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MONITORING OF FLOOD PROTECTION SYSTEMS WITH INSAR IN AUSTRIA

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INTRODUCTION

The frequency and intensity of flooding are increasing due to climate change, posing growing risks to people, infrastructure, and the environment. As a result, sustainable natural hazard management and structural health monitoring are becoming increasingly important. This study explores the potential of using multitemporal Interferometric Synthetic Aperture Radar (InSAR) from Sentinel-1 satellites to monitor the structural health of flood protection systems along the Danube River in Lower Austria.

METHODS

This study uses long-term ground deformation data points from the European Ground Motion Service (EGMS), part of the Copernicus Initiative. Statistical analyses are conducted to evaluate how factors such as natural vegetation, the presence of roads and paths, and the orientation of flood protection structures relative to cardinal directions affect the number of available persistent scatterer (PS) points. The aim is to determine whether, and under what conditions, flood protection structures provide enough PS points for meaningful satellite-based monitoring.

RESULTS

POINT DENSITY DEPENDING ON REFLECTIVE SURFACE TYPE

The flood protection structures in the Lower Austria region were divided into eight surface type categories based on their characteristic locations, or the structures which they are part of. The majority of the investigated flood protection structures are situated in green areas (60%), followed by highways and roads (22%), and residential areas (see Fig. 1).

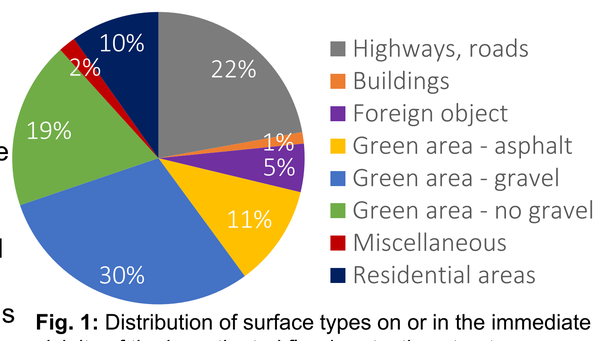


Fig. 1: Distribution of surface types on or in the immediate vicinity of the investigated flood protection structures.

POINT DENSITY DEPENDING ON OBJECT ORIENTATION

The orientation of a flood protection structure is a key aspect since its length is usually significantly greater than its other two dimensions. The orientations of the 155 km of flood protection structures along the Danube River in Lower Austria were analyzed with respect to the cardinal directions. The results show that the flood protection structures are predominantly aligned with the Danube River as evidenced by 43% of the total structure length being oriented in the east-west direction, matching the river's course in this region. In contrast, the shortest flood protection structure orientation is north-south, accounting for only 18 km or 12% of the total analyzed length, as shown in Fig. 2.

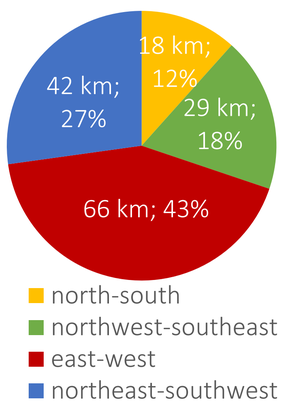


Fig. 2: Orientation distribution of the 155 km-long flood protection structures in the investigated area with respect to cardinal directions.

