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A GEOSPATIAL METHODOLOGY FOR MAPPING LAND PARCELS WITH INDIVIDUAL ON-SITE WASTEWATER DISPOSAL SYSTEMS

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The Geospatial Education and Outreach Project (GEO Project) is a collaborative effort among the Geosystems Research Institute (GRI), the Northern Gulf Institute (a NOAA Cooperative Institute), and the Mississippi State University Extension Service. The purpose of the project is to serve as the primary source for geospatial education and technical information for Mississippi.

A GEOSPATIAL METHODOLOGY FOR MAPPING LAND PARCELS WITH INDIVIDUAL ON-SITE WASTEWATER DISPOSAL SYSTEMS

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INTRODUCTION

Individual on-site wastewater disposal systems (IOWDS) or septic systems are an increasing source of pollution along the Mississippi coastline. These systems are susceptible to the impacts of high groundwater tables, tidal flooding, and storm surge. The release of untreated waste from failed septic systems can contaminate coastal and marine environments, leading to pollution and public health concerns in bay water, sediments, shellfish beds, and beaches (Carey, 2011). One of the additional concerns is that inventories of these systems are not always complete or simply non-existent. This report presents an approach for identifying the potential IOWDS locations and evaluating these locations in relation to potential flooding hazards.

BACKGROUND

According to the 1990 U.S. Census Bureau, about 24% of houses in the U.S. use septic tanks, 16 states recorded values above 30%, and only 7 states recorded values below 15%. These statistics originate from the last country-wide count of the onsite systems incorporated into the "long form" in the decennial Census. In over three decades, this is still considered the official and most complete estimate of IOWDS in the U.S. (National Onsite Wastewater Recycling Association, 2018). The proportion of households that use septic systems varies considerably by state. The state with the highest proportion of septic tanks is Vermont (55%). However, the numbers are higher than the national average for the southern coastal states, with 44% for Alabama and 38% for Mississippi (U.S. Census Bureau, 1990).

Similar trends are observed for the newly constructed houses as well. The highest proportion again is observed in Vermont at 51%, but it is also relatively high in Mississippi and Alabama at 36% (National Association of Home Builders, 2013).

The frequent use of septic tanks in areas susceptible to sea level rise is of significant concern for many rural coastal communities. The rise in sea level causes a rise in groundwater levels, consequently reducing an area of unsaturated soil needed to filter the wastewater. Septic tanks are gradually failing and are unable to correctly filter bacteria and nutrients. This results in a higher chance of polluting groundwater, coastal waters, as well as sources of drinking water (Threndyle et al., 2022; Cooper et al., 2016; Hummel et al., 2018).

PROJECT GOALS, STUDY AREA, AND DATA SOURCES

This project utilized geospatial technologies, specifically geographic information systems (GIS), to locate IOWDS and assess their susceptibility to fluctuating water levels. Numerous studies focusing on the sea level rise impacts on IOWDS were conducted in other coastal states including Florida (Sukop et al., 2018), North Carolina (Humphrey et al., 2013), Rhode Island (Cox et al., 2020), and Virginia (Mitchell et al., 2021). What is unique to our study is the idea of generating a substitute for a non-existing IOWDS inventory using publicly available records and a set of relatively basic geospatial tools. This way our approach can be easily replicated in other coastal communities facing similar issues related to limitations in the availability of existing IOWDS records.

The first goal was to identify and map land parcels that potentially are using IOWDS to create a close replica of a non-existing inventory. The second goal was to assess the susceptibility level of these parcels due to gradually and steadily rising sea levels. ArcGIS Pro ESRI's desktop software was used to carry out these analyses.

The study area covers about 570 square miles. It encompasses most (~79%) of an inland section of Jackson County, Mississippi. Bounded by the Gulf of Mexico, this area's expansive deltas, rivers, and streams make it highly prone to the effects of high groundwater tables, tidal flooding, and storm surge. These conditions create a range of complications in maintaining compliance with regulations and safeguarding public health. This is especially true in relation to the common use of the IOWDS throughout the county as they are an ever-increasing source of non-point source pollution, generating public health hazards and environmental degradation (Collini, 2021).

