Forensic Science International 281 (2017) 67–74

Contents lists available at ScienceDirect

Forensic Science International

journal homepage: www.elsevier.com/locate/forsciint

Utilizing Geographic Information Systems (GIS) to analyze geographic and demographic patterns related to forensic case recovery locations in Florida

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ARTICLE INFO

Article history:
Received 22 October 2016
Received in revised form 31 August 2017
Accepted 11 October 2017
Available online 20 October 2017

Keywords:
GIS
Recovery of human remains
Florida

ABSTRACT

This paper highlights how Geographic Information Systems (GIS) can be utilized to analyze biases and patterns related to physical and cultural geography in Florida. Using case recovery locations from the C. Addison Pound Human Identification Laboratory (CAPHIL), results indicate that the majority of CAPHIL cases are recovered from urban areas with medium to low population density and low rates of crime. The results also suggest that more accurate record keeping methods would enhance the data.

1. Introduction

GIS utilizes geospatial analysis to provide information about the physical and cultural environment in which humans live [1]. Regarding forensic science, GIS has been utilized to predict high crime areas, pinpoint locales with a specific type of crime, such as gun violence or drug dealing, in order to promote more effective police intervention, map the locations of human rights violations, predict the location of mass graves, assess the minimum number of individuals (MNI) and patterns of skeletal element distribution and to analyze the relationship between human recovery locations [2–11]. For the purposes of this research, the authors were interested in utilizing GIS to examine how geographic and demographic factors, such as topography, population density and crime rates, affect the spatial distribution of the forensic anthropology cases that are analyzed by the Director and the CAPHIL analysts at the University of Florida.

Forensic anthropology is the application of biological anthropological and archaeological methods, principles, and theory in a medicolegal context. While forensic pathologists examine all human remains under their jurisdiction, forensic anthropologists traditionally consult on burned, fragmentary, and decomposed individuals (e.g., mummified and/or skeletonized). However, the modern purview of forensic anthropology has expanded beyond these scenarios [12]. As a forensic anthropology laboratory, the CAPHIL consults with Medical Examiner's offices and law enforcement agencies in the analysis of human remains. The CAPHIL assesses a decedent's biological profile (age, sex, ancestry, stature) and other individualizing skeletal traits (pathological conditions, antemortem trauma, anomalous skeletal variation), as well as the presence of perimortem trauma. In addition, the CAPHIL assists investigative agencies in search and recovery operations.

A previous study focusing on Louisiana case recovery locations suggested that selective bias existed in regard to when and where perpetrators were mostly likely to dispose of human remains [6]. Though Florida and Louisiana share geographic and climatic similarities, that is not reason enough to believe that case recovery location biases found in Louisiana would be the same in Florida. Thus, the authors propose that forensic anthropology laboratories, such as the CAPHIL, should evaluate the recovery locations of their respective territories to see how the physical and demographic environments influence biases and patterns in where their cases are recovered. Should patterns in the recovery location data emerge, it might be possible to model the data to predict the most likely case recovery locations. Evaluating this data also allows forensic practitioners to assess their own preconceived notions about where human remains are mostly likely to be recovered.

Although the authors were concerned with any and all information dealing with patterning related to Florida case recovery locations, to assess whether our understanding of where human remains were most likely to be recovered was accurate this

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https://doi.org/10.1016/j.forsciint.2017.10.014
0379-0738/

study examined three predictive hypotheses. It was hypothesized that the majority of the human remains analyzed by the CAPHIL would be recovered from rural areas. This hypothesis was partially based on the idea that decedents recovered from urban areas with high population density would be recovered quickly and therefore retain enough soft tissue characteristics for detailed examination by the medical examiner. Therefore the expertise of a forensic anthropologist would not be required. Individuals recovered from more remote locations, such as swamps and heavily wooded areas, would afford more opportunities for concealment, thus making them better places to dispose of a body. The prolonged concealment provided by these rural areas would extend the post mortem interval (PMI) allowing for partial, if not full, skeletonization to take place, necessitating the involvement of trained forensic anthropologists to aid law enforcement in identifying the decedent and assessing the remains for evidence of peri- and postmortem trauma.

Rural locations are also often areas of low population density. Lower population density reduces the probability that an individual will stumble upon the grave site and reveal evidence of a crime, allowing for decomposition or full skeletonization of the decedent. Advanced decomposition or skeletonization would make the involvement of the CAPHIL more likely. Therefore, it was hypothesized that the majority of case recovery locations would be situated in areas of low population density.

Lastly, it was hypothesized that individuals would be more likely to be recovered from areas with high rates of violent crime. For the purposes of this research, high crime is denoted as 50 murders or more and 50,000 uniformed police reports written annually. The idea behind this hypothesis was that people would be more likely to be murdered and eventually be analyzed in the CAPHIL laboratory in areas with greater amounts of violent crime.

