REUSE POTENTIAL OF RETURN FLOW FOR IRRIGATING PADDY FARMS IN THE VU GIA THU BON DELTA

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Abstract

In recent years, due to the impacts of droughts and saline intrusion, water for irrigation in the dry seasons has become an increasing problem in the Vu Gia Thu Bon Delta. Recycling irrigation return flow is a water-saving measure that helps to deal with water scarcity for irrigation. The study aims to estimate the reuse potential of irrigation return flow. The applied methods were water balance calculation, field measurement, water quality sampling and interviewing. Tu Cau and Thanh Quyt irrigation schemes were selected as the investigated sites. The results indicated that the ratio of surface return flow to the total amount of input water was 0.57 and 0.29 at Tu Cau and Thanh Quyt, respectively. The water quality analysis of collected samples argued that the return flow can be reused for irrigation. The reuse framework developed in this study can be applicable for broader water management scales.

Key words: *Vu Gia – Thu Bon Basin, paddy water balance, irrigation return flow, return flow reuse, irrigation efficiency*

1. INTRODUCTION

As water security for irrigation becomes fragile due to climate change, sea level rise, human intervention and improper practices, improving water management (Harris 2006) and increasing efficiency of irrigation systems (Malano et al. 2004) are essential to ensure sustainable agricultural development in Vietnam. This issue, in recent years, has also drawn much attention from Vu Gia Thu Bon (VGTB) basin, one of the fifth largest river basins by volume in Vietnam (MARD 2009). The changing in water use both in upstream and downstream of this basin and the increasing competition of water demand due to the developments outside of agriculture lead to pressures for the agriculture sector. Furthermore, the prolonged dry season (from January to September) with decreasing of flow by approximately 8.5% (IMHEN 2010) and receiving only 30% of the rainfall causes severe water shortages and problems with saline intrusion. Statistical data indicated that about 8,500 ha crops were faced with water shortage (2012) and about 21,500 ha of agricultural land in 2013 were projected to be affected by drought in different ranges (Quangnam PPC 2013; IMC Quangnam 2012). As a result, the issue of supplying enough water for crops in dry season has become a challenge for this basin, especially in the coastal lowlands.

The VGTB delta is an intensive agricultural area that is mainly covered by paddies, vegetables and other annual crops such as maize, peanuts, watermelon, sweet potatoes and sesame. Rice cultivation, which consumes huge amount of water, accounts for 70% of total agricultural land (Pedroso et al. 2016; Nauditt & Ribbe 2016). Flooded irrigation is applied for all paddy farms in the research area. The applied irrigation method results a huge amount of return flow[1].

According to recent researches, the irrigation return flow coefficient ranges from 0.12 to 0.87 depending on soil texture, slope, climate, and irrigation method (Chen et al. 2002; Dewandel et al. 2008; Chen et al. 2009). Due to the stability in quantity, controllability in quality, and less cost in treatment, the irrigation return flow attracts increasing interests from the irrigation managers as well as experts and

[1] Return flow is determined as applied water that is not consumed by evapotranspiration, but returns to an aquifer or surface water body (Jasper Womach, 2005)

scholars (Fan et al. 2011; Bouman et al. 2007). As stated in the researches of Hochstrat et al. (2008) and Wade Miller (2006), return flow plays a crucial role not only in irrigation management, especially in the water stress periods, but also in sustainable water development at basin scale. If the return flow is properly collected before draining into the river, it can be used as additional water sources for irrigation (Simons et al. 2015). Recycling irrigation return flow is considered as a water-saving irrigation technology with the aim of improving irrigation efficiency (Mateos et al. 2005; Allen et al. 2005; Hafeez et al. 2008; Mohan & Vijayalakshmi 2009; Chinh 2012; Van 2017). However, field surveys show that there has been currently no comprehensive reuse scheme of irrigation water in the VGTB basin. Besides that, the lack of proper regulations and legal framework for water reuse requires the more detailed studies on this issue. Thus, the aims of this study are identifying the potential of irrigation return flow based on quantity and quality analysis and developing an efficient reuse framework. The methods of water balance calculation, field measurement, water quality sampling and interviewing are applied in order to assess the reuse potential of return flow. Changing irrigation management practices and reusing return flow are regarded as potential measures for sustainable adaptation of irrigation system to agricultural water scarcity in the VGTB basin.

2. MATERIALS AND METHODS

2.1. Study area description

The study area is the coastal low-lying plains (with the mean altitude ranging from 2 to 4m ASL) located in the North-eastern of the VGTB basin. The temperature of the VGTB delta varies from 20°C in December and January to 34°C in July and August. The average annual rate of evaporation being 1,044 mm is much smaller than annual precipitation rate (2,763 mm) making wet and humid weather conditions for the region (IMHEN 2009). There are four major soil types (Fluvisol, Ferralsol, Gleysol and Arenosol), in which about 60% of the study area is Fluvisol. Most of agricultural land in this area is irrigated by more than 100 pumping stations installed along rivers. The irrigation canal system is connected to deliver water to paddy farms. The main and secondary canals of the irrigation system are concreted but the on-farm canals and the drainage canals are earth. Winter-Spring Crop takes place, usually from 20th December to 18th April and Summer-Autumn Crop is cultivated from 20th May to 06th September. Data from "Pumping station operation manual" in 2000–2010 period show that the total pumped water in Summer-Autumn is 38.7% higher than in Winter-Spring, and the highest total pumping volume falls into late May. Based on the hydraulic connectivity, the VGTB delta is divided into 13 Water Management Units (WMU) (Viet 2014). The total investigated area is 91.6 ha located within two irrigation schemes of Dong Quang and Tu Cau WMUs (see Figure 1).

