ESTIMATION OF CROP WATER REQUIREMENT AND IRRIGATION EFFICIENCY USING CLOUD–BASED IRRISAT APPLICATION IN THE LOWER PING RIVER BASIN, THAILAND

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INTRODUCTION

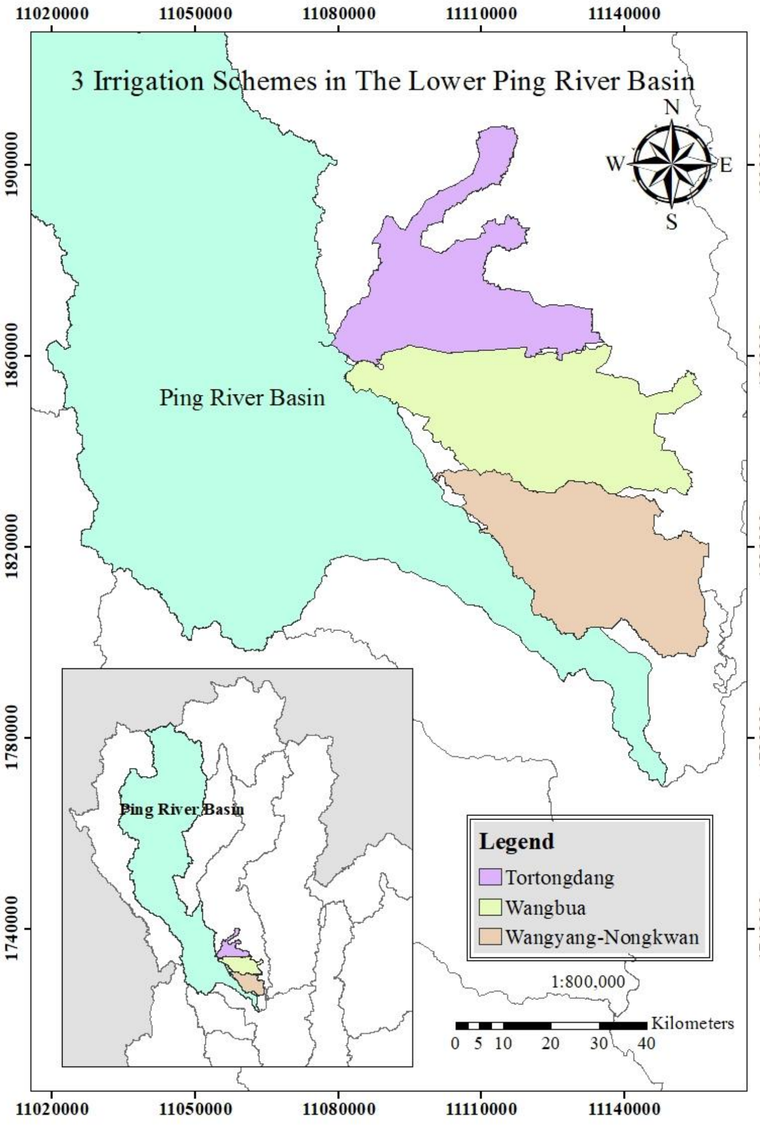


Fig.1 Map of irrigation schemes in the Lower Ping River Basin

Background Information

- Thailand's economic development has been mostly driven by the agricultural sector. Enhancing agricultural productivity in large–scale irrigation schemes plays an important role to raise the economic growth of the country.
- Therefore, water supply facilities and irrigation technologies should be potentially provided to farmers for raising agricultural productivity and modernizing the irrigation systems. Evaluating crop water requirement (ETc) and irrigation efficiency (IE) in irrigation areas requires the crop coefficient (Kc) as an important parameter.