2. Materials and methods

To evaluate physical and cultural geographic patterns related to the CAPHIL case recovery locations, 92 cases spanning over a five year period (2007–2012) were selected for geolocation in ArcGIS® 10.1. This particular five year time period allowed the authors to assess approximately 500 cases in order to search for forensic cases that has enough georeferenced data to fit all of the perimeters of the study. Assessing cases over this five year period also provided a more robust dataset than a dataset that included a shorter time interval. Furthermore, assessing case recovery locations over this particular five year period provided the authors with enough data to allow them to evaluate their own notions about where human remains that fall under the purview of the forensic anthropologist are most likely to be recovered. ArcGIS® was chosen because it is widely available, has the necessary capabilities and it is the GIS program with which many anthropologists are most familiar.

In order for a case to be included in this analysis, the recovery location had to be sufficiently complete for georeferencing using ArcGIS® software, the case had to be located in Florida and the recovery had to yield human remains. For georeferencing purposes, recovery locations could be either physical addresses or GPS points. All cases without a fixed location or with vague, often landmark-based, descriptions were excluded. CAPHIL consults on anywhere from 75 to 100 cases a year. This means that only around a fifth of the available cases assessed by the CAPHIL possessed all of the necessary perimeters for inclusion in the study. Moreover, though the CAPHIL sometimes consults on cases in other states, due to the fact that a vast majority of the laboratory's cases come from within the state, case recoveries located outside of Florida were excluded.

This analysis also does not include any site searches where remains were not recovered. Additionally, cases that only involved the recovery and identification of non-human remains and private cases, such as consultations involving privately cremated remains that were not commissioned by law enforcement personnel, were also excluded.

Data layers were either constructed by the authors or obtained from government databases that contained pre-existing raster and shapefiles. Existing raster and shapefile data layers were collected from the Florida Geographic Data Library (FGDL). The FGDL serves as an archive for GIS map data created by state and federal institutions, such as the Florida Fish and Wildlife Conservation Commission and the United States Census Bureau.

As one of its components, ArcGIS® is equipped with a feature that allows the user to input addresses from a database file and use those addresses to create a point feature class data layer (Fig. 1). These points representing case recovery locations were then overlaid onto map layers of physical land cover (forest, hammock, swamp, agricultural land, etc.), population density and crime rate (Figs. 2–5). To evaluate case locations by Medical Examiner District rather than county, the counties that make up a particular district were merged into a single map element using the ArcGIS® merge tool (Figs. 6 and 7).

For ease of analysis and to create more meaningful categories, some of the data contained in the map features was aggregated. For example, population density was considered low if the area contained less than 300 people per square kilometer (km^2), medium if it contained 300–1000 people per km^2, and high if it contained over 1000 people per km^2. Similarly, crime rate data was aggregated based on the number of murders per year per county and the number of uniformed police reports filed (the police report index or PRI) per county per year. For instance, a county's crime rate would be considered very low if it had a murder rate of less than four murders per year and/or a PRI of under 3000, while a county with a very high crime rate would display over 100 murders per year and/or a PRI of over 77,000. Regarding landcover, the original landcover map of Florida contained 43 classes of data which were reclassified to 18 major landcover classes (Fig. 8). While this type of aggregation allows some of the finer details in a map layer to be lost, it also facilitates visual and statistical assessment of the relationship between recovery locations and the surrounding environment.

The data were assessed using descriptive statistics and chi-square non-parametric methods. Chi-square tests are utilized to assess whether significant differences arise between expected frequencies and observed frequencies in one or more categories of

Fig. 1. Georeferenced point data layer in GIS after conversion from database.

