ARTICLE

Predicting the water use-demand as a climate change adaptation strategy for rice planting crops in the Long Xuyen Quadrangle Delta

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Abstract

This work evaluates the impacts of climate change on water use-demand of three rice planting crops including winter–spring (WS), summer–autumn (SA) and autumn–winter crops for Long Xuyen Quadrangle Delta of Vietnam. Climatic variables scenarios were obtained from the updated report on emission scenarios which are issued by Vietnam's Ministry of Natural Resources and Environment for three future timescales (2016–2035, 2046–2065 and 2080–2099) of representative concentration pathways (RCP) 4.5 and RCP8.5 scenarios. Cropwat model was selected to evaluate the irrigation water demand of three rice planting crops based on simulating actual evapotranspiration (ETc) and effective rainfall for the study area. The results showed that the WS and SA planting crops need more irrigation water demand in the growing and developmental stage for timescales of RCP4.5 and RCP8.5 scenarios. Results also pointed out that compared with current climate condition the tendency to decrease in irrigation water demand in the initial and developmental stages of autumn–winter planting crop with arranging from 2.9–12.9 to 10.0–18.2%, respectively, corresponding to timescales of RCP4.5 and RCP8.5 scenarios is found and a significant downward trend in the late stage approximately 5.8–20.0% and 13.6–20.7%, respectively, for RCP4.5 and RCP8.5 scenarios also recorded.

Introduction

Long Xuyen Quadrangle (LXQ) is one of the large deltas in the Mekong Delta of Vietnam alongside the Plain of Reeds (Deb et al. 2015; Dinh et al. 2012). In recent years, LXQ is being impacted by drought and salt intrusion leading to irrigation water scarcity (Deb et al. 2015; Vu et al. 2018). In addition, flow from the Hau River, one of the large branches belonging to the lower Mekong River, where it supplies the main irrigation water for rice fields in the entire Mekong Delta of Vietnam, has decreased significantly in the dry season (Dinh et al. 2012; Vu et al. 2018) that it is the main cause leading to lack of irrigation water and it has seriously affecting all aspects of people's lives and especially agricultural production (Babel and Turyatunga 2014; Deb et al. 2015; FAO 2016).

The study area belongs to Mekong Delta of Vietnam where is considered as one of the five river deltas which is seriously affected by climate variability (Mainuddin et al. 2013; FAO 2016). MNRE (2016) reported that climate variability has significantly changed in temperature and rainfall patterns including annual rainfall and seasonal rainfall in the delta areas of Vietnam (Shrestha et al. 2014; MNRE 2016). Recently studied results by MNRE (2016) based on the RCP scenarios of CO_2 emission reported that temperature and rainfall at some areas belonging to the Mekong Delta of Vietnam will be increased and it directly affected the growth and developmental stages of plants because they are directly related to climate factors (Trinh et al. 2013; Wassmann et al. 2009). According to RCSA (2016), the Mekong Delta of Vietnam will suffer the worst drought over 90 years and paddy fields will likely be damaged (FAO 2016; Shrestha

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et al. 2016). For agricultural production, rainfall is considered as the major source to provide crop irrigation water; especially in the context of climate variability study area often occurs drought and saline intrusion (Aggarwal and Singh 2010; RCSA 2016).

Studies on the crop water requirement for agricultural production showed that the water requirements for the crops will increase along with the rising temperature under the impacts of climate change (APN 2010; FAO 2016). Therefore, studies on the future crops water requirement are essential for agricultural production, especially in the context of climate change in the near recent (Poudel and Shaw 2016; Shrestha et al. 2014). According to Mainuddin et al. (2013), climate change is one of the greatest challenges facing mankind in the twenty-first century.

In that context, more and more crop models such as CERES, APSIM, CropSyst, WOFOST, Sorkam, EPIC, SAFYE, Aquacrop, Almanac and Cropwat have been constructed and widely applied as a useful tool to support strategic decision for agricultural management policies in at different areas of the world (Adnan et al. 2017; Archontoulis et al. 2014; Yue et al. 2015; Silvestro et al. 2017). Cheng et al. (2018) applied the WOFOST crop model to predict crop growth on Hongxing Field in northeast area of China. They reported that the differences in crop growth stages are caused by a lack of soil nutrients. Umair et al. (2017) simulated actual evapotranspiration, biomass and grain yield at Luancheng Agro-ecosystem Station by using the CropSyst model. They reported that the used model can be applied with a reliable degree of accuracy for simulating crop water requirement and grain yield. Kim et al. (2013) estimated the impact of climate change on rice yield based on a temperate factor by using the CERES crop model. The results showed that the proposed model demonstrates the promising potential for its further application in simulating rice yield. Deb et al. (2016) investigated the climate change impact and used brackish water to irrigate for rice crops in the Ca Mau Peninsula of Vietnam. The results confirmed that the forward and early shifts in the crop plating day and an increase in fertilizer application rates are reported to be beneficial to enhance the crop yield. In addition, Shrestha et al. (2016) also tested the AquaCrop model to evaluate the impact of climate change on rice crops yield at the Central region of Vietnam. They carried out that rice yield will increase from 2.07 to 6.66% in the summer season crop for 2020 s and 2050 s scenarios. Chatterjee et al. (2012) assessed water use requirement in the Gangetic West Bengal under the impact of climate change using the Cropwat model. Results showed the Cropwat model is successfully applied to forecasting water use requirement for the study area. Therefore, the objective of this work is to establish irrigation schedule for rice cropping seasons based on the current climate condition (1992–2017) and climate change

scenarios RCP4.5 and RCP8.5 for 2016–2035, 2046–2065 and 2080–2099 timescales.

Materials and methods

Study area

The study area (09°57′–10°42′N and 104°29′–105°29′E) lies in the northwestern of Mekong Delta of Vietnam (Dinh et al. 2012; Trinh et al. 2013). LXQ is one of the two major deltas in the Mekong Delta of Vietnam alongside the Plain of Reeds area with the total land area about 490,000 ha belonging to the An Giang, Kien Giang and Can Tho provinces (Fig. 1). Yearly, this area provides about 25% of rice output for the Mekong Delta (Dinh et al. 2012; Mainuddin et al. 2013; MNRE 2016).

Agricultural production is evaluated the dominant sector of LXQ area compared with the other areas in the Mekong Delta of Vietnam with annual rice yield reaching approximately 5.0 million tons based on the local rainfall with mean manual rainfall in the entire study area over 2000 mm (Table 1), and irrigation water comes from the Hau River which is one of two river branches belonging to the lower Mekong Delta River (FAO 2016; RCSA 2016).

In addition, the climate condition is suitable for rice production with the mean temperature varying from 25.6 to
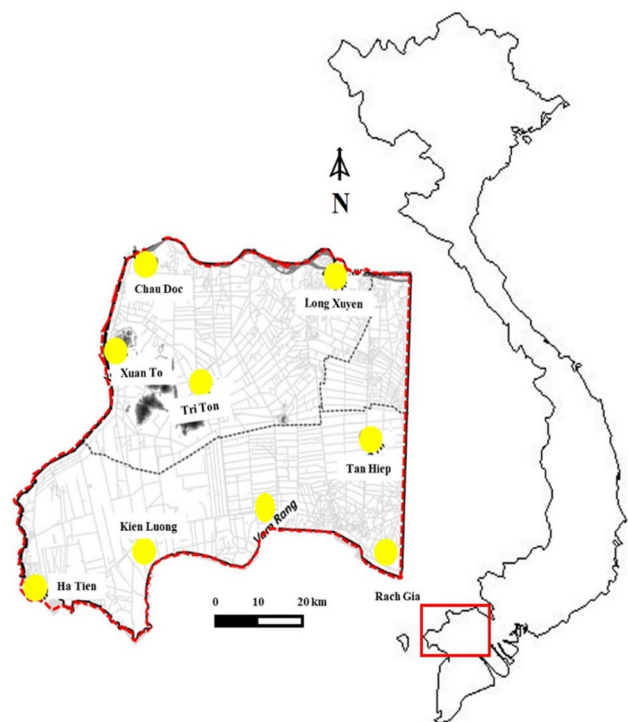

Fig. 1 Study area with meteorological stations

Table 1 Statistics of mean annual rainfall (MAR) and standard deviation (SD)

Station	MAR (mm)	SD (mm)	Latitude (N)	Longitude (E)
Long Xuyen	1401.7	199.87	10°23′08.77″	105°26′3.54″
Chau Doc	1262.4	274.32	10°42′21.07″	105° 6′57.94″
Xuan To	1392.7	278.16	10°35′32.16″	104°56′44.17″
Tri Ton	1488.9	293.73	10°23′50.80″	104°59′08.06″
Vam Rang	1586.4	211.05	10°02′43.51″	105°44′53.09″
Tan Hiep	2956.4	537.18	10°06′55.57″	105°17′00.39″
Kiên Lương	2771.5	443.69	10°18′12.70″	104°38′18.32″
Rach Gia	2143.5	297.89	10° 01′18.32″	105°05′26.52″

28.9 °C (APN 2010; Dinh et al. 2012; RCSA 2016), mean daily sun shines approximately 6.23 h, and mean monthly air humidity 80.16% with rainy season lasts from May to November and accounts for 90 percent of the annual rainfall (Fig. 2).

However, with relatively low terrain (range from 0.25 to 2.0 m compared to mean sea level) (Mainuddin et al. 2013; RCSA 2016; Trinh et al. 2013), agricultural production of LXQ area in recent years is facing many challenges, namely drought, salt intrusion, sea level rise and unseasonal rainfall leading to waterlogging, as part of climate change impact (Deb et al. 2016; RCSA 2016).

Cropwat model description

Cropwat is a crop model which was created first by the Land and Water Development Division of Food and Agriculture Organization (FAO), Italy (FAO 1998; Nazeer 2009). Cropwat model is designed to calculate the reference evapotranspiration, actual evapotranspiration, effective rainfall, irrigation water requirement and irrigation scheduling, and specifically, it can simulate irrigation water requirement for other planting crops corresponding to the future climate

change scenarios (Banik et al. 2014; FAO 1998; Kawasaki and Herath 2011).

In the Cropwat model, the Penman–Monteith formula applied to determine reference evapotranspiration. It is considered as the appropriate formula to define reference evapotranspiration, and it has been recommended to apply in the climate research for regions of the world (Bouraima et al. 2015; Lee et al. 2004; Yadav et al. 2016).

Reference evapotranspiration is determined as Eq. (1):

$$ET_O = \frac{0.408\Delta\left(R_n - G\right) + \gamma\frac{900}{T+273}u_2\left(e_s - e_a\right)}{\Delta + \gamma\left(1 + 0.34u_2\right)} \quad (1)$$

where R_n is the net radiation at the soil surface (MJ/m²/day); G is a soil heat flux density (MJ/m²/day); T is the mean daily air temperature (°C); u_2 is wind speed at 2.0 m height (m/s); e_s is the saturation vapor pressure (kPa); e_a is the actual vapor pressure (kPa); Δ is the slope of the vapor pressure curve (kPa/°C); γ is psychrometric constant (kPa/°C).

In addition, actual evapotranspiration is defined based on reference evapotranspiration and the crop coefficient (K_c); actual evapotranspiration then is provided for the crop water requirement module to define irrigation water requirement for each planting crop through the irrigation scheme (Arku et al. 2012; FAO 1998; Shah et al. 2015).

In the Cropwat model, actual evapotranspiration (ET_c) is defined as Eq. (2) for 10–days.

$$ET_C = ET_O * K_C \quad (2)$$

where K_C depends on each type of the crop and their growth stage.

In agricultural production, crop water requirement is understood as the amount of water which is necessary to be provided for plants due to the evaporation (Bhat et al. 2012; Khoshravesh et al. 2013) and crop water requirement (CWR) for each planting crop is defined through the effective rainfall (ER) over the entire planting area (Bhat et al. 2012; Bouraima

Fig. 2 Mean monthly rainfall at gauge stations in the study area
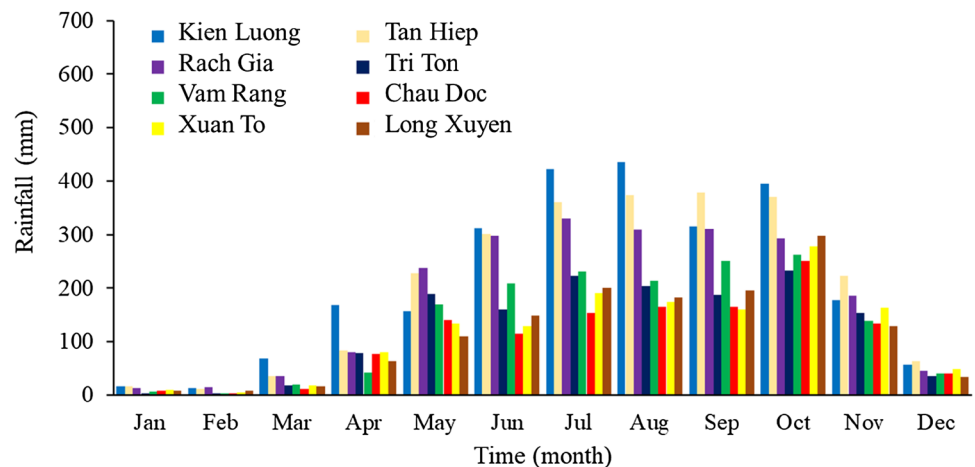
et al. 2015). On the contrary, the ER is defined as that part of the rainfall which is effectively issued for the plants after rainfall losses due to percolation and runoff (Bouraima et al. 2015; Shah et al. 2015). The ER is the rainfall ultimately often applied to define the crop irrigation requirements (CIRs).

ER is defined as follows:

$$ER = 125 + 0.1 \times P_{month} \tag{3}$$

where ER is effective rainfall (mm) and P_{month} is the total rainfall (mm).

Equation (3) is valid for average monthly rainfall at gauge station more than 250 mm. Collected rainfall data at eight meteorological gauge stations in the study area (Table 1) have found that average monthly rainfall in period 1992–2017 on the rainy season is more than 250 mm.

The Cropwat model predicts the monthly water requirements of an irrigation scheme to define crop water requirement for each planting crop as expressed in Eq. (4).

$$Q = \sum_{i=0}^{n} A_i (ET_C - ER) * 10 \tag{4}$$

where Q is monthly agricultural water requirement of irrigation scheme (m^3/day); i is crop index; A_i is crop planting area (m^2); ET_C is actual evapotranspiration (mm/day); ER is the effective rainfall (mm/day).

Input data

In the Cropwat model (version 8.0), to run climate module, input climate data including solar radiation, sunshine duration, temperature, humidity, wind speed and precipitation are required. In this study, input meteorological data were collected at the Southern Regional Hydro-meteorological Center of Vietnam (SRHCV) for the period of 20 years (1992–2017) (Fig. 3).
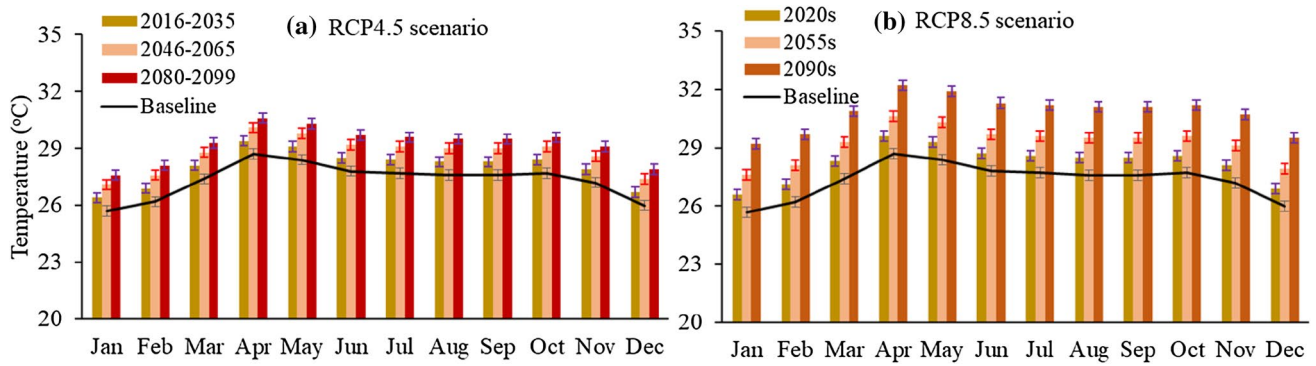
Future change scenarios of RCP4.5 and RCP8.5 in rainfall (Fig. 4) and temperature (Fig. 5) for study area corresponding to time scales 2016–2035, 2046–2065, and 2080–2099 were referenced from the updated report on emission scenarios which are issued by Ministry of Natural Resources and Environment of Vietnam (Table 2).

In addition, to determine the irrigation requirements, information on the various crop characteristics such as the

Fig. 3 Input meteorological data for Cropwat model in the period 1992–2017
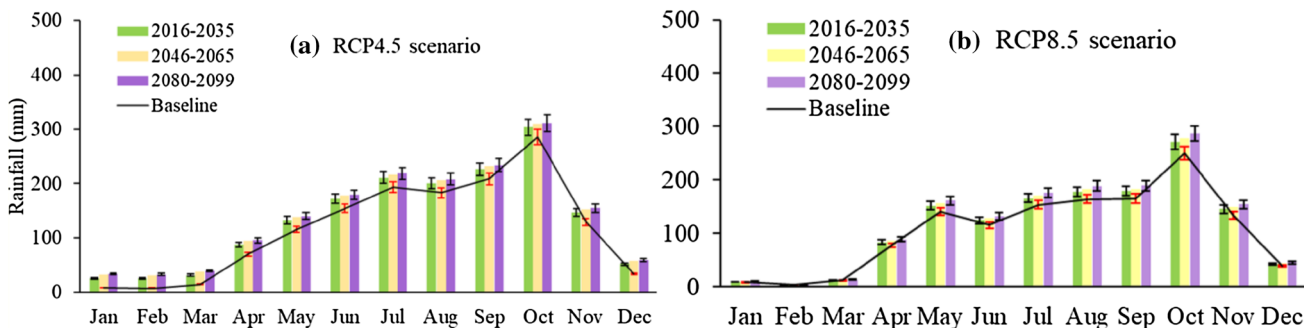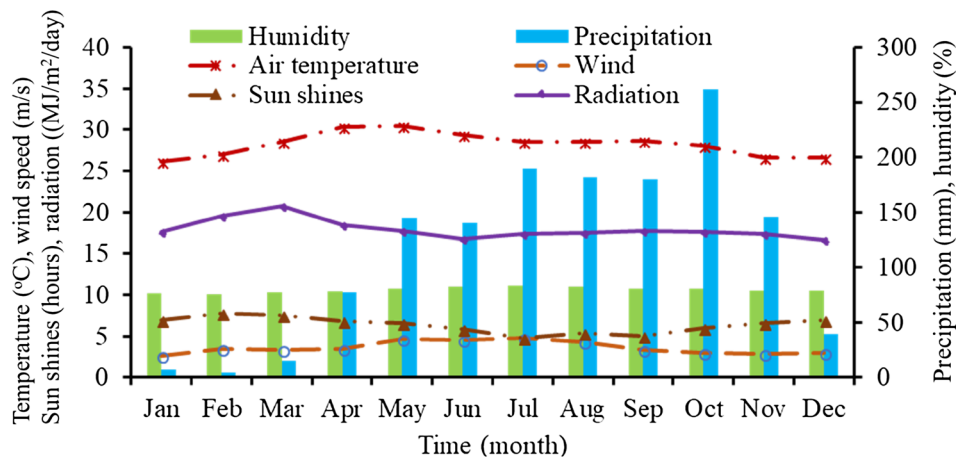
Fig. 4 Scenarios of future changing a RCP4.5 and b RCP8.5 in rainfall for study area

Fig. 5 Scenarios of future changing **a** RCP4.5 and **b** RCP8.5 in temperature for study area

Table 2 Scenarios of future changing in temperature and rainfall for study area

Baseline (1992–2017)	Future timescales	RCP4.5 scenario	Change	RCP8.5 scenario	Change
Temperature 27.36 °C	2016–2035	28.06 ± 0.8 °C	0.7 °C	28.26 ± 0.95 °C	0.9 °C
	2046–2065	28.76 ± 1.5 °C	1.4 °C	29.26 ± 2.0 °C	1.9 °C
	2080–2099	29.26 ± 2.0 °C	1.9 °C	30.86 ± 3.6 °C	3.5 °C
Rainfall 1382.56 mm	2016–2035	1456.41 ± 4.55 mm	4.7%	1495.92 ± 22.04 mm	8.2%
	2046–2065	1563.67 ± 13.55 mm	13.1%	1536.02 ± 18.62 mm	11.1%
	2080–2099	1577.50 ± 13.86 mm	14.1%	1585.79 ± 17.03 mm	14.7%

Table 3 Planting and harvesting dates, growing and crop growth stage coefficient

Crop	Crop coefficient (K_C)				Growth stages (day)				Crop length (day)	Sowing date	Harvesting date
	I	II	III	IV	I	II	III	IV			
WS	0.30	0.54	1.05	0.81	10	10	60	25	105	15-Dec	30-Mar
SA	1.03	1.19	1.74	1.12	10	10	65	31	111	15-Apr	06-Aug
AW	1.04	1.17	1.68	1.14	10	10	60	20	100	20-Aug	30-Nov

WS winter–summer, *SA* summer–autumn, *AW* autumn–winter, *I* land preparation stage, *II* initial stage, *III* developmental stage, *IV* late stage

planting and harvesting dates, length of the crop cycle, growth stages and crop coefficient is given in Table 3.

Besides the crop patterns, information on the soil characteristics such as infiltration rate, plowing depth, water depth, rooting depth and soil moisture was collected and then analyzed (Table 4) based on the Soil Water Characteristics software (Oyeogbe and Oluwasemire 2013). The analyzed results showed that the soil in the study area was mostly silty–clay mix clay with predominantly acidic.

Results and discussion

Actual evapotranspiration

The simulation results of actual evapotranspiration for three rice planting crops (TMPC) corresponding to current period

Table 4 Relevant soil characteristics

Soil description	Values
Maximum rain infiltration rate	105 mm/day
Plowing depth	20 cm
Maximum water depth	50 cm
Water availability at planting	7.5 mm WD
Maximum rooting depth	90 cm
Initial available soil moisture	140 mm/m
Maximum percolation rate after puddling	400 mm/day
Critical depletion for puddle cracking	104
Drainable porosity (SAT-FC)	13%
Initial soil moisture depletion	55%
Total available soil moisture (FC-WP)	140 mm/m

WD water depth, *SAT* the moisture content at saturation, *FC* field capacity, *WP* wilting point

(1992–2017) and future timescales of RCP4.5 and RCP8.5 scenarios are illustrated in Fig. 6. For current climate conditions, the actual evapotranspiration values of winter–spring, summer–autumn and autumn–winter crops recorded approximately 607.9, 699.7 and 584.6 mm, respectively, while the simulated results of actual evapotranspiration corresponding to future climate change scenarios carried out a slight upward tendency 2.07–5.61% of WS crop, 3.48–7.04% of SA crop and 6.14–9.81% of AW crop for timescales 2016–2035, 2046–2065 and 2080–2099 of RCP4.5 scenario. Similarly, for RCP8.5 scenario, an increasing tendency compared with current climate conditions was also detected for WS crop (2.12–5.65%) and a significant upward trend recorded in the SA crop (2.67–10.46%) and AW crop (2.64–10.51%), respectively.

The results also showed that high actual evapotranspiration appeared in the development and late stages of all crops for the current period and timescales of RCP4.5 scenario (Fig. 6a), while timescales of RCP8.5 scenario recorded that high actual evapotranspiration appeared in the development stage (Fig. 6b) of all cropping seasons. Bouraima et al. (2015) reported that in the dry season crops request more water than in the rainy season.

Effective rainfall

The calculated results of effective rainfall for three rice planting crops corresponding to the current period and future timescales of RCP4.5 and RCP8.5 scenarios are given in Fig. 7. Specifically, effective rainfall of winter–spring crop corresponding to current climate conditions and timescales

of RCP4.5 and RCP8.5 scenarios is very low (1.2–3.6 mm/stage) for all growth stages of rice (Fig. 7), while effective rainfall of summer–autumn and autumn–winter crops reached high values in the initial, developmental and late stages (approximately 81.6–148.9 mm/stage).

Analyzed results indicated that simulated model of effective rainfall is consistent with the actual climate conditions; because WS crop coincides with the dry season, the weather did not occur rainfall during this stage.

Effective rainfall corresponding to timescales of RCP4.5 scenario slightly increased by 1.26–1.67%, 1.05–1.18% and 1.06–1.19% %, respectively, for winter–spring, summer–autumn crop and winter–autumn crops compared to the current climate condition. Those values are 1.43–1.96%, 1.11–1.26% and 1.09–1.28%, respectively, for winter–spring, summer–autumn crop and winter–autumn planting crops (Table 5) for RCP8.5 scenario. The results are consistent with the updated report of the MNRE (2016) on predicting rainfall tendency for the Mekong Delta region of Vietnam corresponding to timescales of RCP4.5 and RCP8.5 scenarios.

Irrigation water demand (IWD)

Analyzed results showed that the peak period of irrigation water demand occurred on the land preparation stage of three planting crops (Fig. 8) and then declined in the initial, developmental and late stages of summer–autumn and autumn–winter planting crops for current climate condition and timescales of RCP4.5 and RCP8.5 scenarios (Table 6), while for winter–spring crop, the peak period of irrigation
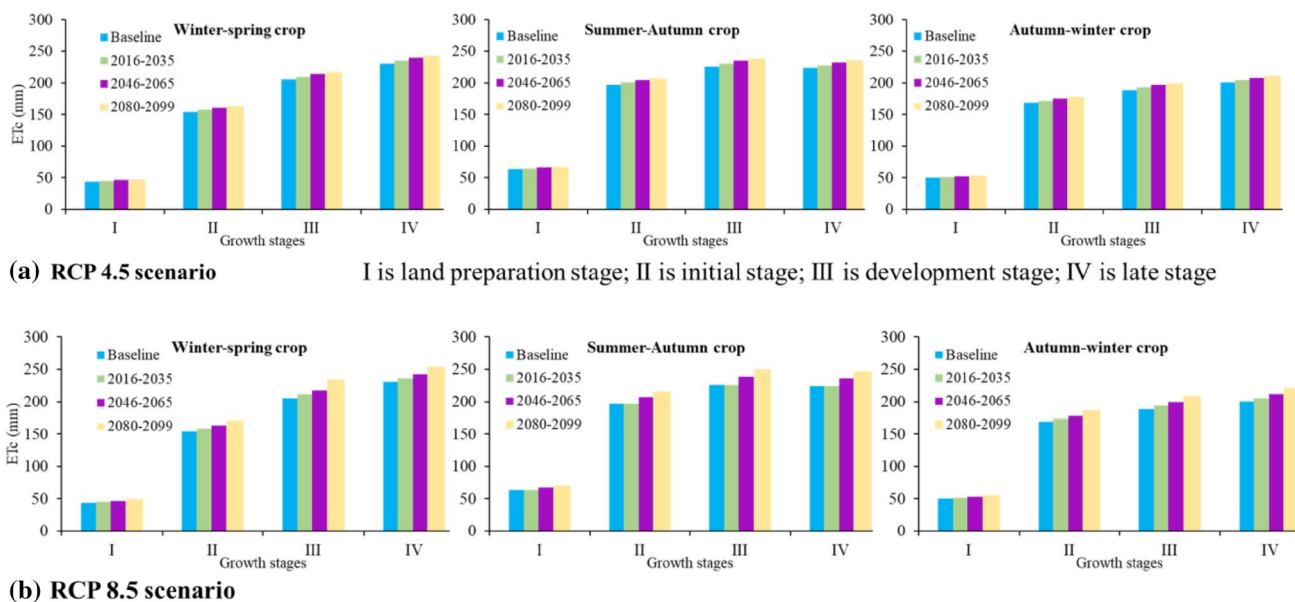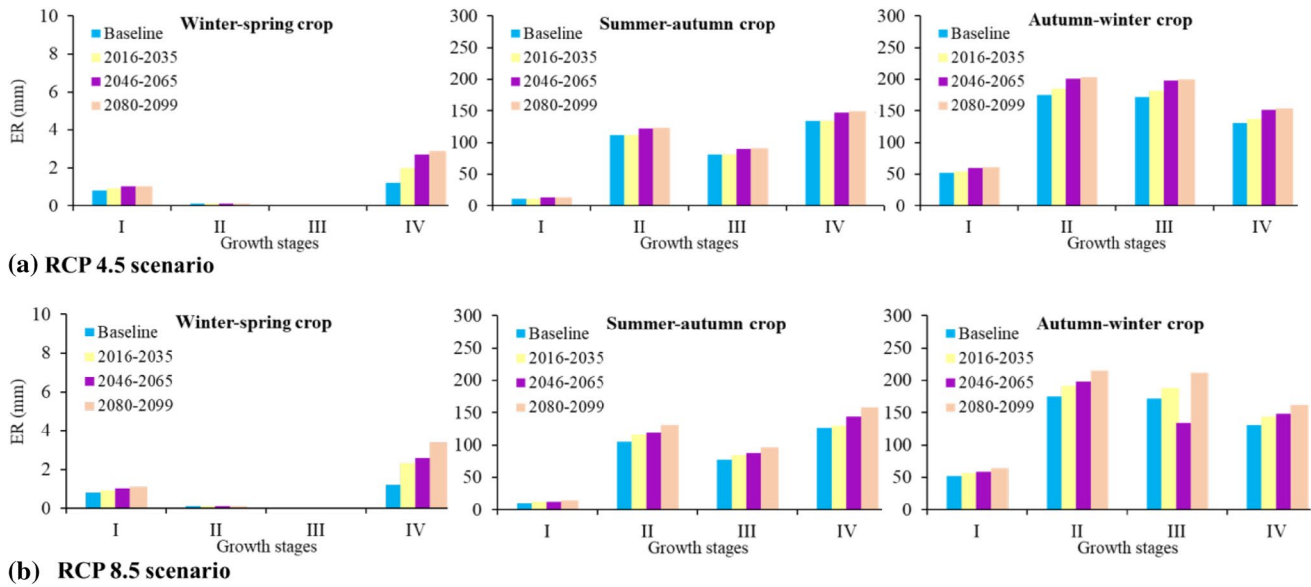

Fig. 6 Simulated results of actual evapotranspiration for three planting crops corresponding to **a** RCP4.5 scenario and **b** RCP8.5 scenario

Fig. 7 Effective rainfall of WS, SA and AW crops corresponding to **a** RCP4.5 scenario and **b** RCP8.5 scenario

Table 5 Changed trend of effective rainfall (mm) corresponding to winter–spring, summer–autumn and autumn–winter planting crops under the future climate scenarios compared with current climate condition

Crop	Stage	Current condition	RCP4.5 scenario			RCP8.5 scenario		
			2016–2035	2046–2065	2080–2099	2016–2035	2046–2065	2080–2099
WS	I	0.8	0.9 (+12.5%)	1.0 (+25%)	1.1 (+37.5%)	0.9 (+12.5%)	1.0 (+25%)	1.2 (+50%)
	II	0.15	0.15 (0%)	0.14 (−6.6%)	0.13 (−13.3%)	0.14 (−6.6%)	0.12 (−20%)	0.11 (−26.6%)
	III	0.07	0.07 (0%)	0.06 (−14.2%)	0.05 (−28.5%)	0.06 (−14.2%)	0.05 (−28.5%)	0.04 (−42.8%)
	IV	1.2	2.0 (+66.7%)	2.7 (+125%)	2.8 (+133%)	2.2 (+83.3%)	2.5 (+108.3%)	3.3 (+175%)
SA	I	10.3	11.1 (+7.8%)	12.7 (+23.3%)	12.9 (+25.2%)	11.9 (+15.5%)	12.4 (+20.4%)	14.1 (+36.9%)
	II	105	111.2 (+5.9%)	122 (+16.2%)	123.5 (+17.6%)	115.7 (+10.2%)	119.4 (+13.7%)	130.7 (+24.5%)
	III	76.6	81.4 (+6.3%)	89.9 (+17.4%)	90.7 (+18.4%)	84.9 (+10.8%)	87.8 (+14.6%)	96.9 (+26.5%)
	IV	126.8	134.0 (+5.7%)	147.1 (+16%)	148.9 (+17.4%)	129.5 (+2.1%)	144.0 (+13.6%)	158.1 (+24.7%)
AW	I	51.0	54.7 (+7.3%)	59.8 (+17.3%)	60.5 (+18.6%)	56.9 (+11.6%)	58.6 (+14.9%)	64.1 (+25.7%)
	II	175.5	184.8 (+5.3%)	201 (+14.9%)	203.7 (+16.1%)	191.8 (+9.3%)	197.7 (+12.6%)	215.6 (+22.8%)
	III	172.4	181.6 (+5.2%)	198.0 (+14.8%)	199.9 (+16%)	188.4 (+9.2%)	204.1 (+18.4%)	211.7 (+22.6%)
	IV	130.5	137.9 (+5.6%)	151.5 (+15.7%)	153.1 (+17.3%)	143.5 (+9.9%)	148.3 (+13.6%)	162.7 (+24.6%)
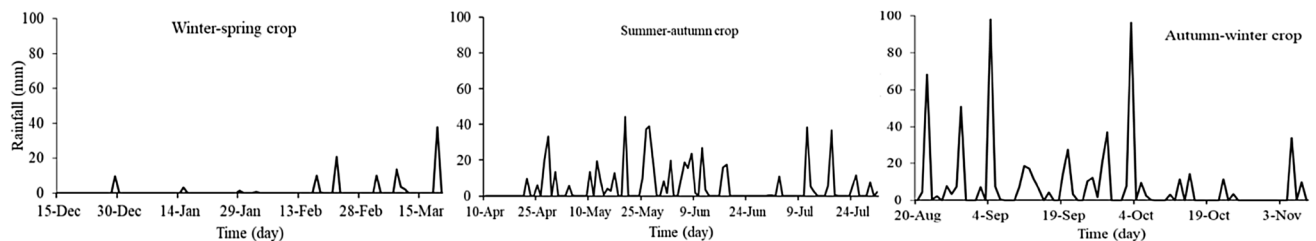
Fig. 8 Average daily rainfall in the period 1992–2017 corresponding to planting and harvesting times of winter–spring, summer–autumn and autumn–winter crops

water demand also occurred on the land preparation stage, declined in the initial stage and then increased again in the development and late stages (Fig. 9).

Analyzed results also showed that compared with current climate condition, irrigation water demand of the land preparation stage of WS and AW planting crops has increased significantly for timescales of RCP4.5 and RCP8.5 scenarios. Specifically, irrigation water demand of winter–spring and autumn–winter planting crops increased approximately 12.5–13.3% and 19.2–21.9%, respectively, corresponding to timescales of RCP4.5 scenario, while these values of RCP8.5 scenario varied from 12.8–14.5 to 25.6–31.3% (Fig. 10; Table 6).

Based on the analyzed results of mean daily rainfall and temperature data (not shown) in the study area during the period 1992 to 2017 carried out that the major reason of the increased irrigation water demand can be explained that high temperature and less precipitation increased the capacity of the air to accommodate water vapor, so the increased air demand for water vapor, which consequently implies high crop evapotranspiration rates, and finally water use requirement of rice also increased in the dry season period.

Irrigation water demand of autumn–winter planting crops appeared a tendency to decrease in the initial and development stages (approximately 2.9–12.9% and 10–18.2%, respectively, for timescales of RCP4.5 and
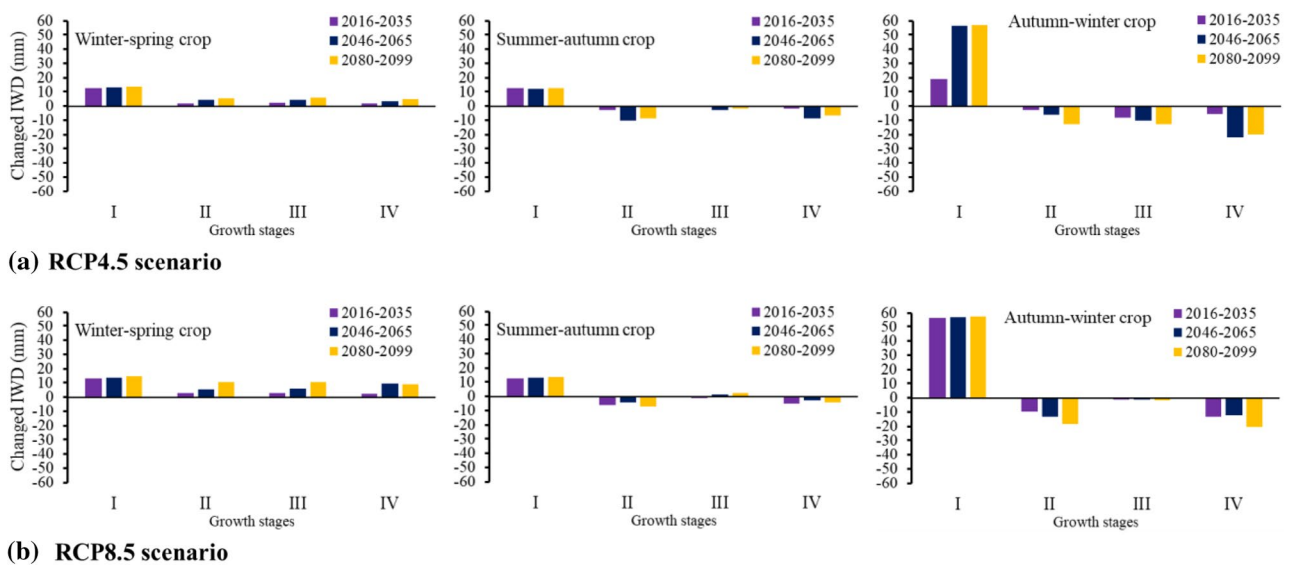
Table 6 Changed trend of irrigation water demand (mm) corresponding to winter–spring, summer–autumn and autumn–winter crops under the future climate scenarios compared with current climate condition

Crop	Stage	Current condition	RCP4.5 scenario			RCP8.5 scenario		
			2016–2035	2046–2065	2080–2099	2016–2035	2046–2065	2080–2099
WS	I	233.5	262.8 (+12.5%)	263.7 (+12.9%)	264.6 (+13.3%)	263.4 (+12.8%)	264.7 (+13.4%)	267.3 (+14.5%)
	II	154.1	157.2 (+2.0%)	160.5 (+4.2%)	162.7 (+5.6%)	158.2 (+2.7%)	162.7 (+5.6%)	170.3 (+10.5%)
	III	206	210.4 (+2.1%)	214.6 (+4.2%)	217.8 (+5.7%)	211.6 (+2.7%)	217.8 (+5.7%)	227.9 (+10.6%)
	IV	228.6	232.5 (+1.7%)	236.2 (+3.3%)	239.4 (+4.7%)	233.4 (+2.1%)	249.8 (+9.3%)	249.5 (+9.1%)
SA	I	239.4	269.4 (+12.5)	268.4 (+12.1%)	269.3 (+12.5%)	268.7 (+12.2%)	270.2 (+12.9%)	271.4 (+13.4%)
	II	91.7	89.4 (−2.5%)	82.3 (−10.3%)	83.7 (−8.7%)	85.9 (−6.3%)	87.7 (−4.4%)	84.9 (−7.4%)
	III	149.4	149.1 (−0.2%)	145.5 (−2.6%)	147.1 (−1.5%)	147.2 (−1.5%)	151 (+1.1%)	153.1 (+2.5%)
	IV	90.6	89.2 (−1.5%)	82.8 (−8.6%)	84.4 (−6.8%)	85.8 (−5.3%)	88.1 (−2.8%)	86.6 (−4.4%)
AW	I	134.2	160 (+19.2%)	183.3 (+14.5%)	195 (+21.9%)	201 (+25.6%)	205 (+28.2%)	209.8 (+31.3%)
	II	1.7	1.7 (−2.9%)	1.6 (−6.5%)	1.5 (−12.9%)	1.5 (−10%)	1.5 (−13.5%)	1.4 (−18.2%)
	III	16.6	15.2 (−8.4%)	14.9 (−10.2%)	14.5 (−12.7%)	16.4 (−1.2%)	16.4 (−1.2%)	16.3 (−1.8%)
	IV	63.4	59.7 (−5.8%)	49.4 (−22.1%)	50.7 (−20%)	54.8 (−13.6%)	55.7 (−12.1%)	50.3 (−20.7%)

(a) RCP4.5 scenario
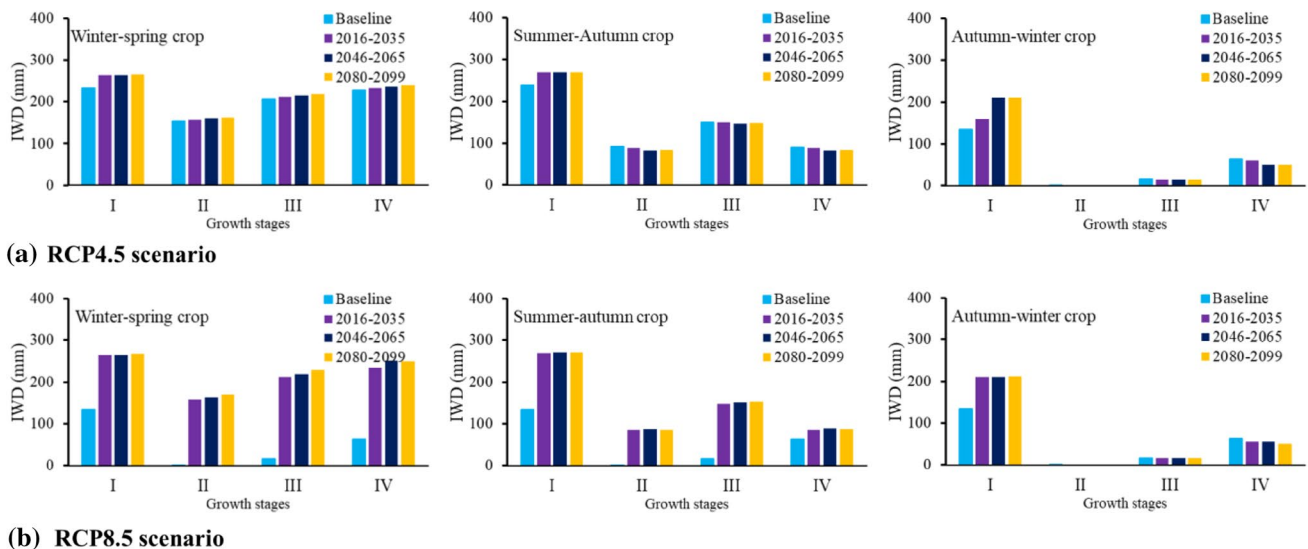
(b) RCP8.5 scenario

Fig. 9 Irrigation water demand of winter–spring, summer–autumn and autumn–winter crops corresponding to **a** RCP4.5 scenario and **b** RCP8.5 scenario

Fig. 10 Changed trend of irrigation water demand corresponding to timescales of **a** RCP4.5 scenario and **b** RCP8.5 scenario of winter–spring, summer–autumn and autumn–winter crops compared with current climate condition

RCP8.5 scenarios compared with current climate condition), while a significant downward trend in the late stage was found with the reduced values 5.8–20.0% and 13.6–20.7%, respectively, for RCP4.5 and RCP8.5 scenarios. A study on irrigation water requirement by Chatterjee et al. (2012) concluded that crop water requirement will be increased approximately 7.2% in 2020 and 14% in 2050.

Irrigation water demand for autumn–winter planting crops decreased in the late stage is because this period coincides with the peak period of the rainy season. In addition, a study on climate change scenarios for Vietnam by MNRE (2016) predicted that rainy season in the Mekong River Delta of Vietnam will be increased approximately 4.7–14.1% and 8.2–14.7% for timescales of RCP4.5 and RCP8.5 scenarios.

Conclusion

Studied results of irrigation water demand through actual evapotranspiration and effective rainfall pointed out that an increasing trend corresponding to timesscales of RCP4.5 and RCP8.5 scenarios occurred in all stages of three rice planting crops. A tendency to significantly increase the irrigation water demand was noted in the initial stage of the autumn–winter planting crop. The results implied that irrigation water demand in the study area will increase in the future due to the impact of climate change.

Besides, a tendency to significantly decrease in irrigation water demand also was found in the late stage of autumn–winter planting crop. The results are consistent with the published report about climate change scenarios

of MNRE (2016). They concluded that precipitation in the study area will increase in the rainy season and will decrease in the dry season corresponding to timescales of RCP4.5 and RCP8.5 scenarios.

The studied results of irrigation water demand can be considered as useful information for farmers to help more adapt than the change in the future climate.

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