Improved Irrigation Demand Estimation via Soil Moisture Data from Satellite Images

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Abstract Nowadays, the development of optimum irrigation efficiency has been becoming more and more important with a primary role of controlling rate and time of irrigation water to meet crop water demand, while constraining losses and preserving water resources (Alhammadi and Al-Shrouf 2013). The soil layer and actual value of soil moisture content (SMC) at any given time must be known before any decisions on improving irrigation management can be made. In recent years, satellite surface soil moisture has tended to be more widely available (Champagne et al. 2016). In the study, the irrigation demand is estimated by using satellite images, LANDSAT. The Enhanced Vegetation Index (EVI) and Temperature Vegetation Dryness Index (TVDI) values are estimated from the plant growth stage and soil moisture to estimate near real-time irrigation demand. The derived irrigation demand estimation will help water allocation for irrigation and dam operation to meet the water demand of stakeholders more effective and efficient.

Definition and methodologies

The EVI2 and TVDI values were calibrated and verified with the field plant growth stages and soil moisture field data in the year 2017-2018. The irrigation demand in the irrigation project is then estimated from the plant growth stage and soil moisture in the Thor Thong Daeng Irrigation Project, Kamphangphet Province. With the estimated irrigation demand, the dam operation will manage the water supply in a better manner compared with using the past operational average data

Soil moisture sensor data

A soil moisture estimation model is established by using a collection of soil moisture observation and remote sensing data. A stepwise multiple regression approach was used to assess the relationship between observed soil moisture data and remote sensing data, i.e., TVDI were used as independent variables. The model can be computed by a regression formula as follows:

$$\text{Estimated soil moisture} = a + b(\text{TVDI})$$

where the estimated soil moisture is given as a percentage (%), and a, b are the coefficients of the regression lines of the TVDI.

The function was verified by comparing observed soil moisture content (SMC) at two observed locations in Phitsanulok Province with estimated SMC which was applied the function and TVDI values. Six Landsat 8 images were used to estimated TVDI and SMC at two locations. The estimated values of SMC presented a good correlation with observed values (adj-R2 = 0.5876) (as in Figure 1).