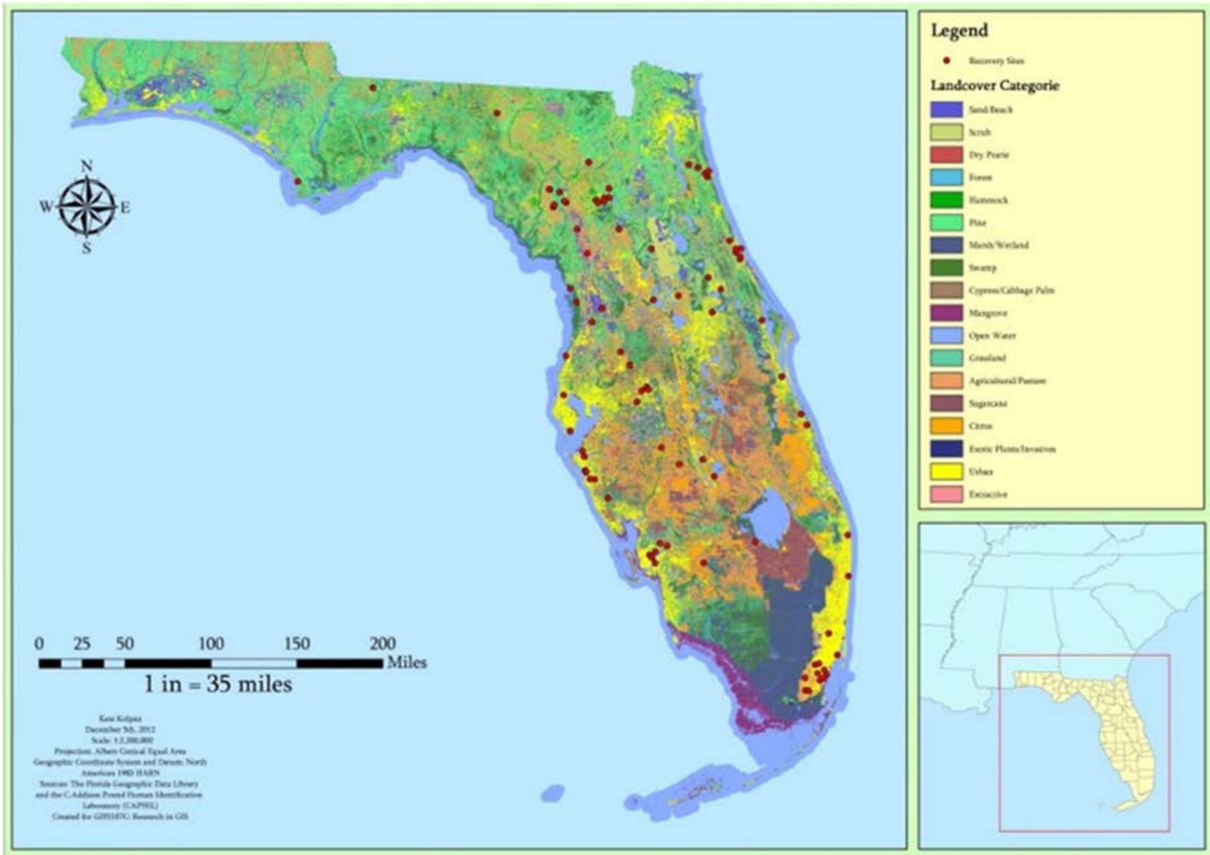

Fig. 2. CAPHIL case recovery locations correlated with landcover.

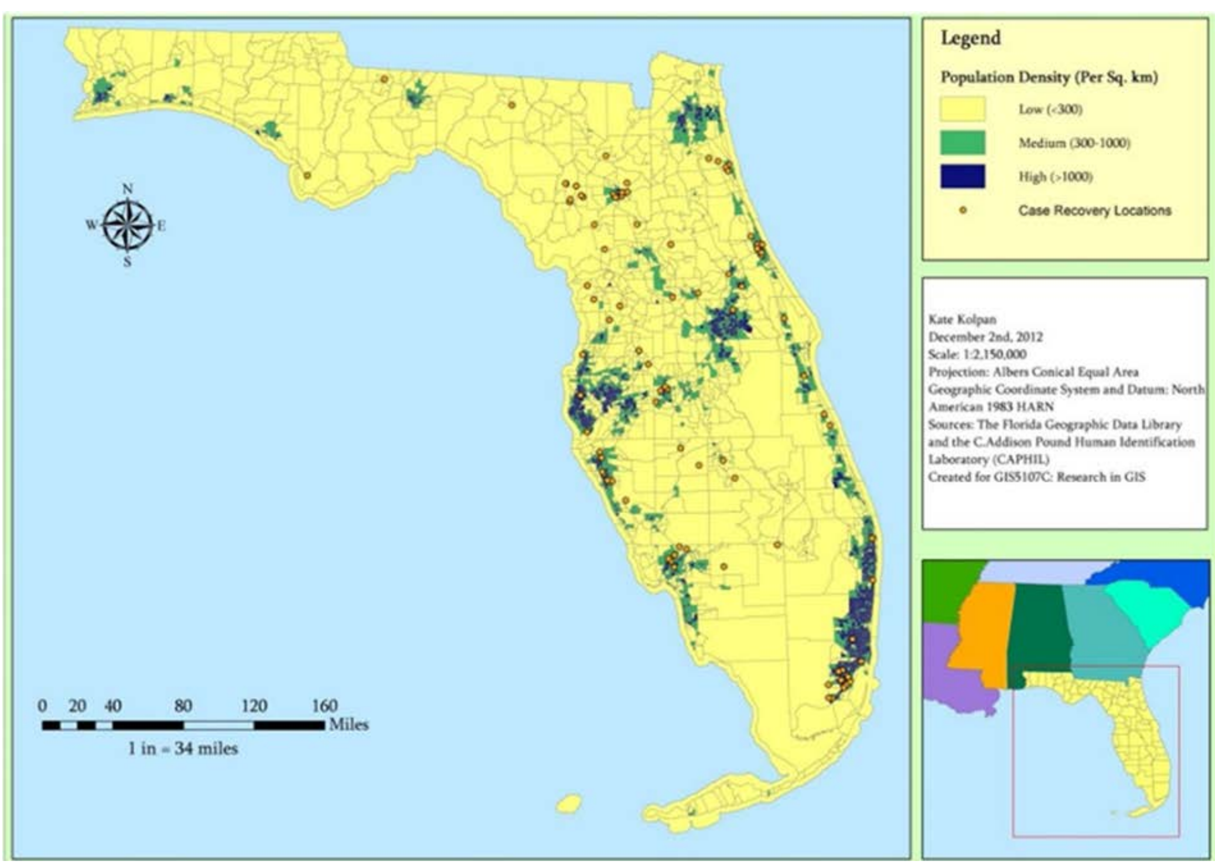

Fig. 3. CAPHIL case recovery locations correlated with population density.

