INSAR-BASED ANALYSIS OF LAND DISPLACEMENT IN SOUTHEASTERN LOUISIANA: LAKE MAUREPAS REGION

Curtis Amo Dwira[1], Ahmed Abdalla[1]

[1]*Louisiana State University, Department of Civil and Environmental Engineering, Baton Rouge, Louisiana, USA*
e-mail: cdwira1@lsu.edu

Land Subsidence, a vertical movement or settling of the Earth's surface is one of the geophysical concerns associated with coastal and low-lying areas particularly in the southeastern part of Louisiana where natural processes intersect with human activities such as groundwater extraction, hydrocarbon development, and infrastructure expansion [1]. This study applies an integrated approach using Interferometric Synthetic Aperture Radar (InSAR) technique specifically the Persistent Scatterer Interferometry (PSI) technique and multi-criteria analysis, specifically the Analytical Hierarchy Process (AHP), to assess surface displacement and land subsidence susceptibility in the region of Lake Maurepas between 2017 and 2020 considering ten key geospatial and environmental variables.

Lake Maurepas, which is situated between Lake Pontchartrain and the Maurepas Swamp Wildlife Management Area, is a critical zone within southeastern Louisiana. Over the years, the region has experienced increasing pressure from both natural and human processes which have led to significant land surface changes contributing to wetland loss, increased flood risk, and infrastructure instability. This study seeks to map and analyze surface deformation trends over the chosen period and identify driving factors and risk zones contributing to land subsidence to inform future mitigation and adaptation strategies [2].

To achieve the set goals, sentinel-1 radar imagery from 2017 to 2020 was used and processed using the PSI-InSAR approach to detect surface motion with a millimeter-level precision to extract vertical deformation signals from stable targets. Applying InSAR technique provides a unique advantage for regional scale monitoring due to its sensitivity to ground displacement over time. The workflow implemented in analyzing land subsidence is shown in Fig. 1.

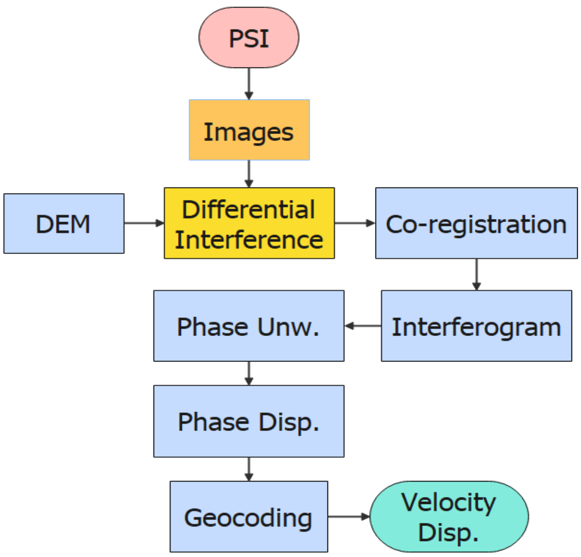

Fig. 1. PSI-InSAR data analysis procedure

The analysis provided a very complex spatial pattern of subsidence, with the most severe rates observed along the eastern and southeastern shores of Lake Maurepas. Areas with the most severe rates of land subsidence include the communities of Ruddock, Akers, and Pass Manchac, exhibiting subsidence rates ranging from -10 mm/year to -15 mm/year. These regions are characterized by unconsolidated sediments, intensive groundwater pumping, and wetland degradation, all of which contribute to accelerated land subsidence. Also, the southern and southwestern portions of the lake showed moderate deformation rates ranging between -5 mm/year and -10 mm/year. Notably, infrastructure such as Interstate 55 (I-55), which parallels the southeastern shore of the lake, intersects these zones. The presence of critical transportation corridors within subsiding regions raises significant concerns regarding the structural integrity of roads, bridges, and drainage systems, particularly under stress from hurricanes and heavy rainfall events. The northern and northwestern parts of the lake displayed relatively stable ground conditions with subsidence rates between 0 mm/year and -5 mm/year. These areas are typically known to have firmer geological substrates and low anthropogenic impact, providing a better comparison to active and vulnerable marshlands. The velocity map for the study area is shown in Fig. 2.

