論 文 の 内 容 の 要 旨

論文題目　Estimation of Global Irrigation Water Demand by Integrating Long-term Remote Sensing Dataset
(長期的リモート・センシングデータセット統合を利用したグローバルな灌漑水需要予測に関する研究)

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Compared with another sector, irrigation pointed as the highest water demand, with 70 % of global fresh water consumption is dominated for irrigation purpose. This sector also counted as the biggest contributor to global water loss problem, where 44% water in irrigation sector wasted. Irrigation Water Demand (IWD) defines as the amount of water needed for the crop to achieve optimal growth. As basis data information of water use in agriculture sector, improving the estimation of global water demand in agriculture sector can improve the irrigation water efficiency estimation, which is an important factor to achieve SDGs targets, especially goal no. 2: to double food production, goal no.6: to give drinking water access for the rapidly growing population and goal no.12: to achieve the sustainable management and efficient use of natural resources. Five main parameters to calculate IWD are Potential evapotranspiration (PET), precipitation, cropping intensity (CI), crop calendar - sowing date and cropping pattern. Monitoring accurately the long-term dynamic of global cropping intensity crop calendar, and rice non-rice cropping pattern is important to support global food security especially to estimate accurately water demand in agriculture sector. In this study our objective is to estimate long- term IWD from 2001 to 2015 at a spatial resolution of 1 km in the global scale. To achieve the main goal, we divide the main goal into three specific goals. The first goal is to harmonize and integrate cropland classes of current global land cover (GLC) datasets into cropland agreement level product. Second, to estimate long-term global cropping intensity, sowing month and dominant cropping pattern of rice and non-rice by integrating MODIS NDVI (optic) and AMSR LSWC (microwave). The last goal is to produce global Irrigation water demand (IWD) and its change by combining remote sensing of climate and dynamic crop coefficient with CROPWAT empirical model.

For developing long-term global Irrigation water demand, first, we estimate cropping intensity, sowing month, and dominant cropping pattern based on combination MODIS and AMSR-E/2. We investigate time series of satellite-sensed normalized difference

vegetation index (NDVI) from 16-Day MODIS (MOD13A2) composite from 2001 to 2015 and divide these 15 years archived data into three group of year (2001-2005, 2006-2010, 2011-2015). For estimating specific rice paddy cropping pattern and flooding session as well, we used Land Surface Water Coverage (LSWC) from daily AMSR-E/2 in three group of year (2003 – 2005, 2008 – 2010, and 2013 – 2015). Second, we develop Crop Coefficient (KC) by combining Cropland Agreement level, MODIS Cropping intensity, MODIS-AMSR Sowing month and MODIS- AMSR Cropping Dominant products. The final analysis is applying Doll and Siebert approach by multiplying MODIS potential evapotranspiration product (MOD16A2) with the developed KC. We include GSMaP precipitation, IIASA crop fraction, FAO-GMIA irrigated and HYDE rice paddy fraction to produce final product of long-term global IWD.

The results of cropland agreement level (CAL) analysis proposed four agreement levels, and the correlation factor obtained from the CAL product and IIASA crop fraction comparison had successfully estimated the percentage of cropland area from four agreement levels. The cropland estimate results from the CAL analysis were observed along with FAO data statistics and showed the highest accuracy, with a 0.70 and 0.71 regression value for 2005 and 2010 respectively. The presented MODIS-AMSR sowing month and cropping pattern products, to our knowledge are the first satellite-based products which derived from integration of vegetation and water index phenology from optic and microwave satellite sensor, that can analyze dynamic change of crop activities as one of essential input for estimating irrigation water demand. The advantages of the MODIS-AMSR sowing month product are capable to detect short period crop cultivation, distinguish rice and non-rice crop type and analyze trend of sowing month change from 15 years' data monitoring.

The final result of global irrigation water demand (IWD) products are the first satellite-based products that can analyze 15 years' dynamic change of water demand in cropland area. The total water use by irrigated and rainfed are 6,137 km3/ year in 2001-2005, 5,834 km3/ year in 2006-2010, and 7,491 km3/ year in 2006-2010. This calculation derived from three water use estimation categories: 1) total blue water (irrigation) used by irrigated crop, 2) total green water (precipitation) used by irrigated crop and 3). Green water used by rainfed crops. The long-term global IWD products are projected to simulate global surface water cycle in agriculture area in more realistic way by considering climate and crop activities which derived from actual, consistent and latest remote sensing datasets. This high resolution IWD product will support to achieve SDGs target in regional and country level analysis.