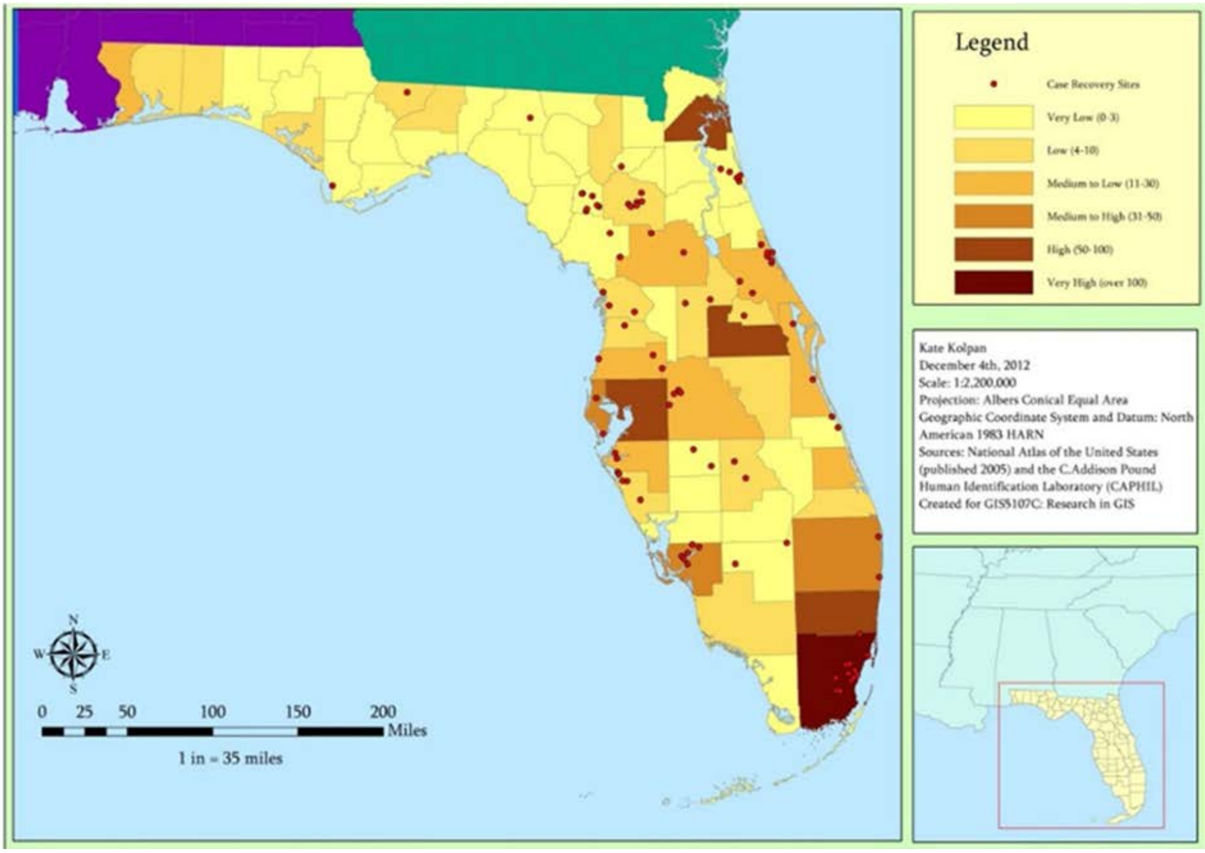

Fig. 4. CAPHIL case recovery locations correlated with murder rate.