As Figure 1 illustrates, the analysis included about 84,000 parcels currently maintained by the Jackson County Utility Authority (JCUA) with many of these parcels directly adjacent to the coastline.

Figure 1. Mississippi county map with the Jackson County highlighted; the extent of the JCUA service area (solid blue color) and a sample of the examined land parcels.

The selected approach required the use of both vector and raster datasets. The incorporated vector data represented the existing service utility provider records, the JCUA customer addresses, land parcels' geometries, and various tabular information, including the improvement values for individual parcels. The incorporated rasters were used as inputs to characterize fluctuating water level conditions.

The following three raster layers were utilized:

- high-tide flooding (NOAA SLR data, available on NOAA's Digital Coast website)
- groundwater table level (Soils Survey Geographic Database, SSURGO public database, available on ESRI's Living Atlas)
- storm surge (NOAA's Research Project Data, known as Ecologic Effects of Sea Level Rise (EESLR))

METHODS

The proposed methodology involved various geospatial techniques combined with multi-criteria decision analysis to identify individual parcels and determine their susceptibility to different flooding conditions.

Goal 1. Identify land parcels that are potentially using IOWDS.

The first and most critical goal was to identify and map land parcels where septic tanks are the most likely found. The idea was to create a close substitute for a non-existing system inventory by careful evaluation of existing JCUA parcel records.

Step 1. Geocode locations serviced by the provider.

The first step involved geocoding existing locations currently serviced by the provider (JCUA). Typically, a geocoding process requires a street address, city name, zip code, and state information. In most situations, geocoding involves mapping multiple locations, and it is beneficial to carry it out at once. This means that the address data needs to be arranged in a single table as shown in Figure 2.

Parcel ID	Street Number	Street Name	City	Zipcode	State
253	800	Lemon	Ocean Springs	39564	MS
254	4900	Deborah	Ocean Springs	39564	MS
255	5000	Midway	Ocean Springs	39564	MS
256	1417	Willow	Ocean Springs	39564	MS
257	1104	Dorothy	Ocean Springs	39564	MS

Figure 2. Sample of the correctly organized geocoding input table.

The process requires a geolocator file that can be created from the Census TIGER Road file. Although this is a valid and frequently used solution it might be also time-consuming. The generated intermediate outputs may require multiple iterations to achieve acceptable results. A recommended approach is to use the ESRI's geocoding tools and the currently available geolocator file accessible to anyone with an ArcGIS Online account. The use of the most current version of the locator file guarantees the most accurate geocoding results. During the geocoding process, postal addresses are converted to vector points. As Figure 3 illustrates, the geocoded points and the parcel data are spatially consistent, allowing geospatial operations relying on both layers, such as spatial selections, overlays, and joins.