Statement of Problem

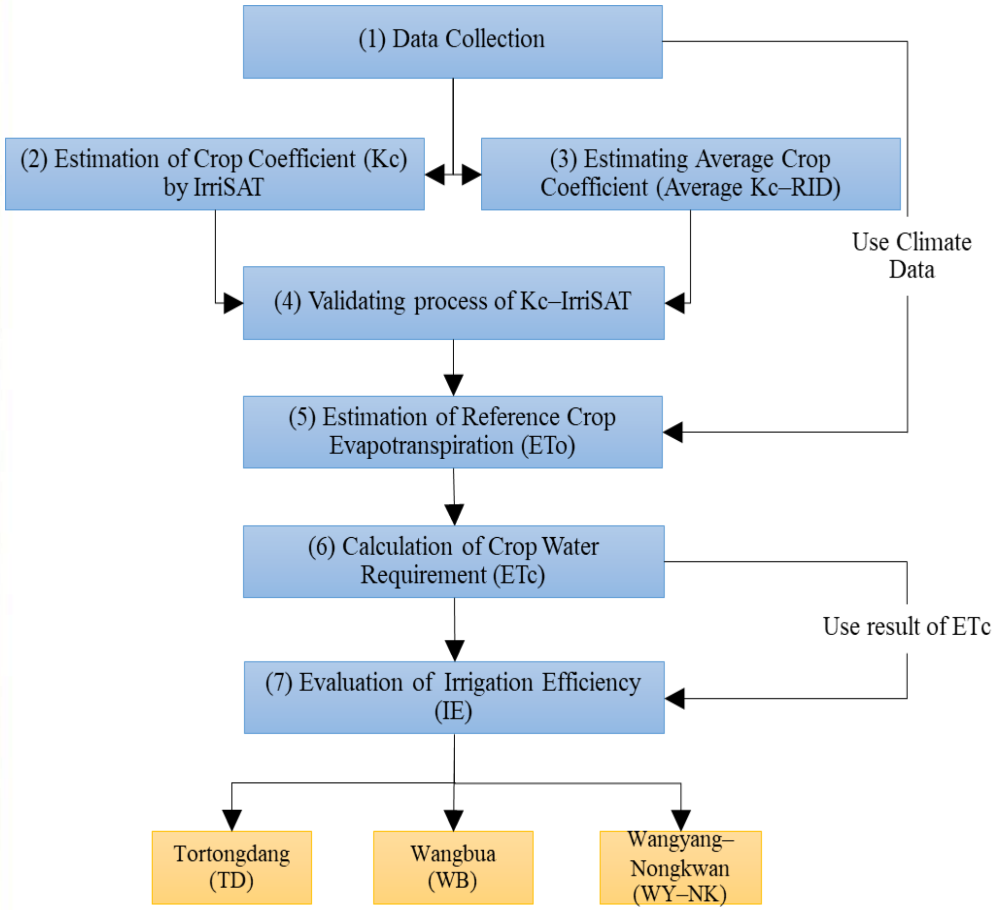
- The values of Kc are mainly subject to the crop types and dynamic growth periods of crops. This leads to the difficulty in estimating the certain amount of water to be delivered in irrigated areas.

Research objectives

- To track the dynamic values of ETc by using cloud–based IrriSAT application to find crop water requirement and irrigation efficiency of three irrigation schemes in the Lower Ping River Basin including Tortongdang (TD), Wangbua (WB) and Wangyang–Nongkwan (WY–NK).

METHODOLOGY

Research Framework



1. Data Collection

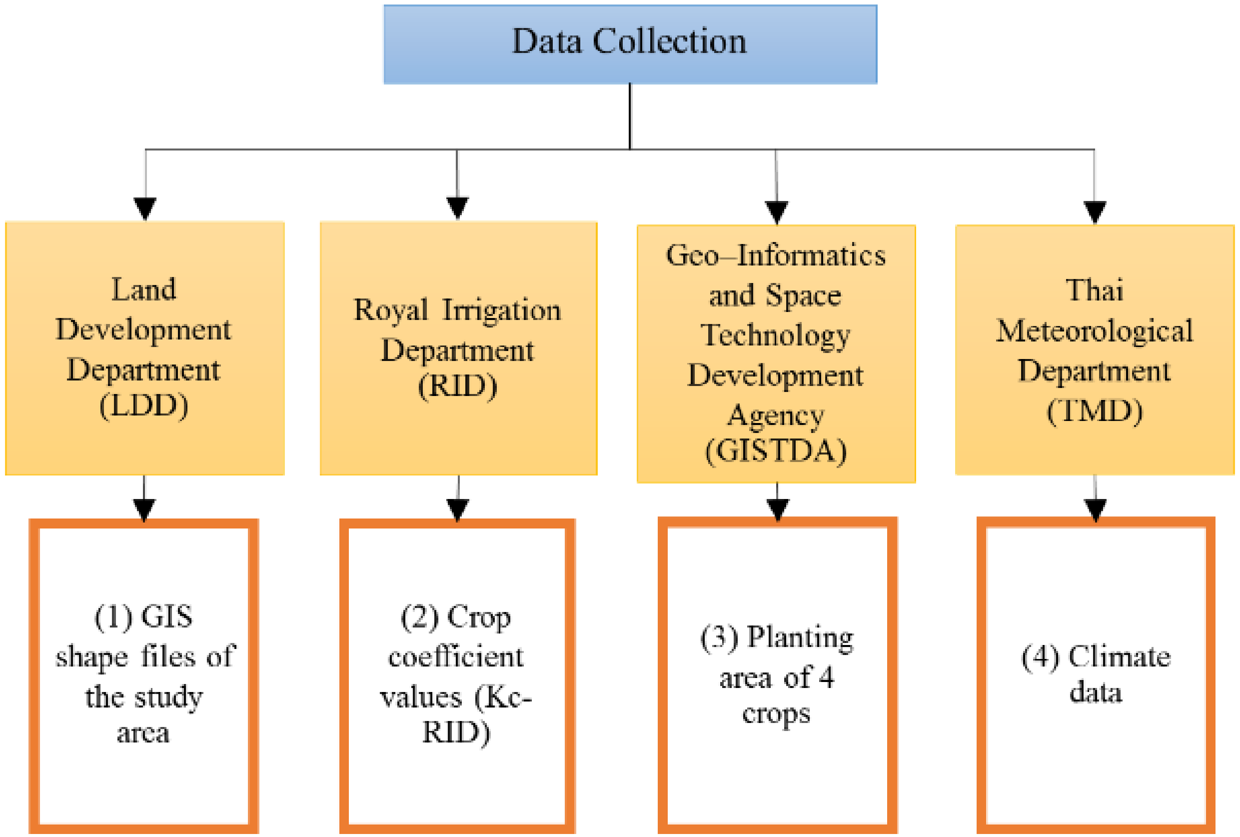


Fig.2 Simplified overview of data collection process

METHODOLOGY

2. Estimating Crop Coefficient Using Cloud–Based IrriSAT Application

- Estimating the dynamic values of crop coefficient over the growth stages can be commonly implemented by cloud–based IrriSAT application which is the satellite–based decision support tool for irrigators.