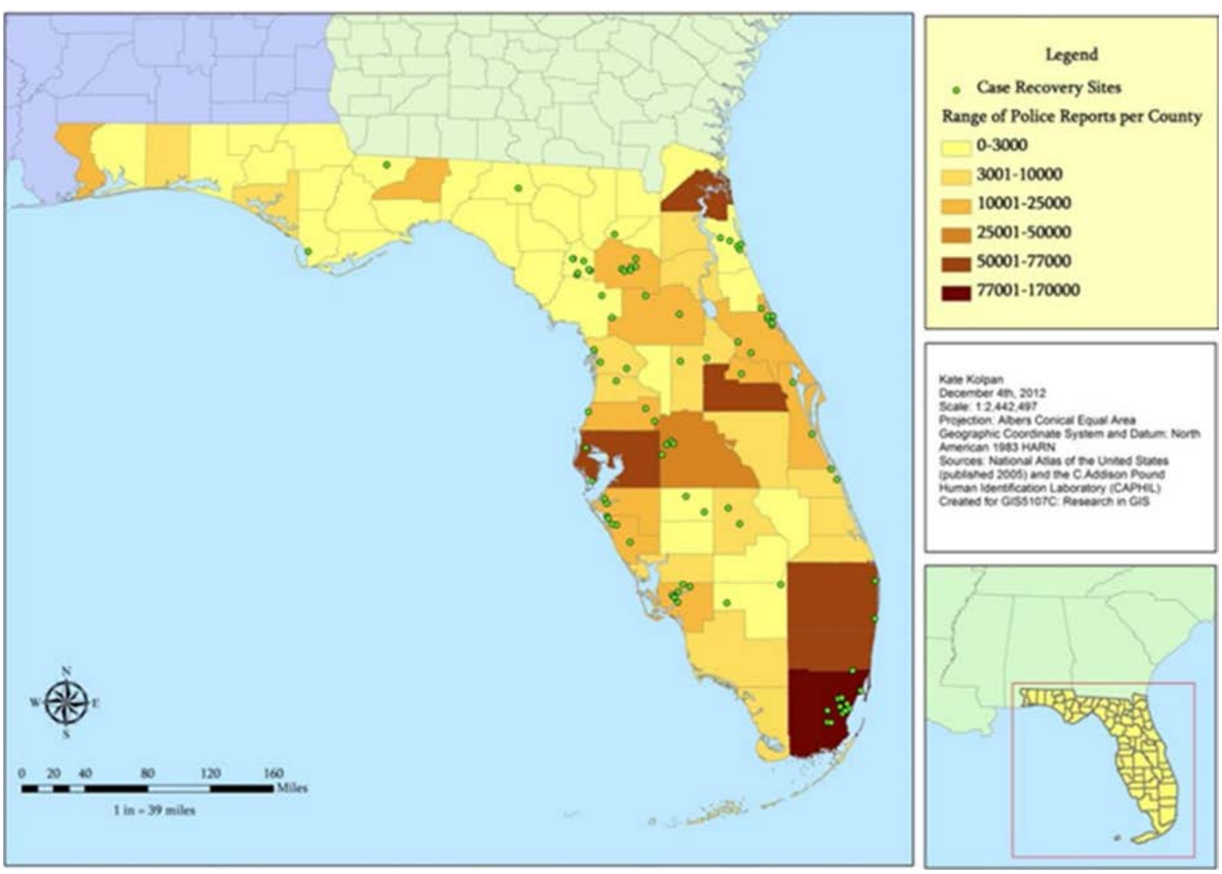

Fig. 5. CAPHIL Case Recovery Locations correlated with police report index.

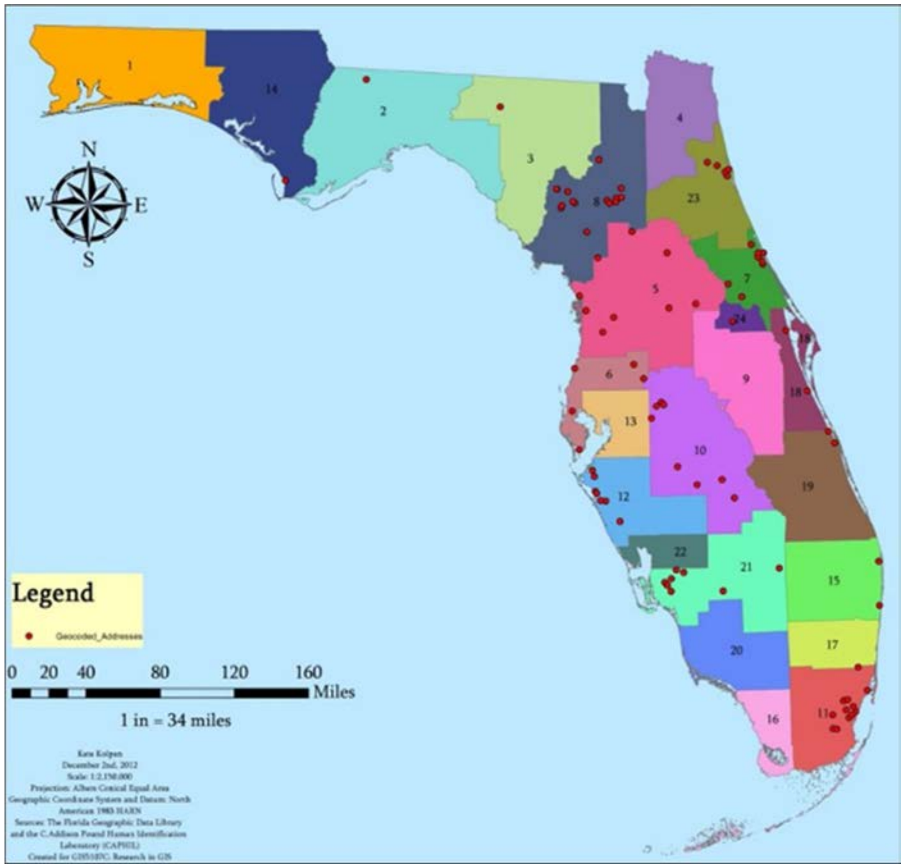

Fig. 6. Map of case recovery locations by medical examiner district.

