2: This map shows the predicted pattern of noise propagation from the recording locations. SPreAD-GIS was used to account for attenuation due to spherical spreading loss, atmospheric absorption, foliage and ground cover loss, upwind and downwind loss, and terrain effects.

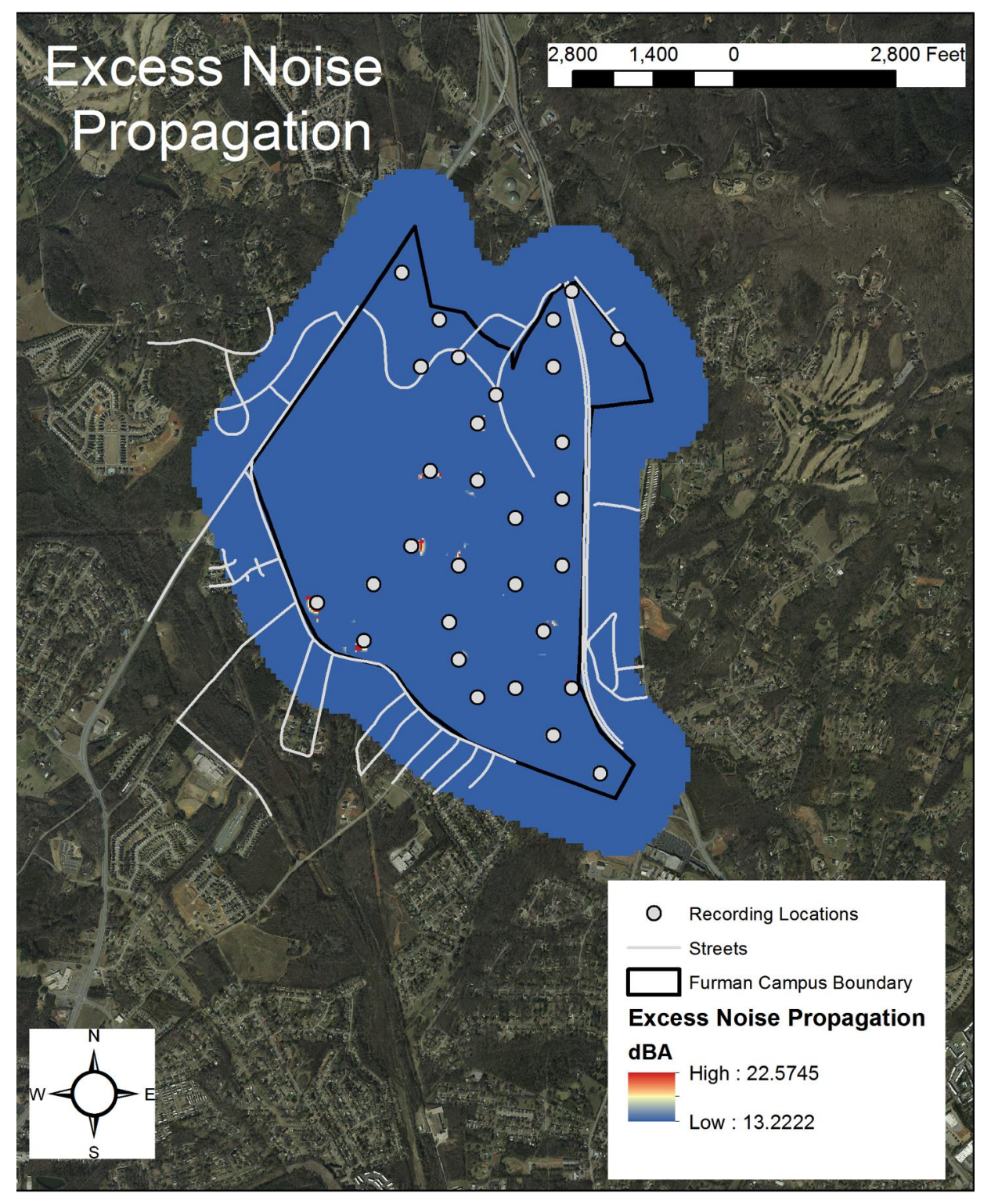


Figure 3: This map shows the difference between introduced noise and background sound levels. SPreAD-GIS was used to calculate this difference.

Results

There were several apparent spatial trends when comparing the distribution of soundscape index values in figures 4-8. Biophony generally was high in low areas of anthrophony, and anthrophony was high in areas of low biophony. This is interesting in that it suggests that anthropogenic sounds drive away biotic life, thus resulting in lower biophony levels. Acoustic diversity also was lower in areas of high anthrophony, and higher in areas of high biophony. It is therefore likely that biotic sounds are more diverse in their distribution of power across spectral frequencies. Acoustic diversity and acoustic evenness also generally had values inverse of each other. This is likely due to the relationship between how the Shannon diversity index and Gini evenness index are calculated. The SPreAD-GIS model in figure 2 generally showed that sound had high levels of propagation in the interior of campus. This is important, because these high propagation values allow the soundscape of the interior of campus to be susceptible to change by anthropogenic noise disturbances, such as roads, that generally occur around the edge of campus. With high propagation values, these anthropogenic noises are able to travel long distances throughout campus, causing changes to the soundscape. The SPreAD-GIS model in figure 3 also shows that ambient noises on campus greatly lower the ability of sound to propagate. When comparing the landscape cover of Furman's campus in figure 1 to the soundscape maps in figures 4-8, it is clear that land cover also greatly impacts the soundscape. Particularly interesting is the high biophony values found in some of the developed land on Furman's campus. This likely means that these areas, while developed, are still very suitable habitats for many biotic species. However, there are some limitations to my models. The soundscape index values were interpolated across Furman's campus to create a continuous set of data. However, a simple method of interpolation was used. In actuality, many factors such as land cover, weather, and elevation would need to be considered to properly interpolate these values. Future research could develop interpolation techniques similar to SPreAD-GIS to properly interpolate these values. The SPreAD-GIS model also has some limitations. The model requires each point to have the same source power level, and only models propagation for a specific set of conditions at one moment in time. Future research can improve the accuracy of this model and allow it to apply to more situations.

References

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Data Sources

All sound data was collected from Furman University's campus using SM2+ automated recording units between August and November 2016.

Land cover data from NLCD 2011.

Elevation data from USGS Elevation Dataset

All maps developed using Environmental Systems Research Institute (ESRI) ArcDesktop, 10.4.1.

Acknowledgements

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