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Ground Subsidence Study of Barisal City and Surrounding Areas Using InSAR for Sustainable Urban Planning

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Abstract: Barisal is a large important city in the south-middle part of Bangladesh which is expanding rapidly. Geologically, it comprises of Recent Flood Plain deposits composed of mixture of un-consolidated sand, silt and clay sediments. This research work is carried out based on RADAR InSAR to estimate vertical ground motion of Barisal City. Persistent Scatterer Interferometry (PSI) method is a multi-temporal InSAR technique for the measurement of terrain movement has been used for the present study. The goal of this analysis is to assess vertical ground motion of the study area and discuss the results in the context of the local geology and geomorphology. There are 239 ascending and descending Sentinel-1 satellite images, covering the period from 2014 to 2020 have been used for analyses. The PSI result shows that the ground motion of the study area ranges from -24.17 mm/year to + 5.63 mm/year, having a mean value of -1.66 mm/year. The negative mean value indicates that the overall trend of vertical motion of the area is slow ground subsidence. These results and geo-factors are very important to consider for geologic conditions like Bangladesh for future sustainable development and urban expansion planning.

Keywords: ***Ascending, Descending, Deformation, InSAR, PSI, Sentinel-1.***

Introduction

The ground motion phenomenon is directly related to the building, utilities, roads etc damage. Bangladesh is considered as densely populated country. The rapid growth of the population has led to significant urban expansion. The rising demand for housing in major cities has resulted in unsustainable consumption patterns. The Interferometric Synthetic Aperture (InSAR) technology use microwave band for coherent imaging (Dai et al., 2020). Without taking into consideration of ground motion and other geo-information, it may cause havoc for development activities. Land Subsidence in urban areas can lead to serious problems, so it is essential to understand the issue properly and then manage it carefully (Ng et al., 2023). Persistent Scatterer Interferometry (PSI) is used to land subsidence study of Barisal City, which lies in the south-middle part of Bangladesh. Output of the analyses is in vector data format. So, the vertical motion of a specific point or of a building or part of a large building can be measured perfectly.

Methodology

Sentinel-1 (C-band) data of the study area covering the period from October 2014 to September 2020 in the ascending and descending orbit directions. There are 277 Sentinel-1 scenes (Ascending: 144 images and Descending: 133 Images). ENVI SARscape Analytics is used for InSAR processing. The Connection Graph is the first step in the PSI chain. In this function, the stack of SAR images analyses the best master image from the stack. An interferogram is created for each connection between two images. The first step in inversion is an estimate of the model parameters. In the second step of the inversion, estimate the atmospheric phase components. The atmospheric phase is removed from the interferometric phase, and the date-by-date displacements are estimated for all images. The final step is Geocoding in which the calculated displacement information is geocoded from SAR slant range geometry into a geographic coordinate system. To achieve a continuous motion time series, the individual subsets are subsequently linked together (Zhou et al., 2017).

Results

Both orbit directions (ascending and descending) results have been processed using the SARscape Analytics PSI workflow. It is found that the PS points are mostly concentrated in the city central area. Some points are also found in the rural settlements area. There is no point found in agricultural areas. Negative vertical ground motions are found mostly in the southern and Middle Western and Positive is found in the middle eastern part of the area. Clusters of negative ground motion are scattered found throughout the middle part. The rest of the areas are stable. Results of PSI analyses show that the minimum velocity is -24.17 mm/year, and the maximum velocity is +5.63 mm/year having a mean value of -1.66 mm/year. The Mean value of the area is negative, which indicates that the whole area has a tendency toward negative ground deformation.

Causes of subsidence

The foundation of any infrastructure has a direct impact on soft, unconsolidated sediments from all new and existing development works. The overlay of ground motion results on the prepared geomorphological map of the area shows that most of the negative motion results fall on the marsh, fluvio-tidal flat and low flood plain geomorphic units. Negative motion indicates that those areas have very weak sub-soil conditions for construction. Recent sediments in the area are more clay than sandy deposits. The area is also considered part of the delta, So, local lithologic differences usually contribute to variations in compaction. Usually, clayey sediments undergo shallower compaction than sands. Fine-grained soft soils like clay or peat are characterized by high compressibility in both the primary and secondary consolidation stages (Huat et al., 2014). The compressibility might be further amplified by a change in the iconic content of the pore water (Cao et al., 2021). Subsidence may also be driven by seasonal water table variation and aquifer compaction. Variation in ground water levels is one of the common factors that lead to land deformation in urban areas (Ng et al., 2023). The rate of negative ground motion is also affected by residential or industrial land use. The cluster of negative ground motion-covered areas of the present city might be vulnerable to high flooding, wide-spread water logging, and sea level rise impacts. The negative ground motion of a house allows it to sink slowly into the subsoil. If a building or structure has been built on compressible clay soil and no ground preparation has been carried out, this will often lead to building subsidence. The tilting of the building in the study area may be due to differential settlement. Groundwater level is an important factor regarding this issue.

Conclusions

This study estimated vertical ground motion using Persistent Scatterer Interferometry (PSI) and interpreted the results in relation to local geology and geomorphology. Ground motion velocities range from –24.17 mm/yr to +5.63 mm/yr, with a mean of –0.76 mm/yr, indicating no major large-scale vertical movements but an overall slow subsidence trend. Higher negative motion occurs in the south and middle east, while positive motion appears in the northeast and parts of the middle east. Areas with negative velocities—often associated with newly built or expanded structures—may be unsuitable for further development without proper geotechnical measures, as building loads and primary settlement likely contribute to subsidence. The region's young, unconsolidated late Holocene tidal deltaic deposits (sand, silt, clay, peat) and floodplain geomorphology are closely linked to the observed ground motion, with groundwater-level changes also influencing subsidence.

Recommendations

The method provides fast and cost-efficient measurement compared to other geodetic methods such as leveling or GPS/GNSS. PSI can be used to detect different displacement rates for different parts of a building. The combined analysis of InSAR and other related data such as geological, geomorphological and hydrological, and land use data may provide the best selection of urban planning because floodplain areas face differential compaction. One potential limitation to consider is the necessary computational work. To properly isolate phase influences due to atmosphere and topography from the actual deformation, many acquisitions are needed. In the case of InSAR, the more acquisitions are used, the better the results.

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