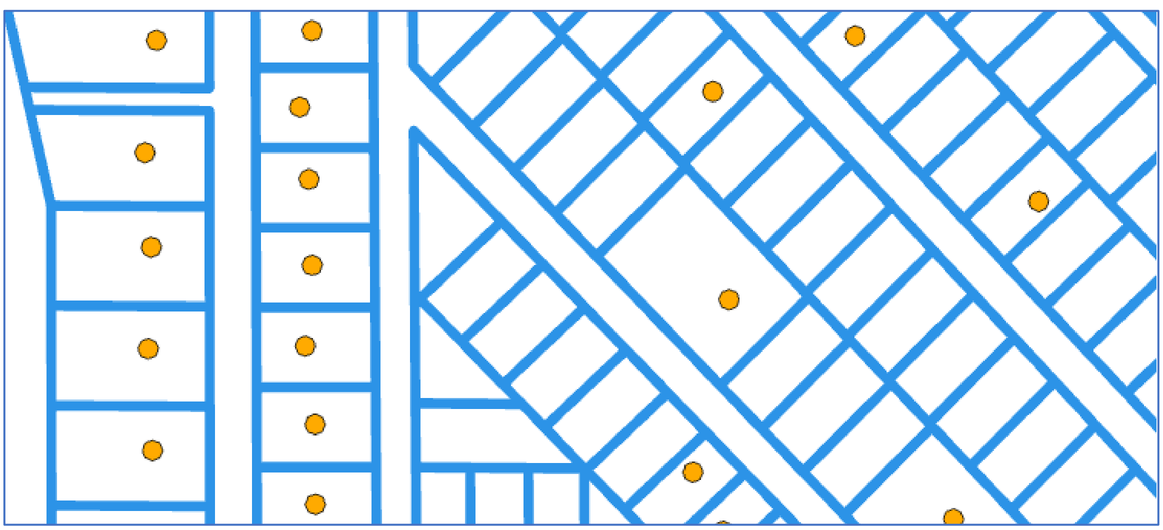

Figure 3. Example of geocoded locations (orange points) overlaid on top of the parcels layer (blue polygons).

Step 2. Select parcels within geocoded points, reverse the selection, and ID parcels that are not serviced.

The second step consisted of the selection of parcels within the geocoded points. More specifically, the point file was used as an input to apply the "Select by Location" option to identify parcels containing the geocoded locations. After that, the current selection of parcel records was reversed. This was a routine attribute table operation but critically important for completing the first goal. It allowed the identification of parcels that currently are not serviced by the JCUA. The selected parcel features were then exported to a smaller dataset to simplify future analysis. Figure 4 highlights the main intermediate steps of this workflow.

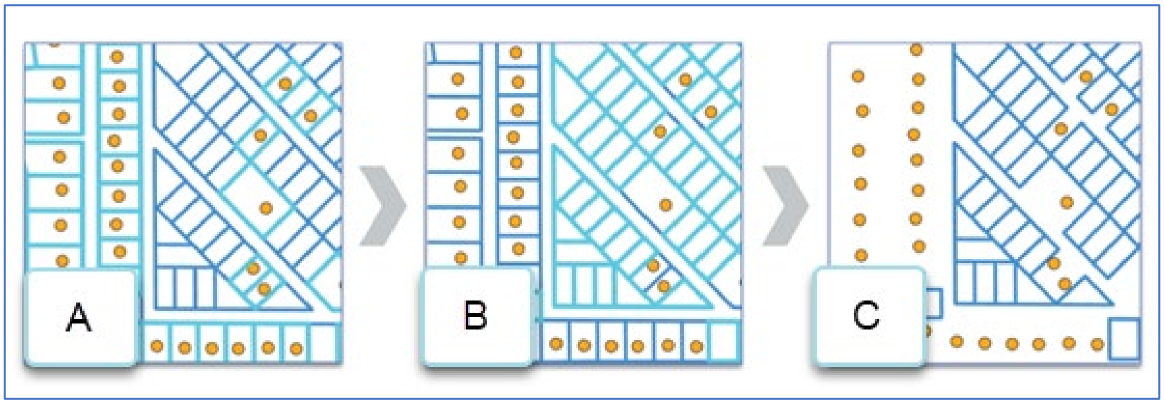

Figure 4. Intermediate steps of the selection process: select by location (a), switch selection (b), and export selected parcels (c).

Step 3. Exclude parcels with less than $7,500 improvement value to ID parcels that are likely to use septic tanks.

The concluding step focused on the exclusion of parcels with less than $7,500 in improvement value. This allowed identifying parcels that are likely to have and use septic tanks. The threshold improvement value of $7,500 was determined after a consultation with the JCUA managers and it is unique to the study area. This value was utilized in a basic attribute query where records below the specified threshold were excluded. This again narrowed the selection, and this time the output included only parcels where septic tanks are likely to be installed.