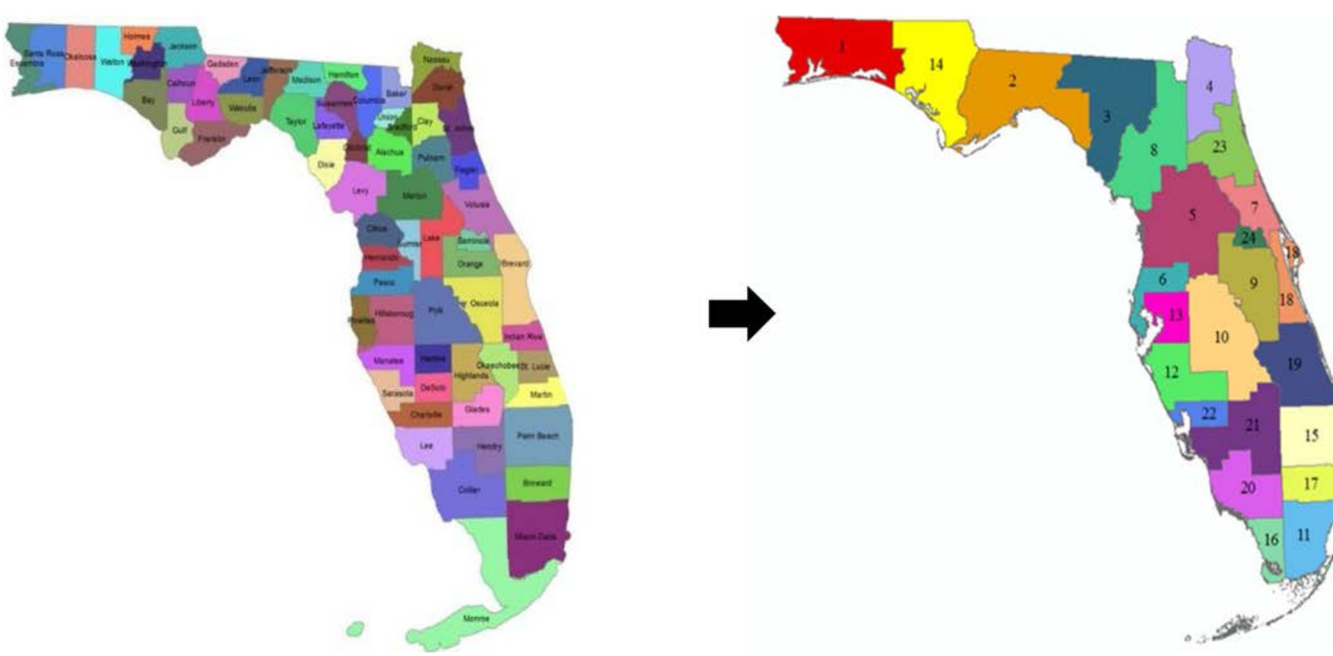

Fig. 7. GIS merge of counties to create map of medical examiner districts. Original map courtesy for the FGDL.

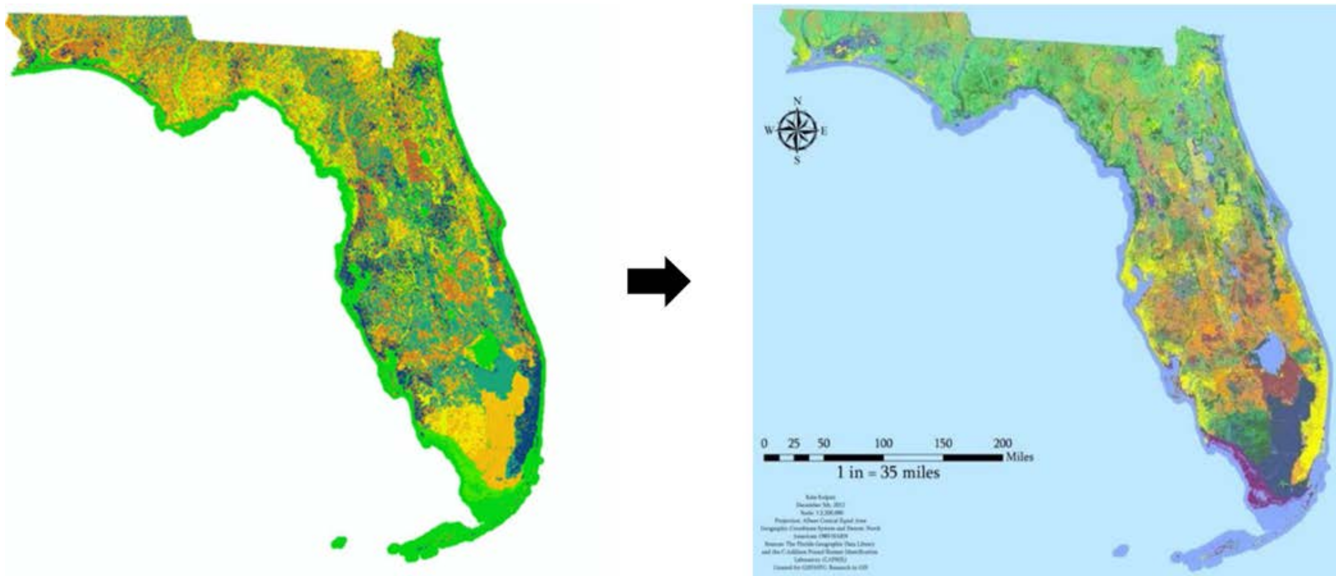

Fig. 8. Reclassification of landcover classes. Original map courtesy of the FDL.

data. Chi-square tests were employed to assess whether the differences between specific classes of nominal data as recorded by the categories utilized in creating the GIS maps, such as population density or land cover, were statistically significant.