- K_c values in the IrriSAT application can be computed using the linear relationship equation with the Normalized Difference Vegetation Index (NDVI) value of crops; $K_c = 1.37\ NDVI - 0.086$

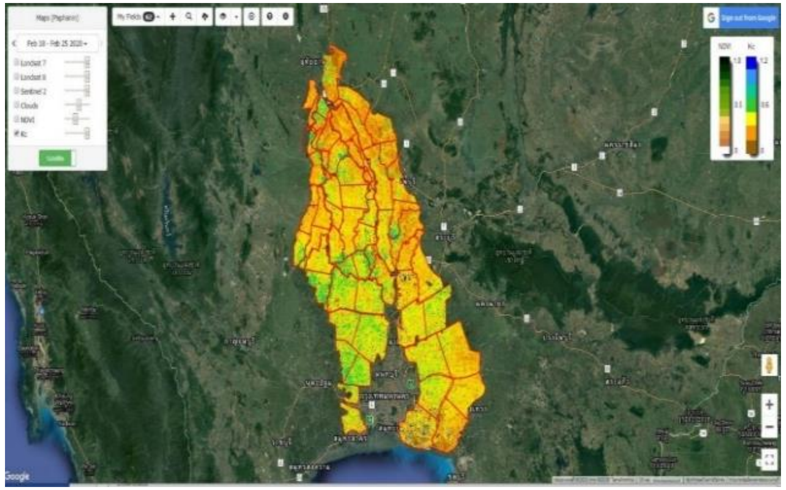


Fig.3 Display of area imported in cloud–based IrriSAT application

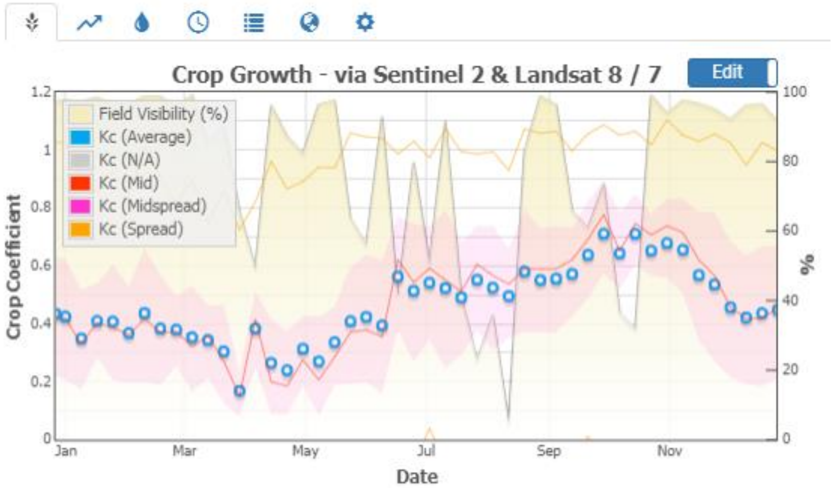
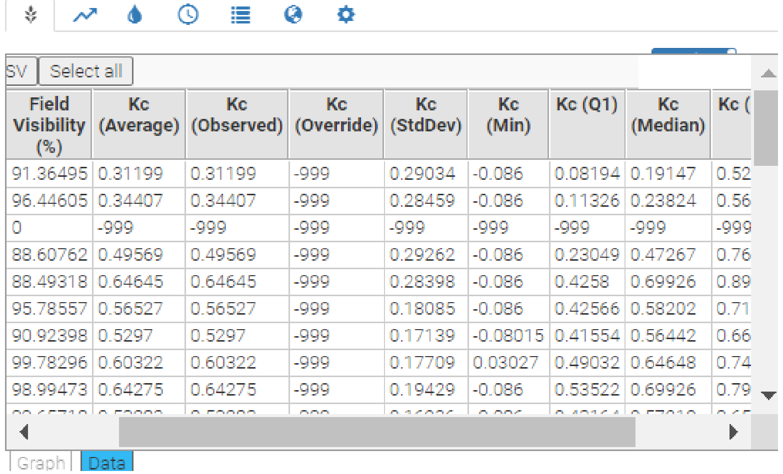


Fig.4 Typical chart of crop coefficient generated by cloud–based IrriSAT application