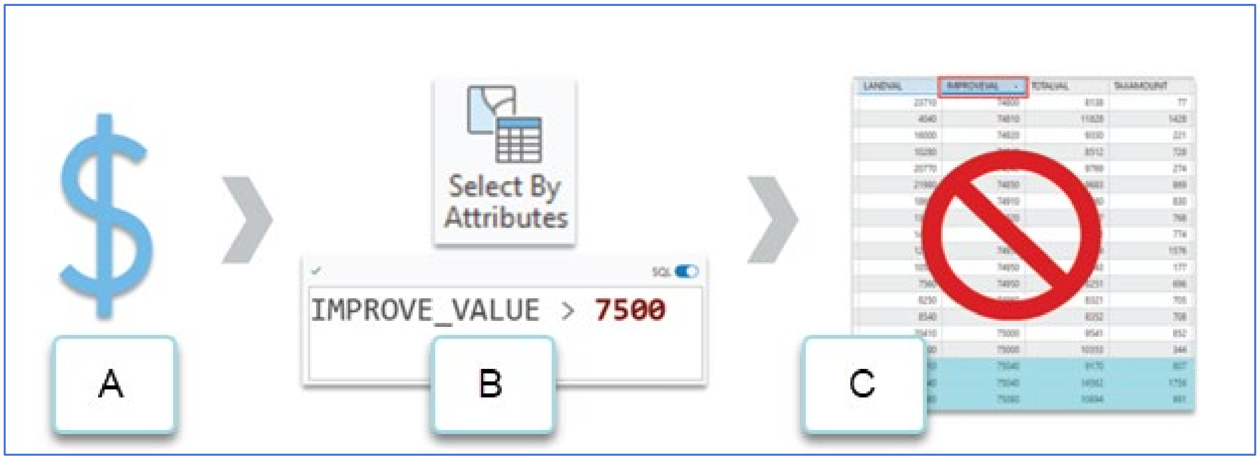

Figure 5. Intermediate steps of the threshold selection process: determine the improvement value threshold (a), perform an attribute query (b), and exclude records below the threshold value from the final selection (c).

Goal 2. Assess land parcels' vulnerability level due to flooding conditions.

The geospatial process for the second goal began with collecting and organizing all three input raster layers in terms of constant resolution and extent. Once these layers were assembled, their values were linked to the parcels' records. Based on the input values the vulnerability ranks ranging from 1 to 3 were determined. The assignment of the vulnerability classes for each input layer is presented in Figure 6.

Vulnerability Class	Depth to Water Table	Storm Surge	High tide Flooding
3	<= 1 Ft	Initial	Current
2	<= 2 Ft	Low	1 ft. SLR
1	<= 3 Ft	Intermediate Low	2 ft. SLR

Figure 6. Multi-criteria analysis to assess identified non-serviced land parcels' risk level.

Based on the raster values from the groundwater table level, storm surge, and high tide flooding, the vulnerability values (1-3), were assigned to individual parcels. This allowed summarization of all parcels and attributing them with a relative susceptibility value representative of all three inputs, ranging from 0 (parcels considered at no risk for any of the three categories) to 9 (parcels considered at maximum risk based on all vulnerability categories). The workflow steps included in this process are shown in Figure 7.

Figure 7. Collect and organize raster input layers; assign the vulnerability values; summarize parcels by vulnerability values from all input layers.

RESULTS

There are two main online products of this project. First is the ArcGIS Story Map that is publicly available (bit.ly/3YVKng9) and explains the analysis steps (Grala and Cartwright, 2023). The second product is an interactive map that was designed for and shared with the JCUA managers (Figure 9). The properties of each parcel can be reviewed on the map, in terms of the final susceptibility, which ranges from high, represented with a red color on the map and a value of 9 in the table, and low vulnerability, shown with a green color, and a value of 0.