3. Results

The results of overlaying georeferenced cases onto map layers of physical landcover, population density and crime rate indicate that for the five year period examined, the majority of cases brought to the University of Florida were recovered from designated urban areas, were found in areas of low population density and were recovered from areas with very low to medium crime rates (a PRI of less an 25,000 reports filed annually; less than 30 murders annually) (Tables 1–4). For the cases included in this study, the CAPHIL received the largest percentage of its cases from law enforcement in District 8 (19.6%), followed by District 11 (13.0%) and District 21 (10.9%) (Table 5).

Regarding landcover, 77% of the georeferenced cases were recovered from designated urban areas (Fig. 9). Chi-square tests revealed a statistically significant difference between types of landcover ($\chi 2 = 1.15572 \times 10^{-83}$, $p < 0.0000$). When all other landcover values were aggregated and compared to the urban area data, the chi square results indicated a statistically significant difference between the number of cases recovered from urban environments and those recovered from all other types of landcover ($\chi 2 = 1.85951 \times 10^{-07}$, $p < 0.0000$).

However, though a large majority of these georeferenced cases come from areas that are classified as urban, that does not make them synonymous with high population density. In fact, according to the data, almost half (48%) of these cases were recovered from areas with low population density (Fig. 10). Chi-square results indicated that there was a statistically significant difference between areas with low, medium and high population densities ($\chi 2 = 0.00965$, $p < 0.0000$), with an increased likelihood of recovering a body from an area of low population density.

Regarding the relationship between crime rates and the selected cases, the results indicate that 78% of cases were recovered from areas with an annual PRI of less than 25000 and that 75% of cases were located in areas with medium to very low

Table 1
The number of case recovery locations by landcover type.

Landcover type	Number of cases
Urban	71
Agricultural/pastureland	8
Scrub	1
Forest	3
Dry prairie	1
Hammock	2
Marsh/wetland	3
Pineland	2
Citrus	1

Table 2
The number of case recovery locations by population density.

Population density (per km^2)	Number of cases
Low (<300)	44
Medium (300–1000)	27
High (>1000)	21

Table 3
The number of case recovery locations by murder rate.

Murder rate	Number of cases
Very low (0–3)	23
Low (4–10)	23
Medium to low (11–30)	23
Medium to high (31–50)	11
High (50–100)	0
Very High (>100)	12

Table 4
The number of case recovery locations by Police Report Index (PRI).

PRI crime rate	Number of cases
0–3000	22
3001–10000	12
10001–25000	38
25001–50000	5
50001–77000	2
77001–170000	14

Table 5
The number of case recovery locations of medical examiner district.

Medical examiner district	Number of cases
1	0
2	1
3	1
4	0
5	9
6	4
7	9
8	18
9	0
10	8
11	12
12	7
13	0
14	1
15	2
16	0
17	0
18	1
19	1
20	0
21	10
22	0
23	7
24	1

murder rates ($\leq$30 murders or less) (Figs. 11 and 12). Chi-square results indicated that there was a statistically significant difference between areas that had an annual PRI under 25000 and areas that had an annual PRI over 25000 ($\chi^2 = 1.85951 \times 10^{-07}$,$p < 0.0000$), with cases being more likely to be recovered from areas with an annual PRI under 25000. Within those areas designated medium to low in terms of murder rate, 66.7% of human remains were recovered from areas that had 10 murders or less annually. When areas with very low to medium murder rates were compared to areas with medium to very high murder rates, chi-square analysis indicated that there was a statistically significant difference ($\chi^2 = 1.62001 \times 10^{-06}$, $p < 0.0000$).

4. Discussion

Georeferenced results indicated that the decedents analyzed by the CAPHIL over this five year period were far more likely to be recovered from areas classified as urban, negating the hypothesis that the majority of recovered cases would be found in rural areas that afforded a lot of landcover. Interestingly, recovery from an urban location does not imply high population density due to the fact that the majority of these decedents were recovered from locales with low population density. It is possible that these decedents were brought to the CAPHIL for analysis due to the fact that low population density within these urban areas provided fewer opportunities for discovery of the decedent, allowing the individual to decompose.

These findings negate the authors' preconceived ideas that decedents deposited in urban areas would be recovered quickly enough to retain the majority of their soft tissue and, therefore, would be examined and identified by the medical examiner's office. The results may also suggest that perpetrators do not go to great lengths to transport the bodies of decedents to remote locations in order to conceal evidence of murder. However, there is also the possibility that these individuals were not victims of crime, but rather individuals who died of natural causes and had the misfortune of not being discovered until their remains had decomposed, necessitating the biological profile expertise of a CAPHIL forensic analysis. Additionally, it is also possible that more CAPHIL cases were recovered from urban environments simply because the bodies were easier to locate. Even an urban area with low population density is likely to have more people than a remote forest or swamp, making the odds of stumbling upon a body more probable, creating a bias in recovery location.