Field Visibility (%)	Kc (Average)	Kc (Observed)	Kc (Override)	Kc (StdDev)	Kc (Min)	Kc (Q1)	Kc (Median)	Kc (
91.36495	0.31199	0.31199	-999	0.29034	-0.086	0.08194	0.19147	0.52
96.44605	0.34407	0.34407	-999	0.28459	-0.086	0.11326	0.23824	0.56
0	-999	-999	-999	-999	-999	-999	-999	-999
88.60762	0.49569	0.49569	-999	0.29262	-0.086	0.23049	0.47267	0.76
88.49318	0.64645	0.64645	-999	0.28398	-0.086	0.4258	0.69926	0.89
95.78557	0.56527	0.56527	-999	0.18085	-0.086	0.42566	0.58202	0.71
90.92398	0.5297	0.5297	-999	0.17139	-0.08015	0.41554	0.56442	0.66
99.78296	0.60322	0.60322	-999	0.17709	0.03027	0.49032	0.64648	0.74
98.99473	0.64275	0.64275	-999	0.19429	-0.086	0.53522	0.69926	0.79

Fig.5 Various forms of Kc were generated through the cloud–based IrriSAT application

METHODOLOGY

3. Estimating Average Crop Coefficient (Average Kc–RID) Using Observation Data

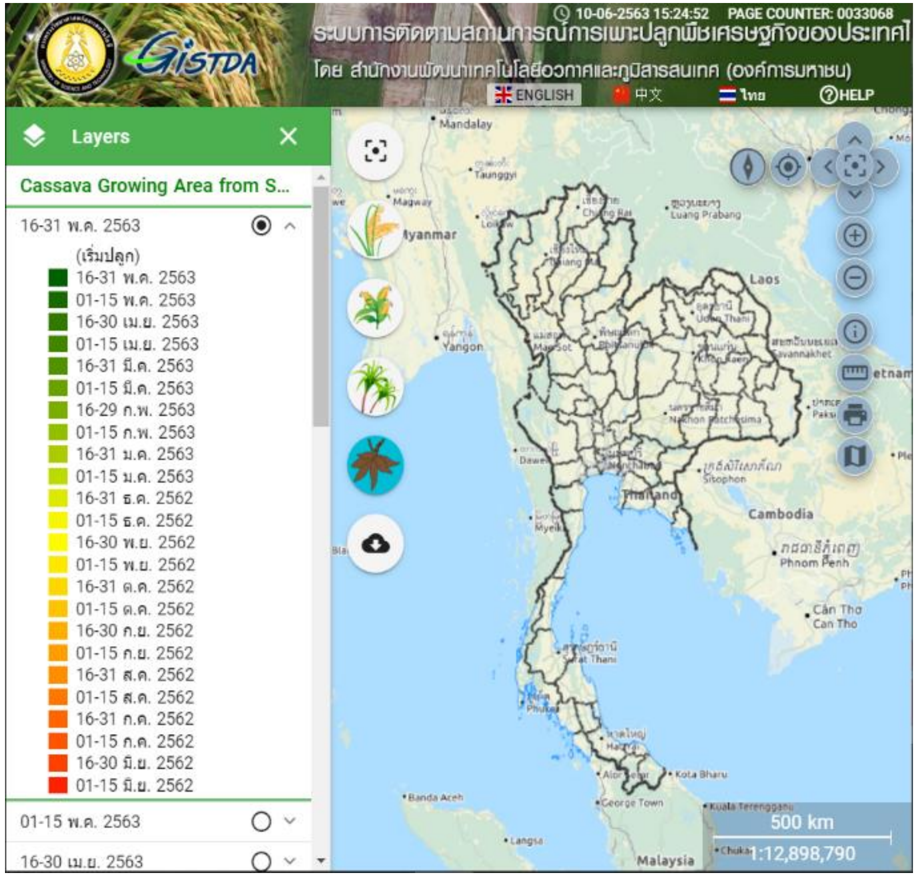


Fig.6 Display of the remote sensing technique (GISagro 4.0) of GISTDA

- Average Kc–RID values were calculated as a function of Kc from field observation for the different types of crop and accumulated area of crops monitored by the remote sensing technique (GISagro 4.0) of GISTDA.

- Average Kc–RID based upon 4 main types of crops namely; (1) rice, (2) sugarcane, (3) maize, and (4) cassava on the weekly scale were computed using Eq.(1).

$$\text{Average Kc} = \frac{(\text{Kcri x Areari}) + (\text{Kcsu x Areasu}) + (\text{Kcmi x Areami}) + (\text{Kcca x Areaca})}{\text{Total Area}} \quad (1)$$

Where
Kcri = crop coefficient of rice, Kcsu is crop coefficient of sugarcane
Kcmi = crop coefficient of maize, Kcca is crop coefficient of cassava
Areari = the accumulated planting area of rice
Areasu = the accumulated planting area of sugarcane
Areacmi = the accumulated planting area of maize
Areaca = the accumulated planting area of cassava

METHODOLOGY

4. Validating Process of Kc–IrriSAT

- Calibrating K_c values performed by IrriSAT was conducted using the least square criterion to envisage the good correlation between K_c–IrriSAT and average K_c–RID and to find the adjusted factors for the specified time periods.
- The method of the least squares is a standard approach in regression analysis to approximate the solution of overdetermined systems by minimizing the sum of the squares of the residuals made in the results.

