Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

ACG30-14 Room:301B Time:May 25 14:30-14:45

Estimation of water storage and evaporation at seasonal wetlands in Namibia by satellite remote sensing

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North-central Namibia, classified as a semi-arid region, forms vast seasonal wetlands during the rainy season. Especially the seasonal ponds near the local farmers' house (*ondombe*) are assumed as important water resources for agriculture. Local farmers mainly have cultivated only pearl millet (*Pennisetum glaucum*), but nowadays they require the introduction of rice cropping in the seasonal ponds to mitigate the risk of poor harvests.

To introduce sustainable rice cropping, evaluation of available water resource and water budget in the seasonal ponds is required. However, there has been few such researches due to the difficulty of the hydrological monitoring because the seasonal ponds are distributed widespread area, and the water storage in the seasonal ponds fluctuate even during a few days. Thus we utilized satellite remote sensing together with field measurement to estimate the chronological water storage and evaporation in the seasonal ponds.

Study site covers north-central Namibia and the part of southern Angola (16:29:43S-19:05:20S, 14:24:59E-17:00:53). Also we set three test sites (each site is 5.4 km by 5.4 km) in the study site for field measurement. First we prepared three different types of satellite data (AMSR-E and AMSR2, MODIS, Landsat ETM+) from 2002 to 2013. We integrated these data by new data fusion technique (database unmixing; Mizuochi *et al*., 2014, *Remote Sensing*) to detect water covered area with temporally and spatially high resolution. Second, we made a field laser measurement in 11 typical seasonal ponds to generate regression model between water covered area and water storage in the seasonal ponds. Then we translated water covered area detected by satellite remote sensing into water storage based on the regression model. Finally, we estimated evaporation from seasonal ponds derived from satellite data, comparing with precipitation data obtained by field observation to reveal the hydrological features in this region.

As the result of database unmixing, the spatial resolution was improved from original resolution of AMSR-E and AMSR2 (25 km) to Landsat ETM+ resolution (30 m). Temporal resolution was also dramatically improved: original Landsat ETM+ provided only 1.8% available data through the study period, whereas database unmixing provided 88.5% available Landsat-like data through the study period. The laser measurement provided 110 samples which shows the relationship between water covered area and water storage in seasonal ponds. Based on these samples we generated regression model, and eventually translated water covered area detected by database unmixing into chronological water storage data from 2002 to 2013. Both the integral water storage and maximum value of water storage for each year reflected the precipitation situation of each year. For example, in the rainy season between 2012 and 2013, which was reported as the severe drought once in 30 years, the water storage was significantly less than the other year's water storage. While in the rainy season between 2008 and 2009, during which the flooding occurred in the surrounding rivers, both the annual integral water storage and maximum water storage were high. By comparing evaporation estimated by the satellite data with the precipitation data in three test sites, it was shown that the evaporation from the seasonal ponds was several to ten percent of the amount of water input by the precipitation. This result shows that both water infiltration into the ground and evaporation from the soil surface are important process to express this region's water budget.

This study not only revealed this region's water storage and water evaporation but also proposed new approach for hydrological monitoring with high spatiotemporal resolution in seasonal wetlands. Further researches should be done in the future on improvement of the algorithm or validation of these result.

Keywords: semi-arid, seasonal pond, database unmixing, laser measurement