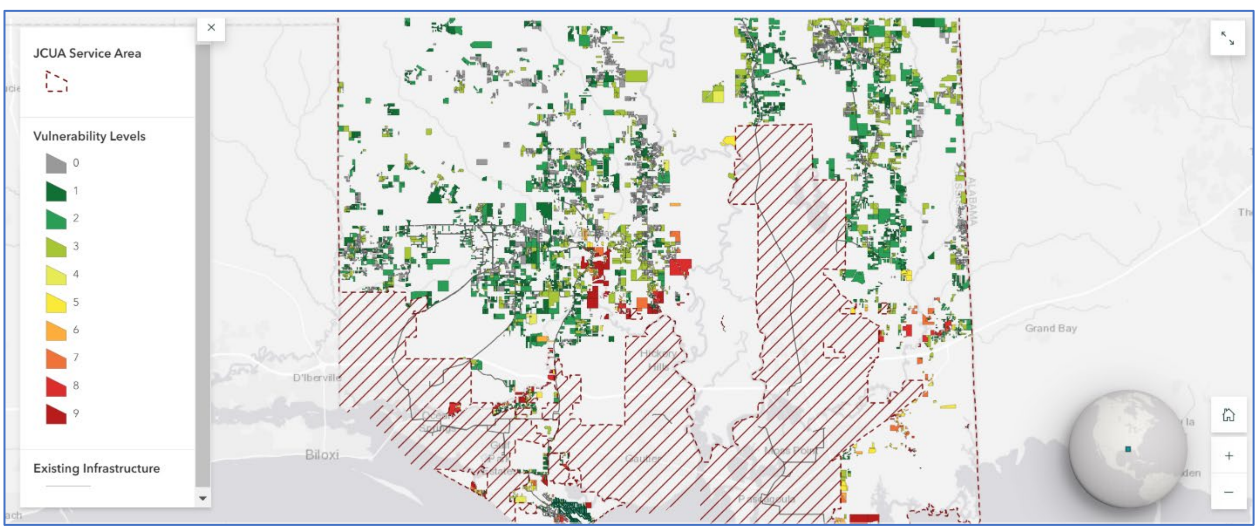

Figure 9. The screen capture of the online map designed to share the results with the JCUA managers.

In addition, proximity to existing infrastructure was examined to assess the ease of connection to the JCUA's system. These spatial analyses identified about 1,600 parcels were near existing infrastructure and that helped prioritize the transition from on-site disposal to a service utility. The advantage of the online map is that managers can check proximity to the existing infostructure (black lines shown on the map) and decide on the priority areas that need immediate action.

Goal 1 Results:

- 27% were identified as parcels currently not serviced by the JCUA sewage lines.
- Applying a threshold improvement value resulted in 11% of parcels that potentially have a septic tank.

Goal 2 Results:

- 65% of these were found to be at some level of risk over the next several decades due to rising groundwater levels, high tide, and/or storm surge.
- 3.5% (339) of the identified parcels were found to be at the top risk level.

Based on the analysis results (combination of the elevated risk and proximity to existing infrastructure) three subdivisions within the JCUA's jurisdiction were recommended as priorities for connection to the existing JCUA's system. These include St Andrews Bay Area 2. Old Fort Bayou Area 3. Vancleave. Additional sections, currently lacking access to sewer lines, were identified as areas representing logistical challenges for the decision-makers (Collini, 2021).

CONCLUSIONS

To conclude, the presented geospatial approach allowed the identification of parcels that likely have septic tanks installed for an area where system inventory does not exist. The analysis detected the areas that are currently not serviced and are at increased risk due to environmental changes. Finally, it highlighted the level of relative vulnerability due to rising groundwater levels, high tide, and/or storm surge as individual inputs and summarized relative risk as well.

This report presented an approach easily adjustable to the needs of other municipalities where comprehensive septic tank inventories do not exist. Also, similar analyses can be successfully implemented in other coastal areas.

Future analysis ideas

- Compare the location results to the existing septic tank permit records.
- Spatially analyze identified IOWDS in relation to all available SLR values (0–10 ft.).
- Extend the analysis to other coastal areas.

The presented results can be easily shared using interactive web-based applications (online maps, story maps, and dashboards) to help identify the most vulnerable subdivisions. Also, our efforts produced easy-to-use geospatial tools to automate data identification and extraction across multiple layers and geometry types. Decision-makers can use the developed tools to improve their decision-making processes and find better adaptive management solutions to ensure that the coastal communities are more robust and resilient to the potential impacts of deteriorating wastewater disposal systems.

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