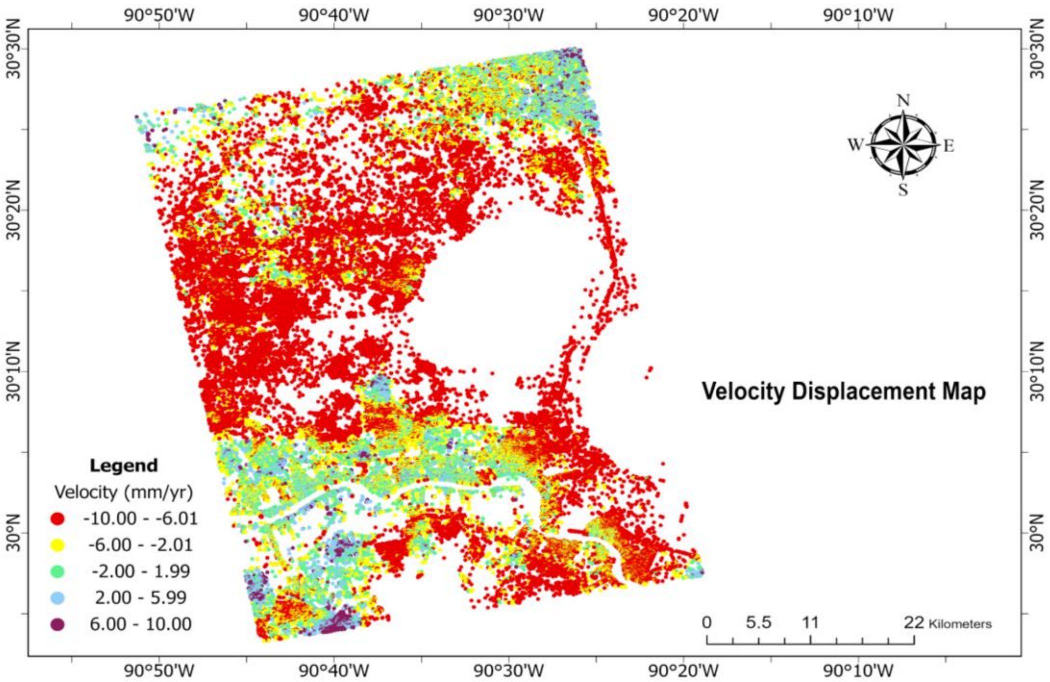

Fig. 2. Velocity Displacement Map

Decorrelation of radar signal over open water restricted coherent signal returns across the lake's central basin, but sufficient Persistent Scatterers along shorelines and wetlands provided a detailed deformation map. To clearly understand these patterns, AHP, which is one of the multi-criteria decision-making frameworks was used in this study to map subsidence susceptibility. This approach enables systematic comparison based on expert decisions by weighting factors contributing to land deformation [3]. The ten variables used for the analysis include geology, land use/land cover (LULC), aspect, slope, elevation, topographic wetness index (TWI), precipitation, distance to fault lines, distance to roads, and distance to rivers. These variables were chosen based on literature precedence and field knowledge. Pairwise comparison matrix is used to assign weight to each factor. To ensure reliability and validity of the model, consistency checks were applied to measure the coherence and transitivity of these comparisons, which indicates how logically the judgments are related. The consistency ratio (CR) for the matrix was below 0.1, indicating an acceptable level of logical consistency in the weighting process. The derived weights revealed that Geology (26.1%) and Land Use/Land Cover (13.72%) were the most influential factors contributing to subsidence. This reflects the dominance of unconsolidated Holocene sediments in the region and the impact of anthropogenic activities such as road construction, urbanization, and industrial activity. Elevation and distance to faults also carried notable weights, suggesting that both topographic setting and structural geology influence susceptibility patterns in this region. Also, moderately weighted criteria such as TWI and aspect revealed the significance of hydrological accumulation and slope orientation which facilitate soil moisture retention and promote subsidence in saturated zones. Slope and distance to rivers also played essential roles, especially in areas adjacent to natural or artificial drainage systems. Precipitation, while an important climatic driver, was assigned the lowest weight due to its indirect impact relative to more immediate geological and land-use conditions. The result for pairwise comparison is shown in Fig. 3.

Matrix		Geology 1	LULC 2	Aspect 3	TWI 4	Slope 5	Distance to Road 6	Distance to river 7	Precipitation 8	Distance to Fault 9	Elevation 10	normalized principal Eigenvector
Geology	1	1	3	4	5	5	6	5	4	1	1	26.10%
LULC	2	1/3	1	3	2	2	3	3	3	1	1	13.72%
Aspect	3	1/4	1/3	1	2	2	2	1/2	3	1	1	8.77%
TWI	4	1/5	1/2	1/2	1	2	2	2	3	1	1	8.78%
Slope	5	1/5	1/2	1/2	1/2	1	2	1/2	3	1	1	6.66%
Distance to Road	6	1/6	1/3	1/2	1/2	1/2	1	1/2	2	1	1	5.20%
Distance to river	7	1/5	1/3	2	1/2	2	2	1	2	1	1	8.22%
Precipitation	8	1/4	1/3	1/3	1/3	1/3	1/2	1/2	1	1	1	4.40%
Distance to Fault	9	1	1	1	1	1	1	1	1	1	1	9.08%
Elevation	10	1	1	1	1	1	1	1	1	1	1	9.08%

Fig. 3. A Pairwise Comparison

The weighted factors were integrated within a GIS environment to produce a subsidence susceptibility map of the Lake Maurepas region. The results were classified into five categories (Very Low, Low, Moderate, High, and Very High susceptibility). The High to Very High categories were predominantly found along the eastern and southeastern shores conforming with areas of active subsidence detected by InSAR. Low to Very Low susceptibility zones were seen in the northern and northwestern parts of the study area. These areas show more geologically stable regions with limited development and better drainage, consistent with InSAR findings showing minimal surface displacement as shown in Fig. 4. The strong spatial correlation between modeled susceptibility zones and observed subsidence patterns confirms the reliability of the integrated approach.