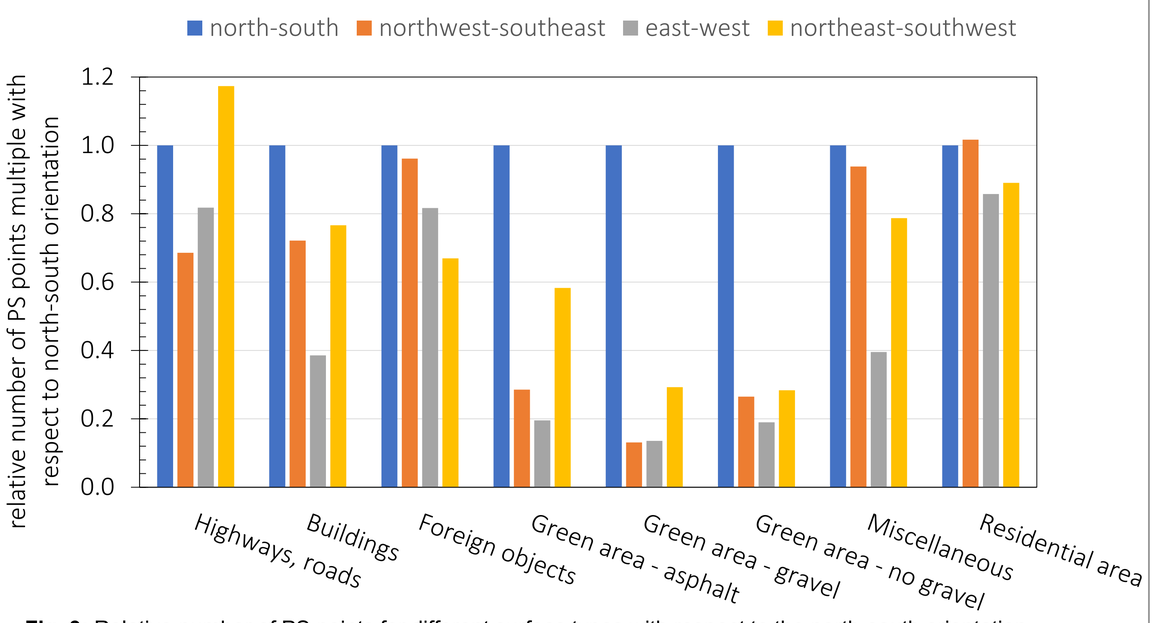


Fig. 3: Relative number of PS points for different surface types with respect to the north-south orientation.

Since the line of sight (LoS) direction of the SAR satellite is related to the cardinal directions, the number of available PS points also depends on the orientation of the observed objects, such as dikes or levees. Based on the analysis of the investigated flood protection structures, the greatest number of PS points are obtained for when the structures are oriented in north-south direction for all surface types except highways and roads, as shown in Fig. 3. Therefore, the number of points in the other directions is shown in relation to this most favorable orientation. Exceptionally high numbers of points are also obtained in all cardinal directions in highways, roads, and residential areas. An important finding is that the number of PS points drops significantly for unfavorable orientations for all types of green areas (see Fig. 4).

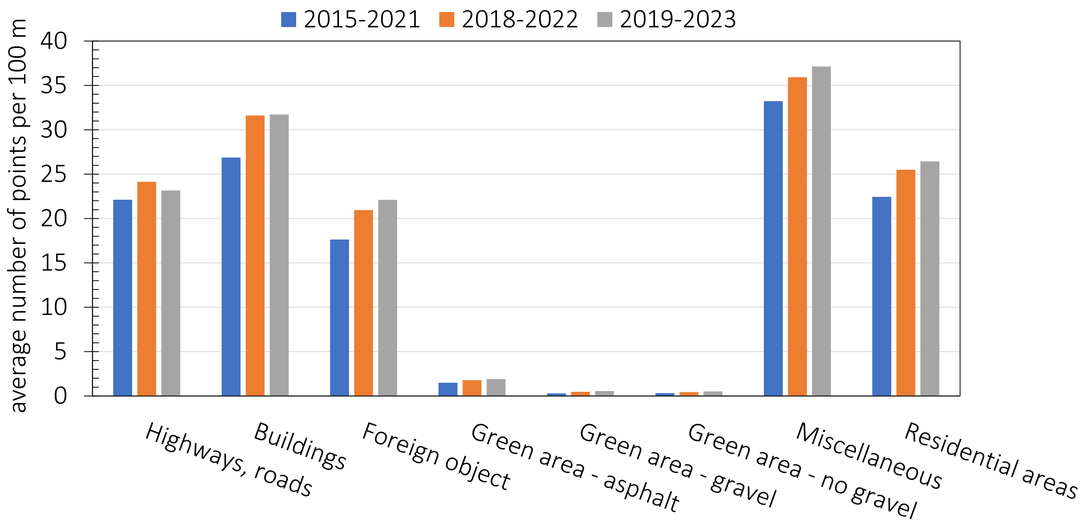


Fig. 4: Comparison of the PS point density for different EGMS database releases and surface types on or in the immediate vicinity of the investigated flood protection structures.