It is also possible that remote recovery locations are actual better represented among the CAPHIL's cases, but are under-numerated due to a lack of locational data and vague record keeping practices. While georeferencing cases does provide an overall pattern of where the CAPHIL cases are recovered, certain types of environments are underrepresented due to location constraints. For example, the CAPHIL received multiple cases from the Ocala National Forest during the time period covered in the study. The Ocala National Forest is a heavily wooded, sparsely populated area, making it quite distinct from the urban areas that form the bulk of this sample. Unfortunately, the human remains recovered from the Ocala National Forest could not be utilized because their locations were either listed as the forest itself or as vague landmarks within the forest. The authors suspect that the lack of locational details, particularly for remote areas, such as swamps, forests and waterways (see below), is a widespread problem for forensic practitioners. Utilizing the Global Positioning System (GPS) in the field would provide more exact information about the recovery location of human remains in remote areas and provide forensic anthropologists with more comprehensive data with which to assess patterning.

The same is true of remains recovered from open water. Florida is surrounded by water on three sides. However, it is often difficult to provide an address for remains recovered from open water. In the current study this affected some counties more than others. District 16, the district representing Monroe County, which contains both the Everglades and the Florida Keys, has many waterways and a preponderance of open water access. The CAPHIL received remains from District 16 during the period of analysis, however the vague locations listed with these open water case locations prohibited their inclusion in the current GIS study. Though Florida has more open water than most states, other states with long coastlines, such as California, or a large proportion of lake and/or river systems, such as Michigan, may be likely to undernumerate the amount of bodies recovered from waterways as well, hence the need for better georeferencing. Providing more comprehensive data about the location of bodies recovered from water, particularly if the original location of death is known, could potentially allow forensic researchers to track the trajectory of the body as it traveled down a waterway. This would be useful for conducting search and recovery missions and for understanding the taphonomic processes the remains may have encountered as they traveled along the waterway.

There are also medical examiner districts with large population areas, such as District 4 which includes Jacksonville, and District 9 which includes Orlando, that appear to lack representation from the CAPHIL. However, rather than having to do with GIS methodology and the limitations of georeferencing, this is due to the fact that certain Florida medical examiner districts are the responsibility of other forensic anthropologists. The CAPHIL does not usually receive cases from Districts 1, 4, 9, 15 and 17, which is the reason that most of these counties contain no georeferenced points.

The largest number of cases included in this study were recovered from District 8. This result is unsurprising because the CAPHIL is located in District 8 and the laboratory has strong ties to local law enforcement. The Medical Examiner District with the second largest number of case recoveries at the CAPHIL is District 11. This likely has to do with the fact that District 11 is comprised of Dade County which includes the Miami Metropolitan Area (MMA), the most populous urban area in Florida and one of the largest urban population centers in the United States.

Regarding the potential patterning of the CAPHIL case recovery locations and areas of violent crime, the georeferenced sample did not support the hypothesis that these individuals were recovered from high crime areas. A possible explanation for this result is that the majority of these cases were recovered from areas of low population density and therefore may have lacked the requisite number of people to be considered a high crime area based on PRI or murder rate. Moreover, the location of the recovery of human remains is not always synonymous with the location of the decedent's death, making it possible that these individuals died in more dangerous areas and were transported to less populous areas with lower rates of crime. Confessions, witness testimony and court documents detailing the location of the murder could be compared with the location of the recovery site to provide more information about whether these individuals had been transported from more populous areas to less populous locations. As with the first hypothesis, there is also the possibility that many of these decedents died naturally and the discovery of their remains was simply delayed. Therefore, these individuals were not victims of violence.

5. Conclusions

In terms of distinguishing patterns of case recovery locations for decedent's analyzed by the CAPHIL, GIS has proved itself to be a powerful tool. In the cases of the CAPHIL case recovery locations, GIS analysis suggests that the CAPHIL cases are most likely to arrive from urban areas of low population density with a PRI of under 25,000 and a medium to low murder rate. However, it is best to exercise caution when relying on the results of GIS due to the fact that many of the cases recovered by the CAPHIL over this five year period could not be georeferenced due to their extreme isolation and/or vague record keeping. In order to increase accuracy and better understand case recovery location patterning and recovery bias, it would be wise to encourage forensic anthropologists to ask for more precise locations for the recovery of human remains. Forensic personnel can urge law enforcement to retain either physical addresses or GPS coordinates of the recovery location of the deceased. GPS coordinates could be taken simply by dropping a pin on a computerized map with a cell phone. Though not as accurate as using a GPS device, these GPS pinned locations would require very little effort and expense on the part of law enforcement personnel and would provide a location that could be cross-referenced with physical and cultural landscape data, which would aid forensic anthropologists in their assessment of how demographics and geography influence the locations where the human remains they analyze are recovered.

Acknowledgements

The authors would like to thank Dr. Mario Mighty, Katie Rubin, Janet Finlayson and the analysts at the CA Pound Human Identification Laboratory.

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