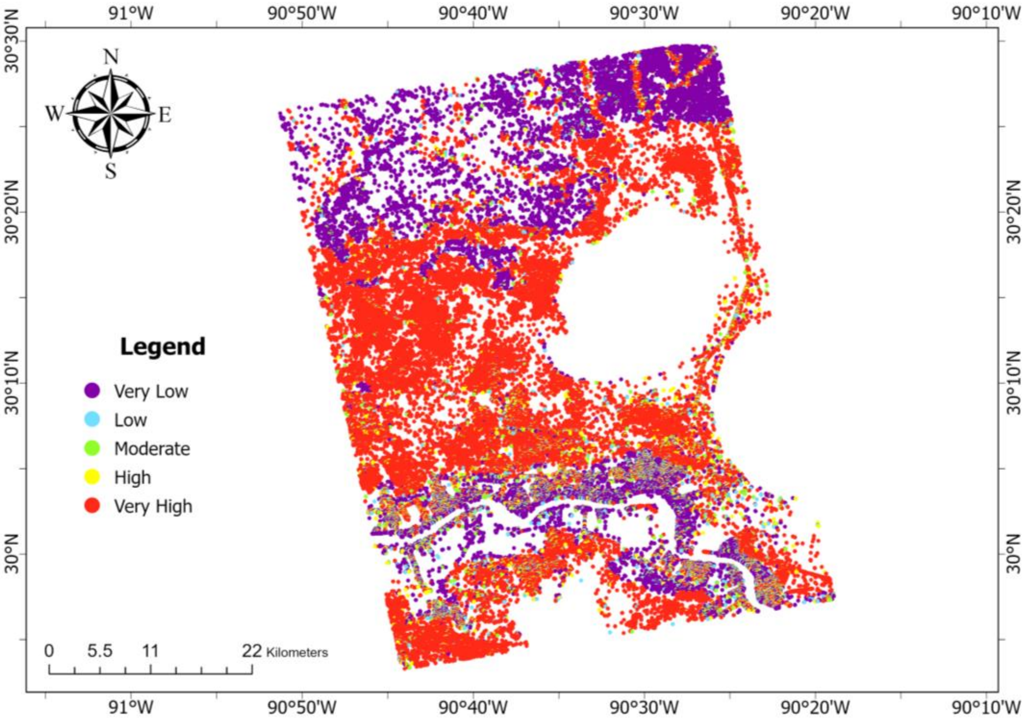

Fig. 4. Land Displacement Susceptibility Map

The findings of this study have several important implications. First, the overlap between infrastructure networks and areas of active subsidence suggests the need for long-term monitoring, maintenance prioritization, and possible design adjustments to protect critical assets like I-55. Second, the susceptibility map offers a valuable decision-support tool for land use planning, wetland conservation, and disaster preparedness. By identifying priority areas for intervention, the model supports the development of adaptive strategies to mitigate future impacts. This research also demonstrates the advantages of combining remote sensing data with structured geospatial decision models. PSI-InSAR provides highly accurate and repeatable measurements of land surface change, while AHP offers a flexible and transparent framework for evaluating complex spatial relationships. Together, they enable a comprehensive understanding of the causes and consequences of land subsidence across variable landscapes.

Nevertheless, certain limitations are acknowledged. InSAR's inability to generate reliable data over open water and dense vegetation limits its coverage in some wetland environments. AHP, while systematic, depends on expert input for pairwise comparisons, which may introduce subjectivity. Future research should explore the integration of machine learning techniques, such as Random Forest or Gradient Boosting, to assign weights more objectively and explore nonlinear relationships between variables. Additionally, incorporating ground-based data from GNSS stations could enhance the calibration and validation of the deformation model.

In conclusion, this study provides a rigorous and replicable framework for subsidence analysis in complex coastal settings. By integrating PSI-InSAR and AHP, the methods delivered a better understanding of both where and why land subsidence is occurring in the Lake Maurepas region. These insights contribute directly to ongoing efforts in coastal resilience, infrastructure planning, and environmental stewardship in southeastern Louisiana. As subsidence continues to threaten ecological systems, human settlements, and critical infrastructure, the tools and methodologies demonstrated here will be increasingly essential for guiding evidence-based decision-making and long-term sustainability planning.

References:

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