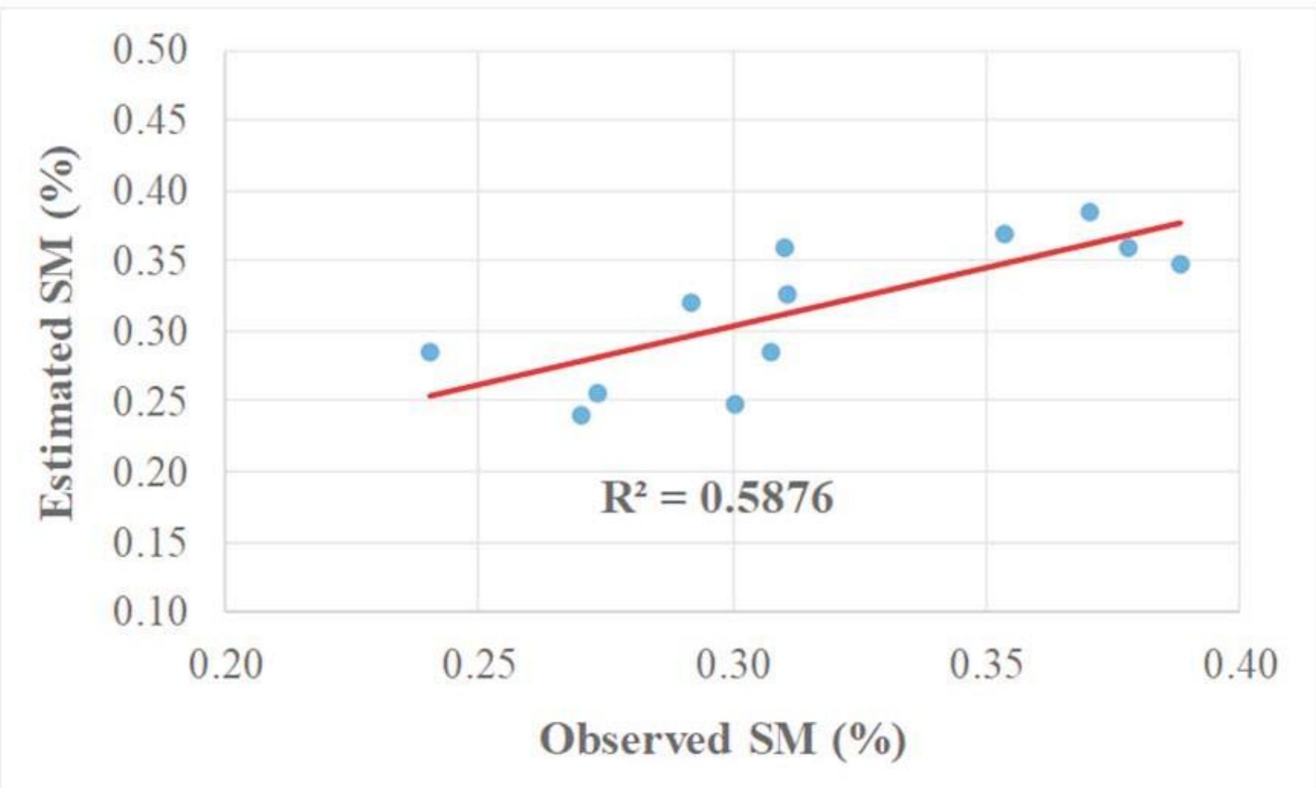

Figure 1. Calibration results of observed and estimated SMC

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Irrigation demand estimation

Crop water demand is defined here as "the depth of water needed to meet the water loss through evapotranspiration (ETcrop) of a disease-free crop, growing in large fields under non-restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment".

This water can be supplied to the crops in various ways such as by rainfall, irrigation or a combination of irrigation and rainfall. In this study area, part of the crop water need is supplied by rainfall and the remaining part by irrigation. In such cases, the irrigation water demand is the difference between the crop water need (ET crop) and that part of the rainfall which is effectively used by the plants (Pe) as the following formula:

$$IWD = ETcrop - Pe = Kc*ETo - Pe$$

where Pe is effective rainfall and ETo is reference crop evapotranspiration which can be calculated based a three-stage procedure of Allen et al. (1998).

Besides, total water demand of irrigation area can be estimated by using EVI2 coefficient to define growth stage and NDVI to distribute crop area. Table 1 shows the estimation of the irrigation water demand of the whole irrigation area. The estimated demand is highest in March due to heading and ripening period of paddy. During the logging and harvesting period in April, the demand increased to about 65 MCM/month. 2018

Table 1 Irrigation water demand estimation during dry season

Month	Monthly rainfall (mm)	Ce	Effective rainfall (m)	ETo (mm/d)	Kc	ET_{crop} K_c*ET_o (m)	Area (m^2)	Irrigation demand MCM
January	3.21	0.00	0.000	3.26	1.07	0.105	5.84E+08	61.30
February	14.16	0.80	0.011	3.91	1.37	0.161	5.84E+08	87.46
March	15.34	0.80	0.012	4.35	1.44	0.187	5.84E+08	102.19
April	48.61	0.80	0.039	5.01	1.01	0.152	5.84E+08	65.94

Efficiency improvement potentials

Based on the water loss from agricultural fields due to evapotranspiration and conveyance, irrigation water demand for the command area was calculated from January to April 2018. In this study, the net irrigation water demand was computed on monthly.

Table 2 Comparison of irrigation supply and demand ratios

Time	Irrigation demand MCM	Water supply MCM	Net Demand - Supply MCM	Ratio of Supply/Demand	Soil moisture
Jan-18	61.30	77.5	-16.20	0.72	27%
Feb-18	87.46	60	27.46	0.51	38%
Mar-18	102.19	75	27.19	0.47	40%
Apr-18	65.94	0	65.94	0.00	30%

Conclusions

To improve irrigation efficiency, demand and cultivation area estimation is very crucial. In this study, the satellite data provided the cultivation area, plan growth, and demand via ground data verification. The derived irrigation demand estimation will help water allocation for irrigation and dam operation to meet the water demand of stakeholders more effective and efficient.

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