Integrated Use of GRACE-Derived Terrestrial Water Storage Changes and MODIS Vegetation Indices for RS-Based Drought Monitoring

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Abstract: The Philippines has been experiencing recurring drought events accentuated by the increasing incidence of El Niño phenomenon, particularly in Cagayan Valley Region. To address the negative effects of unpredicted drought events especially with the perceptible climate change, this research developed a methodology for RS-based drought monitoring by integrating 16-day MODIS Vegetation Indices (VIs) product with 250-m resolution and monthly Terrestrial Water Storage changes (TWSC) data in 1° (111-km) grids from NASA's Gravity Recovery and Climate Experiment (GRACE). Time-series data of TWSC and VI anomalies were statistically analyzed and compared with ground-based measurements of rainfall and water levels from monitoring stations within Cagayan River Basin (CRB) using 3-month running averages cross-correlation analysis.

Results showed that changes in ground water and vegetation health as indicated by TWSC and VIs, respectively, have varying correlations and response delays with respect to rainfall and water level changes depending on the condition of wetness or dryness of the prevailing season. However, it was observed that the results of running averages cross-correlation analysis between TWSC and VI anomalies exhibit a trend during drought events−high correlation coefficients coupled with low time lags. This can be used as an indicator of drought onset, duration, and spatial distribution. Because of this, the lag-normalized correlation analysis was developed to monitor and characterize the drought periods, and to identify the drought-prone areas in CRB as well.

Drought-sensitive areas in CRB were identified to be range lands located in flat grounds (0-17% slope) and has a soil texture of loam, silty loam, or clay loam based on the cross-correlation analysis, mostly situated at the central part of the river basin. Majority of the *barangays* identified as drought-prone based on the lag-normalized correlations between 2-year time series of TWSC and EVI anomalies are located in Cagayan and Isabela, with total areas of 2595.71 hectares (68.21%) in 696 *barangays* and 3751.02 hectares (56.89%) in 271 *barangays*, respectively. These provinces are also the most extensively affected by drought events based on actual historical records. The trends identified using lag-normalized correlations were also validated using additional rainfall values and volume of crop production and the results corresponded very well.

Since monitoring schemes usually depend on precipitation-derived indices alone and do not account for groundwater variations, the methodology performed in this study using the RS-based VI datasets and TWSC values was found to provide a reliable means of detecting the onset of droughts and assessing its progression. This in turn can help efforts to mitigate the adverse impacts of droughts to people, economy, and environment.

Keywords: drought, MODIS, GRACE TWS, vegetation index, lag-normalized correlations