(2) Estimation of Crop Coefficient (Kc) by IrriSAT

(3) Estimating Average Crop Coefficient (Average Kc–RID)

(4) Validating process of Kc–IrriSAT

- To estimate these adjusted factors, the solver in MS excel will be used as an analytical tool and long-term data sets of Kc-IrriSAT and K_c–RID are prepared on the daily basis.

METHODOLOGY

5. Estimating Reference Crop Evapotranspiration (ETo)

- The monthly calculations of reference crop evapotranspiration (ET_o) was implemented based upon the FAO Penman–Monteith equation using ET_o calculator. The Penman–Monteith equation requires air temperature, humidity, solar radiation, and wind speed data as key inputs as expressed in Eq.(2).

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \qquad (2)$$

- where, ET_o is reference evapotranspiration (MJ m^{-2} day^{-1}), R_n is net radiation at the crop surface (MJ m^{-2} day^{-1}), G is soil heat flux density (MJ m^{-2} day^{-1}), T is the mean air temperature at 2 m height (°C), u_2 is the wind speed at 2 m height (m s^{-1}), e_s is saturation vapor pressure (kPa), e_a is actual vapor pressure (kPa), $e_s - e_a$ is the saturation vapor pressure deficit (kPa), Δ is the slope of the vapor pressure curve (kPa $°C^{-1}$), and γ is the psychometric constant (kPa $°C^{-1}$).

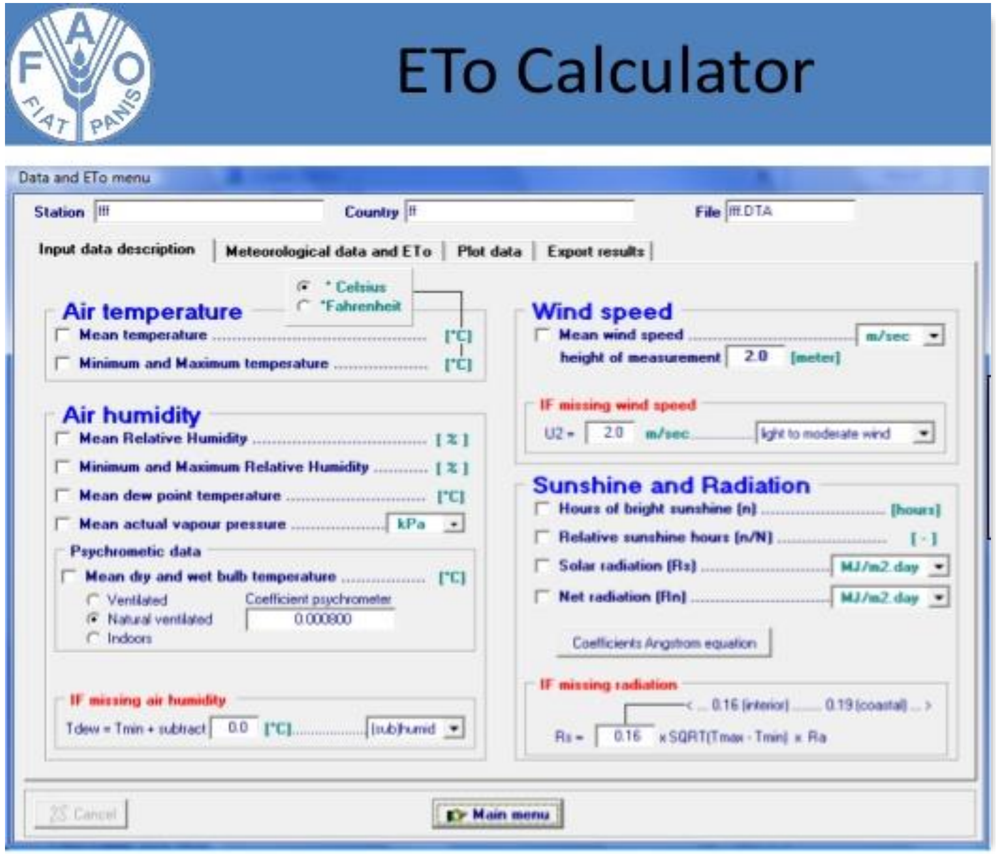


Fig.8 Display of ETo calculator

METHODOLOGY

6. Calculating Long–Term Crop Water Requirement (ETc)

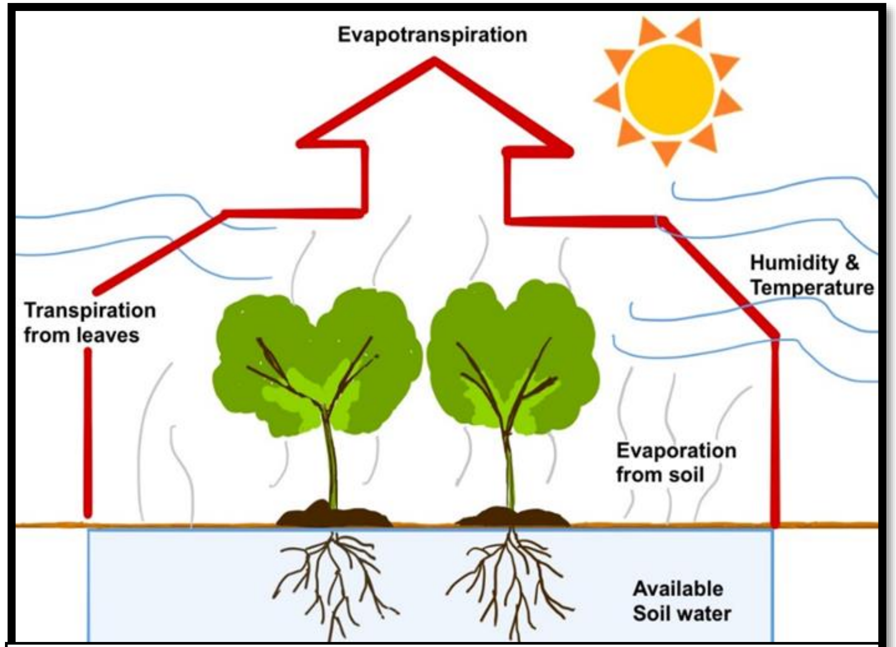


Fig.9 Crop Water Requirement

Evaporation of water from soil

Transpiration of water from leaves

- Crop Water Requirement (CWR) also known as crop evapotranspiration (ET_c), is described as the depth of water (millimeters) needed to compensate for the water losses through crop evapotranspiration.

- After validating process of K_c–IrriSAT and ET_o calculations were successfully done, the yearly crop water requirement (ETc) was quantified using Kc–IrriSAT adjusted and ET_o values.

$$ET_c = K_c \times ET_o \qquad (3)$$

- where, ET_c is crop water requirement (mm/period), K_c is crop coefficient done by could–based irrisat application (K_c–irriSAT adjusted) and average K_c–RID, and ET_o is reference crop evapotranspiration (mm/period).

METHODOLOGY

7. Evaluation of Irrigation Efficiency (IE)

- After all the related data were computed, the last step was to calculate the irrigation efficiency of the Lower Ping irrigation schemes by using the following eq.4.

$$\text{IE (\%)} = \frac{\text{Net Irrigation Water Requirement (NIR)}}{\text{Gross Irrigation Water Requirement (GIR)}} \times 100 \quad (4)$$

- Where GIR = the amount of water supplied through irrigation (mm)
  NIR = the amount of water consumed by crops (mm)

- To estimate Net Irrigation Water Requirement (NIR), it requires the values of deep percolation and effective rainfall as given in the following equation.

$$NIR = ETc + Dp - Re$$

- Where NIR = net water requirement (mm)
  ETc = potential crop evapotranspiration (mm)
  Dp = deep percolation losses (mm)
  Re = effective rainfall (mm)

- Gross Irrigation Water Requirement (GIR) is analyzed from the observed flow data collected from the Royal Irrigation Department (RID) including flows at the intake structures of Lower Ping Irrigation schemes.

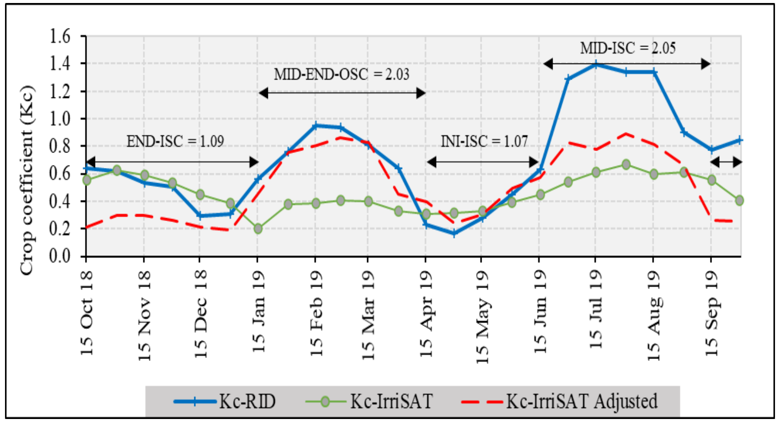
RESULTS AND DISCUSSIONS

Crop Coefficient (Kc) Generated from Cloud–Based IrriSAT Application

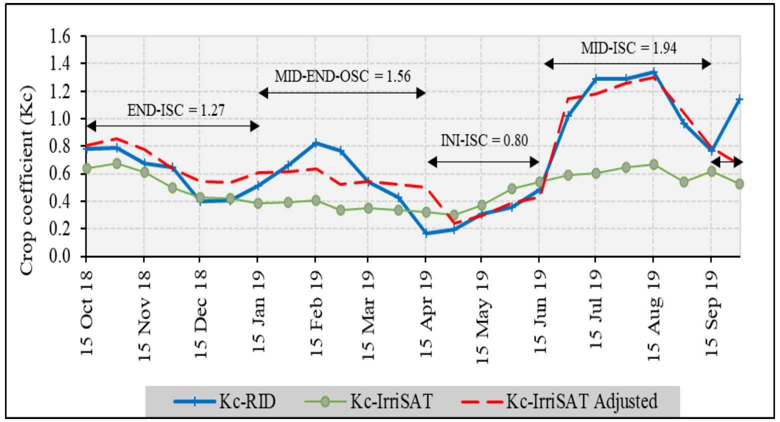
Table 1 The crop coefficient values obtained from cloud–based IrriSAT application and RID

Name of Irrigation Scheme	Max. K_c(avg.)–IrriSAT	Max. K_c(avg.)–RID
TD	0.6698	1.3942
WB	0.6760	1.3412
WY–NK	0.6841	1.3415

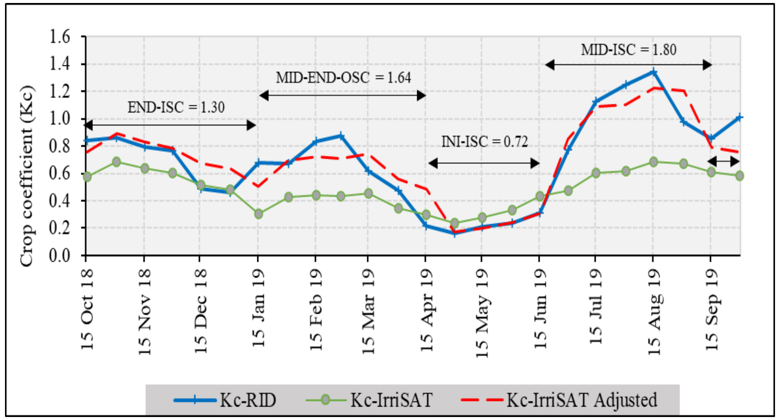
Relationship between Kc–IrriSAT and average Kc–RID



(a) Tortongdang



(b) Wangbua



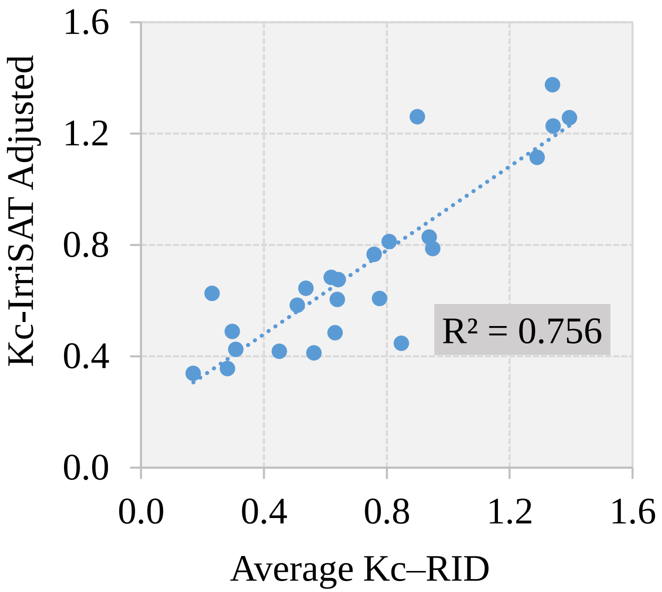
(c) Wangyang–Nongkwan

Fig.10 The pattern of K_c values over the growth stages of crops

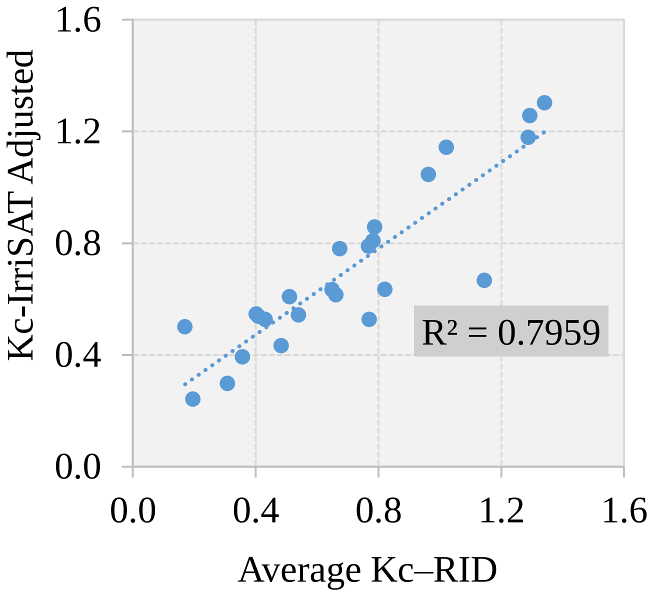
RESULTS AND DISCUSSIONS

Relationship between Kc–IrriSAT and average Kc–RID

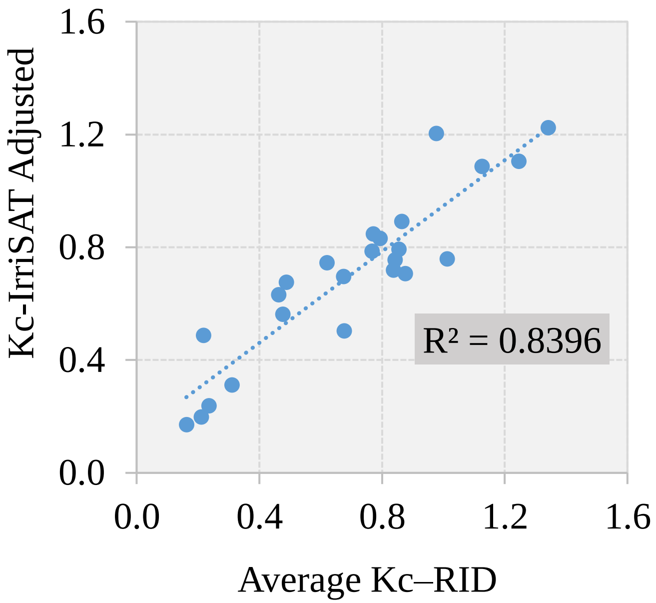
- In addition, correlations between Kc–IrriSAT and average Kc–RID for TD, WB, and WY–NK irrigation schemes are relatively high with R^2 of 0.7560, 0.7959, and 0.8396, respectively after the validation process was successfully done.



(a) Tortongdang



(b) Wangbua



(c) Wangyang–Nongkwan

Fig.11 The correlation between K_c–IrriSAT Adjusted and K_c–RID

RESULTS AND DISCUSSIONS

Crop Water Requirement (ETc) and Irrigation Efficiency (IE)

- The yearly estimated values of NIR are 406.25, 382.83, 247.00 MCM for TD, WB, and WY–NK irrigation schemes, respectively and the yearly measured values of GIR are 562.54, 476.56, and 437.06 MCM for TD, WB, and WY–NK irrigation schemes as illustrated in Fig. 12.

- However, high irrigation efficiency were definitely found in the TD and WB irrigation schemes with IE of 72.16% and 80.33%, respectively. Irrigation efficiency of WY–NK irrigation scheme was 56.49% considering as good in term of irrigation performance.

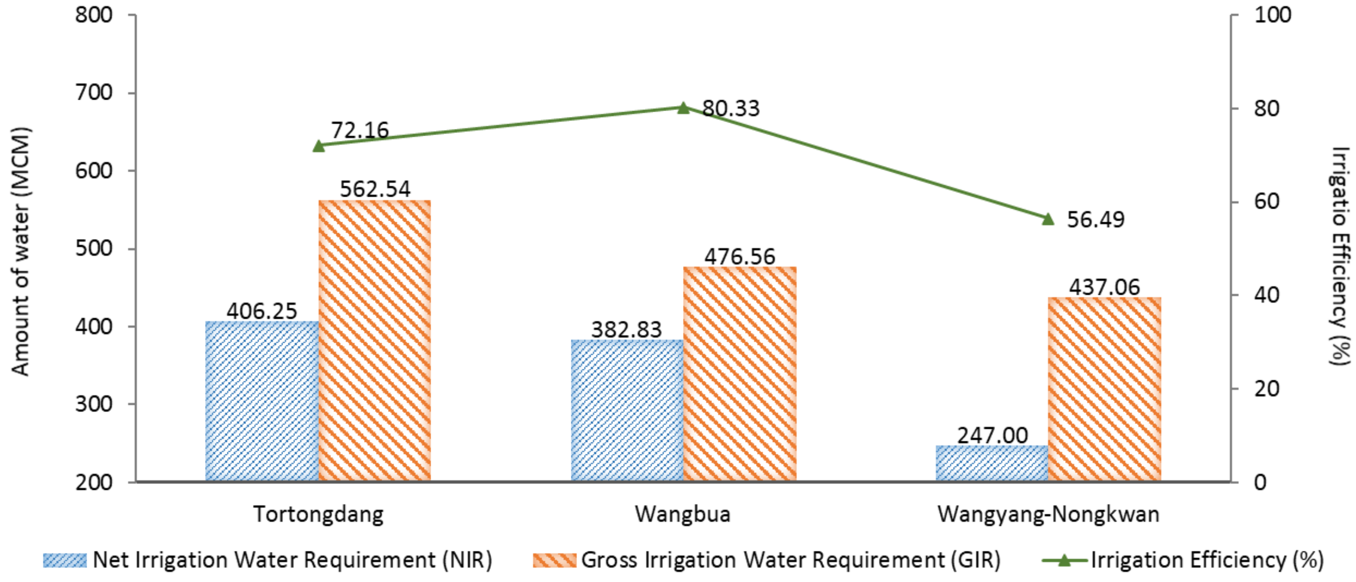


Fig.12 Comparison of yearly NIR and GIR and irrigation efficiency of three irrigation schemes

CONCLUSIONS

- This research revealed the estimation of crop water requirement and irrigation efficiency of three irrigation schemes in the Lower Ping River Basin using the cloud–based IrriSAT application.

- It could be drawn that IrriSAT application can be a useful tool to trace the dynamic values of crop water demand particularly in the small to large irrigation areas.

- In addition, it is very helpful for the canal operators to specify an affordable amount of water delivery and to improve the irrigation efficiency at the field scale.

- This is a good technique to use the remote sensing technology to trace crop water demand in the spatial large scale area because it is cheaper and more rapid than using human observation.

THANK YOU