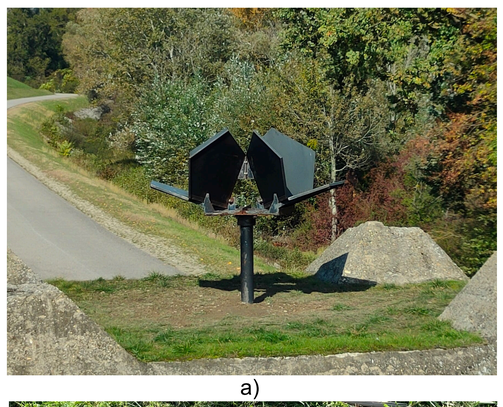
POINT DENSITY DEPENDING ON EGMS RELEASE DATE

The number of available reflection points also depends on the release date of the postprocessed InSAR database. The EGMS database used in this study contains three releases that vary by time period (epochs): 2015–2021, 2018–2022, and 2019–2023. Except for the newest data release in the "highways and roads" category, the number of available measurement points increases slightly with later release time, as can be seen in Fig. 4.

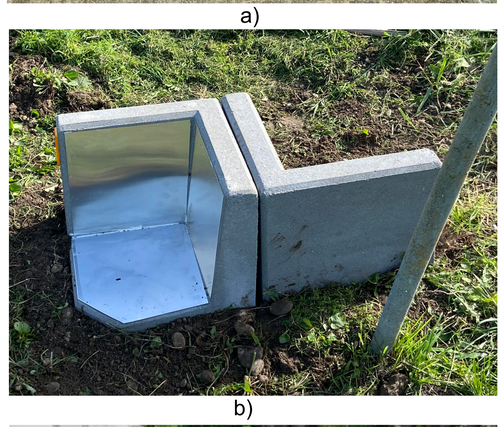
DISCUSION

The lack of PS points in vegetated areas, where most flood protection systems are located, can be addressed through the use of corner reflectors (CRs), see Fig. 5a).
To this end, the potential of low-cost CRs suited for deployment on flood protection structures has been investigated and will remain a focus of future research.

Two pairs of concrete CRs with an edge length of 40 cm were installed on a flood protection structure along the Danube River, see Fig. 5b). However, the backscatter was found to be insufficient, prompting the development and testing of CRs with a larger reflective area. To improve signal quality, a larger CR was installed in the backyard of the AIT facility, see Fig. 5c), showing significantly better backscatter. Further work is underway to optimize reflector design and assess long-term performance in field conditions.



a)



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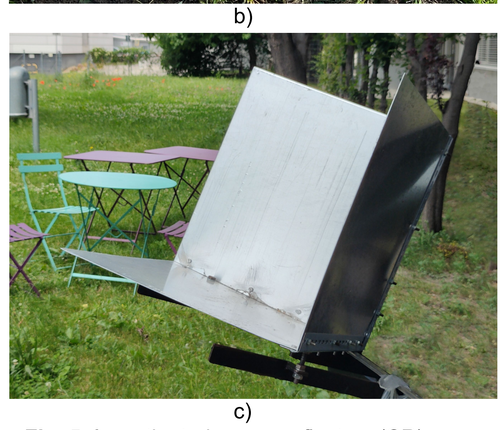

c)

Fig. 5: Investigated corner reflectors (CR): a) standard steel CR, b) small concrete CR with aluminum sheets, c) experimental aluminum CR.

CONCLUSIONS

InSAR is a powerful tool for monitoring surface displacements over large areas under all weather conditions, offering valuable insights into the structural health of infrastructure assets. This study demonstrates the potential of applying InSAR to monitor flood protection structures along the Danube River, while also highlighting key limitations due to the low density of natural reflectors. Future research will focus on increasing the number of reliable reflection points through the use of low-cost, widely deployable corner reflectors, and on exploring InSAR data from other existing and upcoming satellite missions.

ACKNOWLEDGMENTS

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More info at: