

*Original Research*

# Effect on Water Consumption and Non-Point Source Pollutants Loss under Different Water and Nitrogen Regulation of Paddy Field in Southern China

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## Abstract

Irrigation methods and fertilizer application could affect water use and pollution transportation in paddy field. The results showed that water consumption for conventional irrigation was 22.3% and 21.1% higher than that for intermittent irrigation and rainfall storage-intermittent irrigation, and the water consumption showed no significance between two water-saving irrigation methods. Irrigation modes had great effect on irrigation quota in the growing period rather than that in the soaking period, and irrigation quota for conventional irrigation was obviously higher than that for water-saving irrigation in whole growth period of rice. Lower precipitation in 2019 resulted in lower soaking volume. Irrigation quota was closely related to hydrological year and it had negative correlation with precipitation. The correlation curve showed 6-degree exponential relationship. Yield for conventional irrigation was 18.2% lower than that for water-saving irrigation treatments. The effect of fertilizer methods on yield was not significant, while the fertilizer amount on yield was extremely significant ( $P \leq 0.01$ ). Irrigation modes showed no significance on yield, and water-saving methods could promote yield to a certain extent. The difference between control fertilization and other fertilizations was extremely significant ( $P \leq 0.01$ ). WUEI (water use efficiency of irrigation) was affected by yield and irrigation amount, and it was obviously higher for water-saving irrigation. The differences between control fertilization and other fertilizations on WUEI, WUEP (water use efficiency of precipitation) and WUEET (water use efficiency of evapotranspiration) were extremely significant ( $P \leq 0.01$ ). The pollution load of TN,  $\text{NO}_3^-$ -N,  $\text{NH}_4^+$ -N and COD for water-saving irrigation was lower than that for conventional irrigation. Fertilizer amount and method

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had a greater impact on the pollutants emission from paddy fields. It was found that TP, TN,  $\text{NO}_3^-$ -N,  $\text{NH}_4^+$ -N and COD emission in field surface drainage accounting for 89.3%, 69.6%, 22.8%, 83.4% and 89.1%, respectively.

**Keywords:** irrigation quota, water consumption, hydrological year, WUE, pollution

## Introduction

With the declining availability of water needed for food production, water-saving issues are a growing socio-economic concern worldwide. Traditional flooding irrigation requires large quantities of fresh water, and flooding irrigation could cause field surface runoff when fields are over-irrigated or heavy rainfall occurs. However, regulating and controlling soil moisture could reduce irrigation frequency and irrigation amount, and then achieve water conservation and pollution runoff reduction. Therefore, water-saving irrigation techniques of rice were widely studied to ease the contradiction between water supply and demand [1]. On the other hand, there has abundant rain during the growth season of rice in south China. Most of the rainwater is wasted through paddy field runoff and ground leakage, and large amount of nitrogen and phosphorus element entered into the ambient water bodies, resulting in low rain-water utilization efficiency and non-point source pollution [2-4].

Previous studies indicated that irrigation modes showed significant effect on water consumption, evapotranspiration, leakage and water use efficiency [5,6]. Compared to conventional irrigation, intermittent irrigation could increase water and fertilizer use efficiency and rice yield [7, 8]. Luis found that intermittent irrigation provides greater water conservation, does not reduce rice yield compared with conventional flooding irrigation, and improves the WUE of rice [9]. Nie found compared with conventional irrigation condition, intermittent irrigation could decrease the water loss through evapotranspiration and soil percolation, and the ANOVA analysis showed that at the 0.05 level [10]. The total water consumption under intermittent irrigation was significantly different. The water use efficiency under intermittent irrigation was increased, and was significantly different with that under conventional flooding. Deng found that it showed water conservation effect under intermittent irrigation and rainfall storage-intermittent irrigation methods according to reduce irrigation and drainage frequency and amount, and it could reduce the total nitrogen and total phosphorus emission under rainfall storage-intermittent irrigation in Jiangxi [11]. As water saving irrigation technique, rainfall storage-intermittent irrigation could reduce water runoff owing to the increased storage of rainwater [12], improving rainfall water use efficiency and reduce irrigation quota and drainage frequency [13-16]. Li found that the rainfall storage irrigation treatment showed a rather better

rainfall and water utilization efficiency compared to conventional irrigation [17].

This article analyzed the law of water consumption and daily water consumption with comparison of conventional and water-saving irrigation methods. According to irrigation quota in different hydrological year, the water consumption law of rice was further studied. Pollution emission under different water and fertilizer treatments could reveal the effect of water conservation and pollution reduction, which could provide instruction for solving not-point source pollution in rice production.

## Materials and Methods

### Experimental Site

This study was conducted at Yongkang Irrigation Test Station at Jinhua in Zhejiang Province from 2017 to 2019. The test area is located at  $119^\circ 58' \text{E}$ ,  $28^\circ 56' \text{N}$ , which could represent the basic characteristics and environmental characteristics of agricultural water use in the central hilly area of Zhejiang province. The average annual precipitation is 1387 mm, the average temperature is  $17.5^\circ \text{C}$ , the frost-free period is 245 days, the annual relative humidity is 82%, and the annual sunshine is 1909 h. The tested soil is loam, with pH value of 5.2, bulk density of  $1.4\text{--}1.5 \text{ g/cm}^3$ , total nitrogen of  $2.1 \text{ g/kg}$ , organic matter of  $36.2 \text{ g/kg}$ , alkali-hydrolyzed nitrogen of  $155.4 \text{ mg/kg}$ , available phosphorus of  $8.6 \text{ mg/kg}$ , and exchangeable potassium of  $59.5 \text{ kg/kg}$ .

### Experiential Design

Paddy rice (hybrid rice Zhongzheyong No.1) was grown using random block method with 3 irrigation methods (W0: conventional flooding irrigation; W1: intermittent irrigation; W2: rainfall storage-intermittent irrigation), and 3 fertilizer managements (F1: control treatment with no nitrogen fertilizer; F2: fertilizer twice, 50% base fertilizer and 50% dressing fertilizer; F3: fertilizer three times, 50% base fertilizer with 30% tillering fertilizer and 20% jointing fertilizer). The fertilization level was recommended by Zhejiang Academy of Agricultural Sciences, with nitrogen of  $225 \text{ kg/ha}$ ,  $\text{P}_2\text{O}_5$  of  $100 \text{ kg/ha}$  and  $\text{K}_2\text{O}$  of  $120 \text{ kg/ha}$ . There were 7 water and fertilizer regulations and each was replicated for 3 times. Water control in each irrigation treatment was shown in Table 1. The whole growth stage of rice was divided into seven

Table 1. Water control in paddy field for different irrigation methods.

Irrigation method	Upper and lower limit	Regreen	Early tillering	Late tillering	Jointing-booting	Heading-flowering	Milky	Ripening
W0	Lower limit (mm)	20	20	30	30	10	10	0
	Upper limit (mm)	30	50	60	60	50	50	0
	Rain storage limit (mm)	50	70	90	100	100	60	20
W1	Lower limit (mm)	0	Exposing field 3-5d	Exposing field 7-12d	Exposing field 2-4d	Exposing field 2-4d	Exposing field 3-5d	Natural drying
	Upper limit (mm)	30	30	Field drying	40	40	30	
	Rain storage limit (mm)	40	50	Field drying	60	60	60	
W2	Lower limit (mm)	0	Exposing field 3-5d	Exposing field 7-14d	Exposing field 1-3d	Exposing field 1-3d	Exposing field 3-5d	Natural drying
	Upper limit (mm)	30	30	Field drying	40	40	30	
	Rain storage limit (mm)	50	70	20	120	100	60	

Notes: (1) When field water layer was lower than lower limit, the field needs irrigation, and drainage is needed when the water later was higher than upper limit. (2) The rain storage limit is the highest water layer in paddy field when there was rain event happen.

stages: soaking, re-greening, tillering, jointing-booting, heading-flowering, milkying and ripening stage (Table 2).

### Indicators and Measurements

Water consumption was measured by the change of water level in field surface according to the measuring needle when there has a water layer, while it was measured by soil water content change according to soil moisture analyzer at 8:00 am every 3-5 days. Water leakage was measured by the leakage meter every day, and then the leakage amount was calculated according to reading difference by the measure needle before and after. The transpiration was the difference between water consumption and leakage. Irrigation quota was measured by water meter in entrance in each experimental plot. The total irrigation quota in whole growth stage was the sum of irrigation quota in every growth stage.

Water use efficiency (WUE<sub>y</sub>) was defined as yield per unit of water consumption and expressed as formula (1).

$$WUE_y = Y/WU \quad (1)$$

...where, WU was water consumption; Y was economic yield. The water use efficiency could be divided into three types, and they were WUEI, WUEP and WUEET when the WU represented irrigation water, rainfall and crop water consumption, respectively.

Irrigation and drainage water was sampled when there has irrigation or drainage process, and leakage water was sampled once every growth stage by leakage meter. Total nitrogen (TN) in field surface water and ground water was measured by potassium persulfate oxidation and ultraviolet spectrophotometry method. Total phosphorus (TP) was measured in unfiltered samples according to indophenol blue method. COD was measured by potassium dichromate method. NH<sub>4</sub><sup>+</sup>-N was determined by the Nessler's reagent colorimetric method. The NO<sub>3</sub><sup>-</sup>-N concentration was measured by ultraviolet spectrophotometry method [18].

### Statistical Analysis

Data calculation and diagramming was completed by Excel 2013. Correlation and regression analysis

Table 2. Statistics on growth stages in 2017-2019.

Year	Growth Stage	Soaking	Re-green	Tillering	Jointing-booting	Heading-flowering	Milkying	Ripening	Total
2017	Date	6/21-6/27	6/28-7/4	7/5-8/8	8/9-8/28	8/29-9/5	9/6-9/20	9/21-10/11	6/26-10/11
	Days	7	7	35	20	8	15	21	106
2018	Date	6/20-6/28	6/29-7/4	7/5-8/9	8/10-9/1	9/2-9/11	9/12-9/24	9/25-10/15	6/29-10/15
	Days	9	6	36	23	10	13	21	109
2019	Date	6/23-6/28	6/29-7/5	7/6-8/10	8/11-8/31	9/1-9/10	9/11-9/22	9/23-10/9	6/29-10/9
	Days	6	7	36	21	10	12	17	103

was carried out by SPSS Statistics 19. The variance homogeneity of the ANOVA was tested before ANOVA analysis.

## Results and Discussion

### Water Consumption

The change of water consumption in 2017~2019 was shown in Table 3. In general, the water consumption under water-saving irrigation was obviously lower than that under conventional irrigation, and the water consumption showed no significance under two water-saving irrigation methods. Water consumption for W0 was 22.3% higher than that for W1, while it was 21.1% higher than W2. The water consumption for W2 was slightly higher compared to W1. Water leakage for W0 was 64.7% and 63.8% higher than that for W1 and W2 respectively, while it was almost the same for both W1 (17.3 mm) and W2 (17.4 mm). Evapotranspiration for W0 was 20.3% and 19.7% higher than W1 and W2. Rainfall use rate showed no significance under different irrigation and fertilizer treatments. As for different fertilizer treatments, water consumption for F3 was higher than others, while it showed no significance between three fertilizations.

In summary, water consumption of rice was affected mainly by irrigation method. As for water-saving irrigation (W1 and W2) methods, the water layer of paddy field was effectively controlled, resulting in wet and dry alternation for rice plant. While ensuring the physiological water demand (evapotranspiration) of rice and ecological water demand of rice fields, the field surface evaporation was reduced, therefore the water consumption could be significantly reduced. The water layer for W1 and W2 was slightly different after rainfall event, resulting in no significant difference for reducing leakage. Due to not much different for rainfall use rate, the difference of evapotranspiration between W1 and W2 was not obvious, therefore the water consumption difference was not significant.

### Daily Water Consumption

Daily water consumption (DWC) in 2017, 2018 and 2019 was shown in Fig. 1. The change law for F2 or F3 was almost the same under the same water control (W0, W1, or W2). Generally speaking, DWC was about the same at the beginning and end of growth period, while it was lower for water-saving irrigation (W1 and W2) than that for conventional irrigation (W0) during the other main growth periods. There was no significant difference between W1 and W2. It illustrated that field water condition could be improved according to water-saving irrigation, which could effectively reduce field water consumption.

The peak of DWC was at late tillering and heading-flowering stages for W0 in 2017, while it was at heading-flowering stage for W1 and W2. Therefore, according to W1 or W2, the DWC at tillering stage was reduced greatly because of field drying for a certain time. The total water consumption at tillering stage for W1 was 27.3% lower than W0, while it was 28.4% lower for W2 in 2017. During the heading-flowering stage, rice plant grew fast, and evaporation and transpiration was large, resulting in large DWC. At milking stage DWC reduced rapidly to the same value for W0, W1 and W2. The peak of DWC was at early tillering stage for W0 in 2018, and it decreased gradually with the growth of rice, while there were 3 peak values for W1 and W2, respectively at early tillering, jointing-booting stage and milking stage. In 2019, the peak value of DWC for water-saving irrigation was relatively lagging compared to conventional irrigation, with first peak value at late tillering stage for W0 and jointing-booting stage for W1, W2. The second peak value was at milking stage, and the difference between W0 and W1 was 2.72 mm/d, while it was 2.91mm/d between W0 and W2. Therefore W2 showed lower daily water consumption in comparison to W1.

### Irrigation Quota

Irrigation quota in soaking period was mainly related to soil moisture, soaking time and climate,

Table 3. Water consumption under different water and fertilizer regulation (2017-2019).

Treatment	Leakage (mm)		Water consumption (mm)		Evapotranspiration (mm)		Rainfall use rate (%)
	Total	Average per day	Total	Average per day	Total	Average per day	
W0F1	27.7±1.55a	0.27±0.03ab	624.2±37.79ab	5.9±0.33ab	596.5±38.86ab	5.6±0.26a	59±12a
W0F2	27.0±1.60a	0.27±0.03ab	676.9±38.24a	6.4±0.29a	649.9±36.69a	6.1±0.21a	61±12a
W0F3	30.8±1.15a	0.30±0.00a	677.8±39.53a	6.4±0.32a	646.9±39.91a	6.1±0.23a	61±12a
W1F2	17.3±0.88b	0.20±0.00bc	541.2±24.81b	5.1±0.15c	522.3±24.93b	4.9±0.13b	66±11a
W1F3	17.2±1.37b	0.13±0.03c	537.2±21.03b	5.1±0.15c	527.0±25.57b	5.0±0.12b	66±12a
W2F2	16.8±1.07b	0.17±0.03c	547.1±23.61b	5.2±0.13bc	530.0±24.47b	5.0±0.12b	67±11a
W2F3	17.9±1.23b	0.17±0.03c	542.1±23.96b	5.1±0.15c	524.5±25.30b	4.9±0.10b	67±12a

and it has no relationship to irrigation and fertilizer treatment, therefore it showed no obvious significance under different water and fertilizer conditions in 2017~2019. However, irrigation quota in growing period was mainly affected by irrigation modes, and irrigation quota for conventional irrigation (W0) was obviously higher than that for water-saving irrigation treatments (W1 and W2) in whole growth period of rice.

The soaking volume was mainly related to soil moisture, soaking time and climate before soaking, which had no relevance to water and fertilizer treatments. Therefore the irrigation quota at soaking

period was much the same in the same year. The averaged irrigation quota in soaking period was 1106.8 m<sup>3</sup>/ha, 1049.6 m<sup>3</sup>/ha and 861.6 m<sup>3</sup>/ha respectively for 2017, 2018 and 2019. The precipitation year in 2017 and 2018 was 331.9mm and 352.9 mm, which was obviously lower than that in 2019 (595.5 mm), resulting in lower soaking volume in 2019. The irrigation quota in growing period was affected by irrigation modes, and it was obviously higher for conventional irrigation compared to water-saving irrigation, which was significantly different between W0 and W1 and W2. In 2017, the irrigation quota for W0 was 58.3% and 57.7% higher than that for W1 and W2.

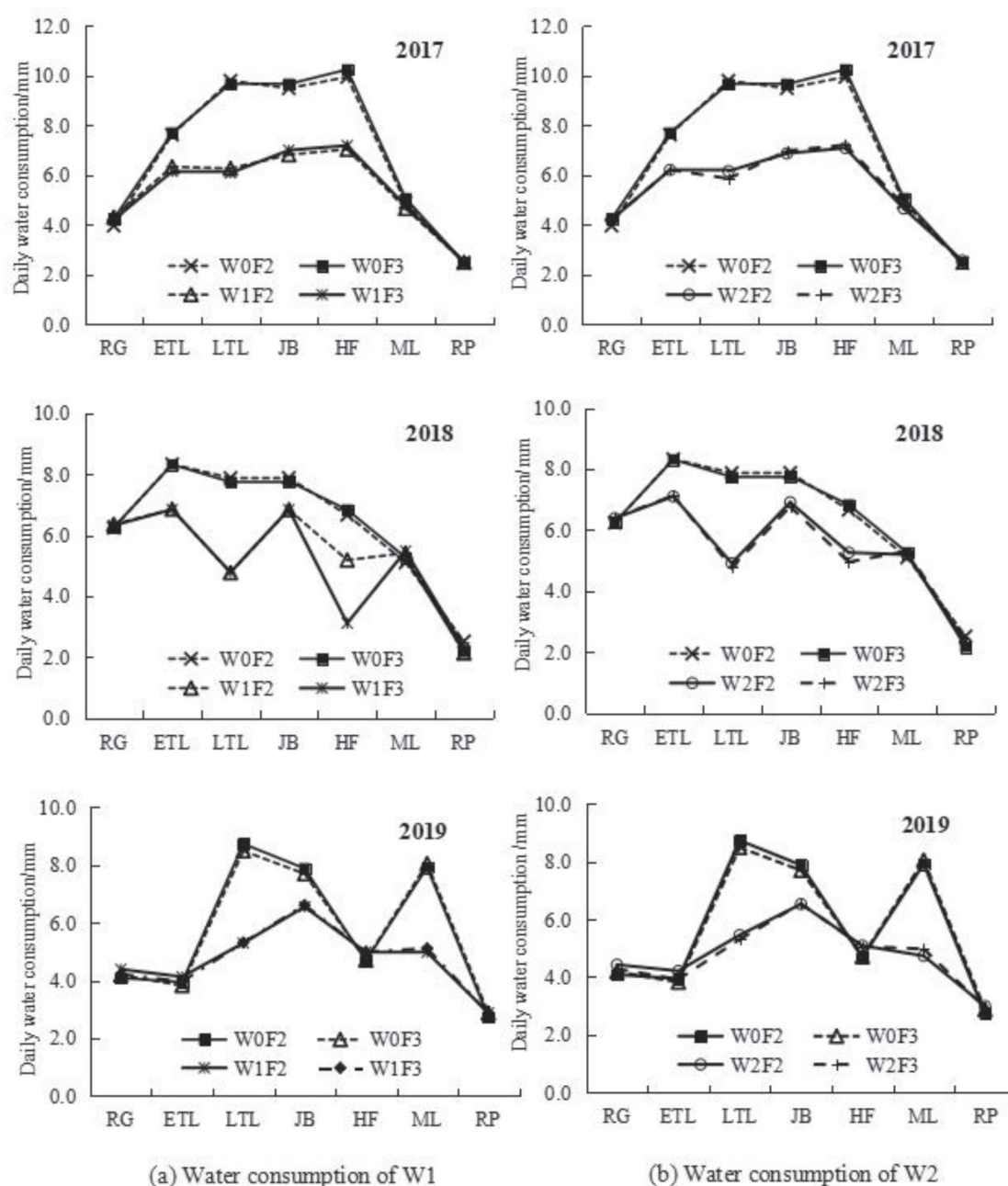


Fig. 1. Daily water consumption of paddy rice under different irrigation modes from 2017 to 2019. Note: RG,ETL,LTL,JB,HF,ML and RP represented for the growth stage of re-greening, early tillering,late tillering, jointing-booting, heading-flowering, milkying, and ripening of paddy field.

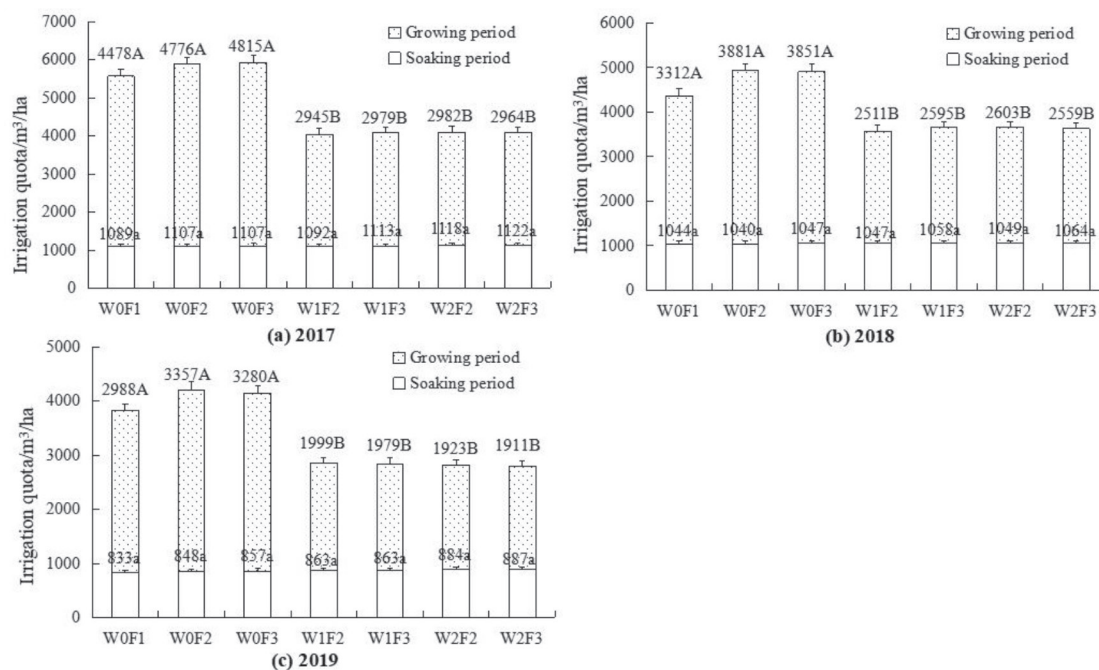


Fig. 2. Change of irrigation quota under different irrigation and fertilizer regulation from 2017 to 2019.

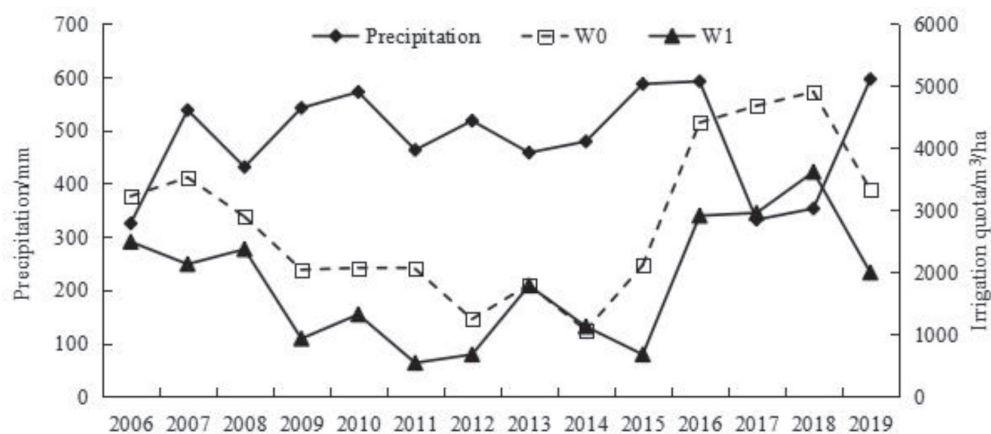


Fig. 3. Change of precipitation and irrigation quota under different irrigation modes from 2006 to 2019.

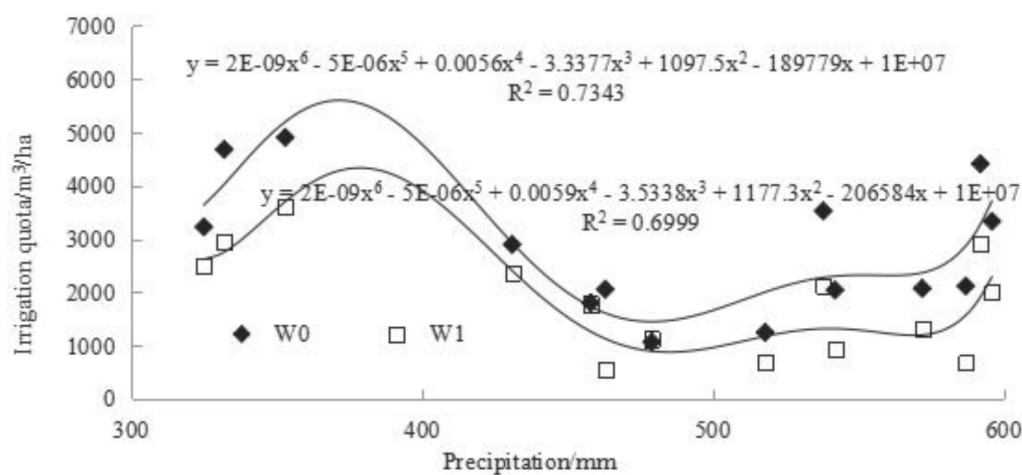


Fig. 4. Relationship between precipitation and irrigation quota from 2017 to 2019.

In 2018, the irrigation quota for W0 was 23.6% and 23.2% higher, while in 2019, it was 40.1% and 42.2% higher than that for W1 and W2. However, the difference between W1 and W2 was not significant. The fertilizer application showed no regularity on irrigation quota.

#### Relationship between Hydrological Year Type and Irrigation Quota

The relationship between irrigation quota and precipitation was shown in Fig. 3 and Fig. 4. It was clear that they were inversely proportional. The irrigation quota in large precipitation year (2010, 2012, 2015 and 2019) was obviously lower than other years, and it was moderate in moderate precipitation year (2008 and 2013), while it was relatively large in special drought year 2017 and 2018, with precipitation of 332mm and 353mm. The results were consistent with the previous analysis in section 3.3. The irrigation quota under water-saving irrigation was significantly lower than that under conventional flooding irrigation. From Fig. 4 the correlation curve for irrigation quota under conventional and water-saving irrigations showed 6-degree exponential relationship, therefore irrigation quota was closely related to hydrological year. Many studies have shown that, rainfall use in paddy field was related to rainfall uniformity, single rainfall intensity and synchronization of rainfall and water demand [19, 20]. Thus, the irrigation quota and precipitation were not absolutely negatively correlated, which was similar to the results in this study. Analysis on the water consumption and irrigation amount of single-cropping rice with long series in the whole growth period was helpful for mastering the water consumption law of rice, and could provide basic data for related application research.

#### Yield and WUE

As shown in Table 4, rice yield for W0 was both 18.2% lower than W1 and W2, and irrigation modes showed no significance on yield. Thus, water-saving methods could promote yield to a certain extent, however there was no significance between W1 and W2. The difference between control fertilization (F1) and other fertilizations was extremely significant ( $P \leq 0.01$ ). The yield for 3 fertilizations (F3) was highest, followed by 2 fertilizations, and the yield for F1 was 41.2% and 42.2% lower than F2 and F3, respectively. The difference between F2 and F3 was not significant ( $P > 0.05$ ). Therefore, the effect of fertilizer methods on yield was not significant, while the fertilizer amount on yield was significant.

Water use efficiency of rice could directly reflect the economic benefits of water resources. The WUEI, WUEP and WUEET for W1 was highest compared to W0 and W2, with the averaged value of 3.2 kg/m<sup>3</sup>, 3.6 kg/m<sup>3</sup>, 1.8 kg/m<sup>3</sup>, followed by W2, with the averaged value of 3.2 kg/m<sup>3</sup>, 3.5 kg/m<sup>3</sup>, 1.7 kg/m<sup>3</sup>, which was almost the same to W1, and WUEI, WUEP and WUEET for W0 was 1.9 kg/m<sup>3</sup>, 3.3 kg/m<sup>3</sup>, 1.2 kg/m<sup>3</sup>, respectively. WUEI was affected by yield and irrigation amount, and it was obviously higher for water-saving irrigation (W1 and W2). However, W1 and W2 had no significant difference because of uniform rainfall. The differences between control fertilization (F1) and other fertilizations on WUEI, WUEP and WUEET were extremely significant ( $P \leq 0.01$ ), while they were not significance between F2 and F3 ( $P > 0.05$ ). The WUEI, WUEP and WUEET for F1 was 1.5 kg/m<sup>3</sup>, 2.3 kg/m<sup>3</sup>, 0.9 kg/m<sup>3</sup>, while averaged value for F2 was 2.8 kg/m<sup>3</sup>, 3.6 kg/m<sup>3</sup>, 1.6 kg/m<sup>3</sup>, and it was 2.8 kg/m<sup>3</sup>, 3.7 kg/m<sup>3</sup>, 1.6 kg/m<sup>3</sup> for F3, respectively.

Table 4. Different water use efficiency under water and fertilizer regulation (2017-2019).

Treatment	Yield	WU/m <sup>3</sup> ·ha <sup>-1</sup>		WUE/kg·m <sup>-3</sup>			
		kg/ha	Rainfall	Water consumption	WUE <sub>I</sub>	WUE <sub>P</sub>	WUE <sub>ET</sub>
W0F1	5387.0±364.5 b	3955.5±810.9 a	2324.0±128.5 bc	6245.0±378.3 ab	1.5±0.3 b	2.3±0.1 b	0.9±0.1 c
W0F2	9044.0±206.9 a	4548.0±667.5 a	2397.5±97.2 b	6772.5±382.5 a	2.1±0.3 ab	3.8±0.2 a	1.3±0.1 b
W0F3	9190.5±222.1 a	4541.0±690.5 a	2393.0±101.9 b	6781.0±395.7 a	2.1±0.3 ab	3.9±0.3 a	1.4±0.1 b
W1F2	9224.5±208.1 a	3019.5±508.5 a	2643.5±25.6 a	5415.0±248.3 b	3.2±0.5 a	3.5±0.1 a	1.7±0.1 a
W1F3	9383.5±168.6 a	3094.0±499.0 a	2609.5±31.8 ab	5374.5±210.1 b	3.2±0.5 a	3.6±0.1 a	1.8±0.1 a
W2F2	9240.0±276.7 a	3101.5±499.0 a	2681.0±26.8 a	5473.0±236.0 b	3.1±0.5 a	3.4±0.1 a	1.7±0.1 ab
W2F3	9381.0±252.0 a	3068.0±509.0 a	2653.5±15.6 a	5423.5±239.8 b	3.2±0.5 a	3.5±0.1 a	1.7±0.1 a

Table 5. Total emission of pollution in field surface and ground water under different water and fertilizer regulation.

Treatment	TP (kg/ha)	TN (kg/ha)	NO <sub>3</sub> <sup>-</sup> -N (kg/ha)	NH <sub>4</sub> <sup>+</sup> -N (kg/ha)	COD (kg/ha)
W0	1.35 b	4.06 a	1.24 a	2.28 a	102.80 a
W1	1.77 a	3.25 b	0.97 b	1.79 b	70.70 b
W2	1.49 b	2.95 b	0.96 b	1.76 b	68.27 b
F1	1.56 b	3.88 a	1.37 a	2.25 a	115.78 a
F2	1.31 b	3.80 a	1.05 b	2.07 a	87.14 b
F3	1.70 a	3.10 b	1.02 b	1.82 b	69.71 b

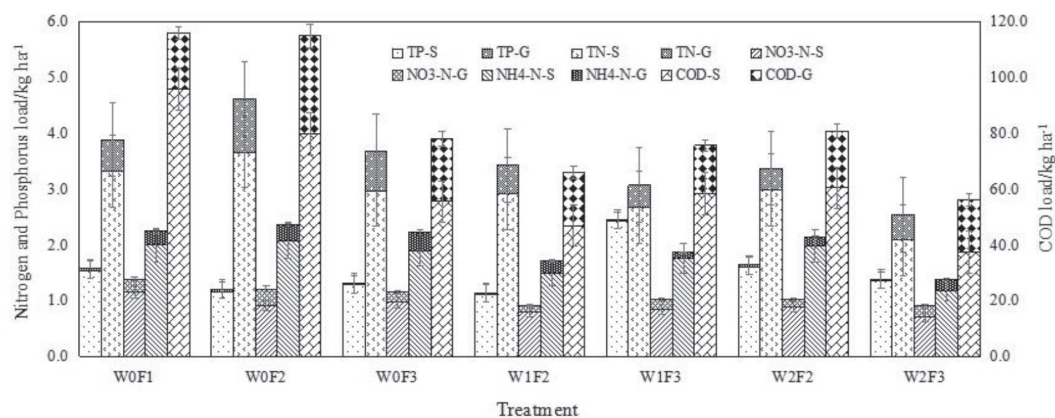


Fig. 5. Dynamics of pollution emission under water and fertilizer regulation. Note: S represented field surface drainage, G represented ground leakage.

### Pollution Emission in Field Surface and Ground Water

The dynamics of pollution emission in paddy field was shown in Fig. 5, and the total pollution load was shown in Table 5. It was clear that nitrogen was the main pollution in surface and ground water, while phosphorus account for a lower proportion. The NH<sub>4</sub><sup>+</sup>-N emission was higher than NO<sub>3</sub><sup>-</sup>-N. The pollution load of TN, NO<sub>3</sub><sup>-</sup>-N, NH<sub>4</sub><sup>+</sup>-N and COD for water-saving irrigation was lower than that for W0. Compared to W0, the TN, NO<sub>3</sub><sup>-</sup>-N, NH<sub>4</sub><sup>+</sup>-N and COD emission for surface drainage under W1 was 28.9%, 31.2%, 20.1% and 29.1% lower-respectively, while for ground water leakage it was 17.2%, 18.3%, 18.1% and 25.1% lower. Under W2, the TN, NO<sub>3</sub><sup>-</sup>-N, NH<sub>4</sub><sup>+</sup>-N and COD emission for surface drainage was 53.6%, 36.0%, 31.5% and 36.1% lower than W0, while it was 42.7%, 46.3%, 26.9% and 39.5% lower for ground water leakage. Total phosphorus (TP) content in surface water showed the trend of W1>W0>W2. With the comparison of W1 and W2, TP, TN, NO<sub>3</sub><sup>-</sup>-N, NH<sub>4</sub><sup>+</sup>-N and COD emission under W2 was lower than that under W1, which was mainly due to the increasing depth and duration of water storage after rain for W2, which was favorable for nitrogen absorption by plant and nitrogen fixation by soil. With the comparison of 3 fertilizations, the nitrogen emission under F1 was

highest, followed by F2, while it was lowest for F3, which was consistent with the theory that dispersed fertilization is beneficial to increase the absorption and utilization of nitrogen fertilizer. Therefore, fertilizer amount and method had a greater impact on the pollutants emission from paddy fields.

According to the analysis on the contribution of surface drainage and ground leakage to the emission of various non-point source pollutants in rice fields, it was found that TP, TN, NO<sub>3</sub><sup>-</sup>-N, NH<sub>4</sub><sup>+</sup>-N and COD emission in field surface drainage accounting for 89.3%, 69.6%, 22.8%, 83.4% and 89.1%, respectively. This result was slightly different from Xiao et al. [3, 21], which found the declining degree of nitrogen and phosphorus was higher compared to the results in this article. This was mainly because drainage occurs when the rain storage limit was 150-200mm without precipitation, thus the surface drainage and ground leakage was effectively controlled. While in this article, with consideration on precipitation, the drainage criterion (50-120 mm) in each growth period was significantly lower.

### Conclusion

From the above results and discussions, we could draw the following conclusions.

(1) Water consumption, water leakage and evapotranspiration showed no significance under two water-saving irrigation methods. Fertilizer showed no significance between three fertilizer treatments. Water consumption for W0 was 22.3% and 21.1% higher than that for W1 and W2. Daily water consumption was lower for water-saving irrigation (W1 and W2) than that for conventional irrigation (W0) except at the beginning and end of growth period.

(2) Irrigation quota in soaking period showed no obvious significance under different water and fertilizer conditions, while it was greatly affected by irrigation modes in growing period. Irrigation quota for conventional irrigation was obviously higher than that for water-saving irrigation treatments in whole growth period of rice. Irrigation quota was closely related to hydrological year, and the irrigation quota and precipitation were inversely proportional. Therefore, the precipitation in 2017 (331.9mm) and 2018 (352.9 mm) was obviously lower than that in 2019 (595.5 mm), resulting in lower soaking volume in 2019. Rainfall use rate showed no significance under different irrigation and fertilizer regulations.

(3) Yield for W0 was 18.2% lower than W1 and W2, and irrigation modes showed no significance on yield, while the difference among fertilizations was extremely significant ( $P \leq 0.01$ ). The WUEI, WUEP and WUEET for W1 was highest compared to W0 and W2.

(4) Nitrogen was the main pollution in surface and ground water, while phosphorus account for a lower proportion. The total pollution load of TN,  $\text{NO}_3^-$ -N,  $\text{NH}_4^+$ -N and COD for W1 was 28.9%, 31.2%, 20.1% and 29.1% lower-respectively than W0, while for ground water leakage it was 17.2%, 18.3%, 18.1% and 25.1% lower. Under W2, the TN,  $\text{NO}_3^-$ -N,  $\text{NH}_4^+$ -N and COD emission for surface drainage was 53.6%, 36.0%, 31.5% and 36.1% lower than W0, while it was 42.7%, 46.3%, 26.9% and 39.5% lower for ground water leakage.

In total, the main non-point source pollutant was nitrogen in south China according to the above conclusion. How to avoid these pollution to reserve more nitrogen nutrients in field was not mentioned, which could be the focus in the next research.

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### Conflicts of Interest

The authors declare no conflict of interest.

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