Application of SBAS-DInSAR technique to investigate the association between subsidence pattern, groundwater levels, and rainfall variations in Choushui River Alluvial Fan

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Abstract: The Choushui River alluvial fan (CRAF) is a critical region of farming in Taiwan. In this region, groundwater is the main supply for irrigation, industrial and domestic usage. For decades, the amount of extracted groundwater in CRAF has significantly increased, resulting in land subsidence and negatively impacting human lives as well as infrastructures, especially the high-speed railroads and the highways. Therefore, monitoring the ground elevation changes in this area over time is necessary, providing the spatial patterns of subsidence and investigating subsidence mechanisms in the study area. This study applied the SBAS-DInSAR technique to process over 90 Sentinel-1A SAR images acquired from 2018 – 2020 to observe the recent land subsidence patterns in the CRAF. SBAS-DInSAR is a time-series InSAR technique that exploits the distributed scatterers, scattering objects having constant responses over time without dominant ones. The SBAS-DInSAR typically requires the low perpendicular baseline and temporal baseline of the co-registered image pairs, minimizing the decorrelation phenomena. The workflow is shown in **Figure 1**. Regarding the datasets, Sentinel-1A is the European Space Agency's sun-synchronous imaging radar mission (ESA), providing continuous all-weather, day-and-night imagery at C-band radar wavelength with 12 days of revisiting. Besides the InSAR method, a system of GPS stations and leveling benchmarks has been installed for decades to monitor the vertical displacements in the study area. Over 1100 precise leveling benchmarks are provided by the Taiwan Water Resources Agency (WRA) in the fluvial plain of the Choushui River, consisting of yearly measurements ranging from 2000 to 2019. Moreover, 32 GPS stations provided by the GPS Lab of Academia Sinica, Taiwan, are located within the area of interest, giving daily observations of three-dimensional surface displacements. Each GPS station is separated from another roughly 10 – 15 km. Measurements from GPS and leveling measurements will assess the results achieved from InSAR. The assessment indicated that InSAR average velocities were relatively consistent with GPS velocities in 2018 (MAE = 0.56 cm/y; RMSE = 1.3 cm/y) and 2019 (MAE ≈ 1 cm/y; RMSE = 2.33 cm/y). . Meanwhile, the resulting metrics between InSAR and leveling presented a high correlation, with MAE = 0.1 cm/y and RMSE = 0.35 cm/y. The validated InSAR results first show that the sinking rates in both counties were relatively high in 2018 when severe subsidence mainly occurred during this period. Although the subsiding rates significantly decreased in 2019 and 2020, the subsidence situation in some places was still in alarm. Specifically, the regions that severely suffered from land subsidence are located in the western central parts of Yunlin County.

The maximum cumulative displacements in these regions reached –13 to –18 cm at the end of the research period. On the other hand, Changhua County only observed moderate subsidence, with the accumulated subsidence values mainly varying from –2 to –5 cm. The maximum displacement values, up to -7 cm, occurred in Puyan and Xihu districts in this county. Next, this study also investigated the correlation between surface displacements, precipitation, and groundwater levels. It is witnessed that the variations of surface deformation were closely associated with the oscillations of groundwater levels. In detail, the remarkable settlement that occurred in the entire CRAF corresponded to steep declines in groundwater levels and vice versa; the uplifting followed the groundwater recovery. The cross-correlation analysis showed that the variations of cumulative displacements have moderate correlations with the groundwater level fluctuations, varying from 0.4 to 0.7. Meanwhile, the rainfall might be a minor factor impacting the subsidence since the correlation between rainfall changes and subsidence was not strong. It is concluded that the groundwater level fluctuations had a superior impact on the surface deformation in the CRAF. Therefore, it is necessary to pay more attention to groundwater monitoring and management in the study area to mitigate the surface deformation. Lastly, this study also provided the spatio-temporal developments of cumulative displacements along the high-speed railroads (HSR). It was observed that the subsidence in the railroad segments located in Changhua County was generally not significant. After three years, the maximum ground elevation sinking was over 6 cm but only occurred in a small area. Oppositely, the HSR segments located in Yunlin County witnessed high-rate sinking. The most severe subsidence occurred in the Huwei, Tuku, and Yuanzhang sections, which were the centers of subsidence of the HSR profile. The maximum cumulative displacements here reach over -17 cm to -20 cm. The results of this study could be an estimation of the spatial and temporal development of land subsidence in the CRAF. Based on this result, the decision-makers could introduce appropriate policies to control the land subsidence issues in the CRAF.

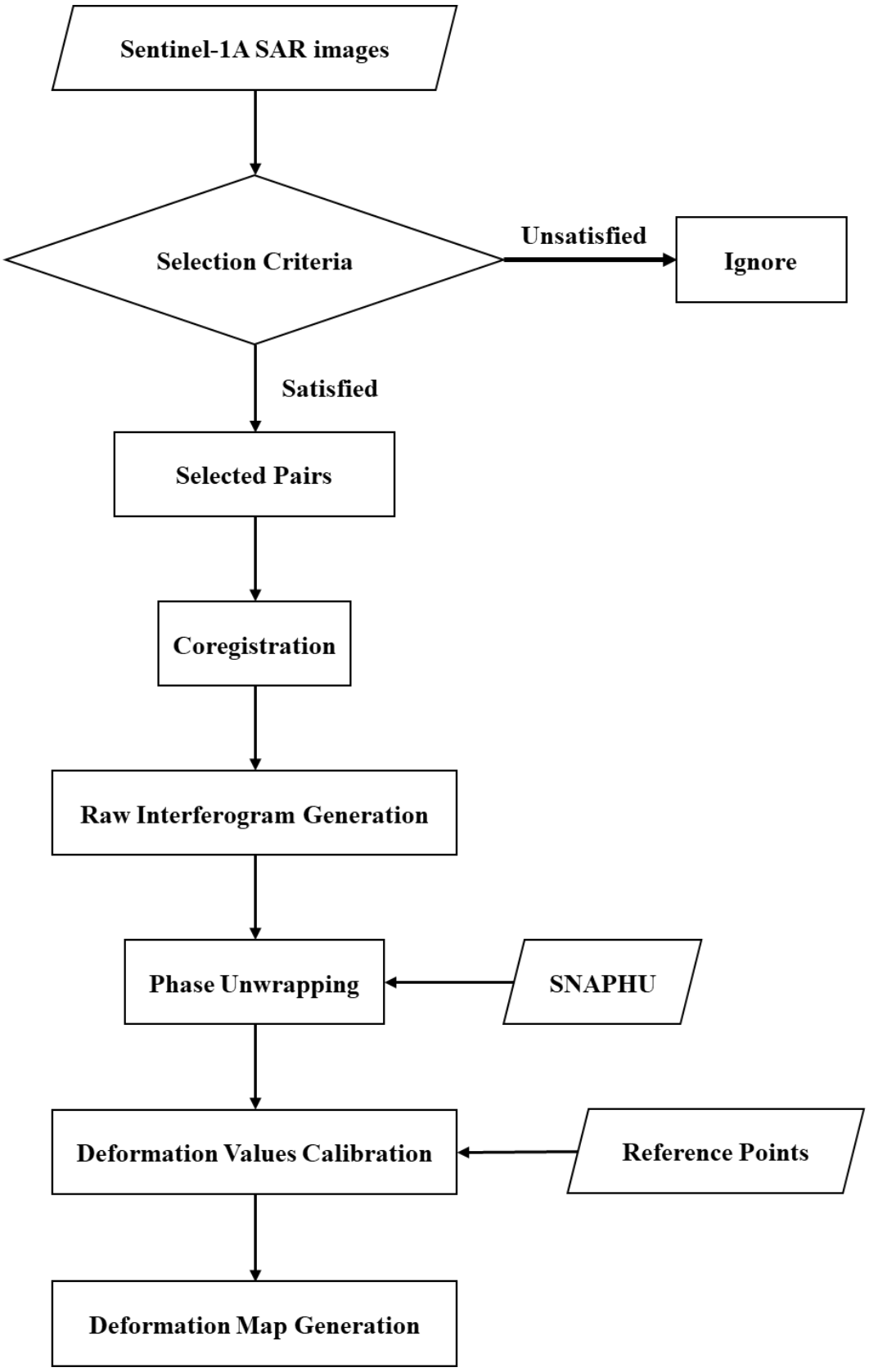

Figure 1: The flowchart of SAR image processing

Keywords: land subsidence, surface deformation, InSAR, SBAS-DInSAR