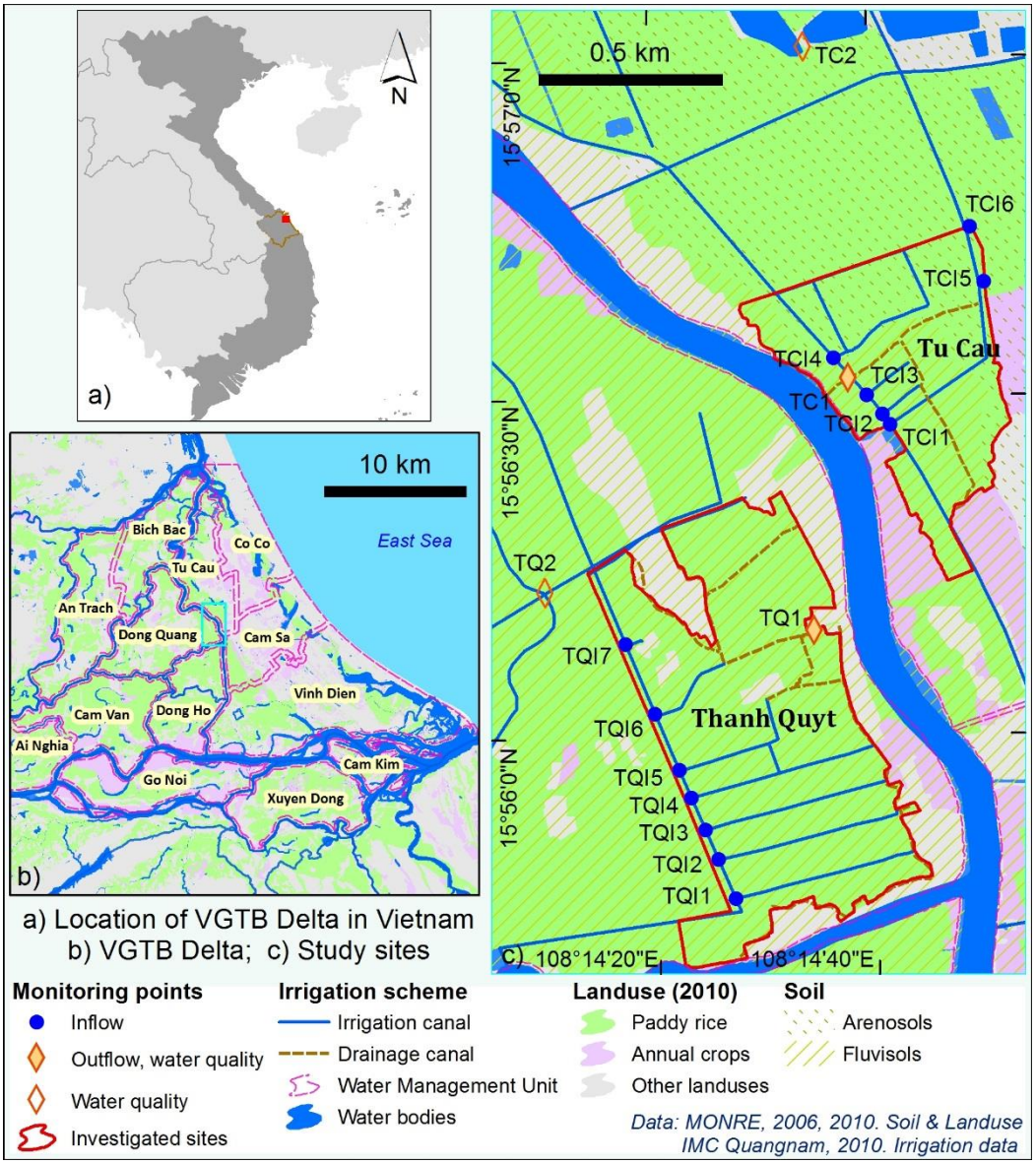


Figure 1. Study sites

2.2. Paddy water balance approach

The water balance model helps to explain the process of return flow from paddy fields. The input includes pumped water (***IRR***) and effective rainfall (***P_e***) generated inside the sites. The output includes the change in ponding water depth (***WD***) during the rice crop season, evapotranspiration (***ET_{crop}***), deep percolation and horizontal seepage (***SP***), and surface runoff (***DR***) over the spillway. The change in water depth of farms is ignored in calculation through the whole crop duration from soil preparation phase to harvesting phase. Therefore, the balance can be expressed as follows:

$$P_e + IRR = WD + ET_{crop} + SP + DR \qquad (1)$$

It has been seen that the seepage flow, deep percolation and surface overflow are parts of return flow. However, in practice, seepage and percolation flows are not easily to distinguish due to transition flow, thus within the scope of this study, both are combined as sub-surface return flow (***RF_{sub}***) (Wickham and Singh, 1978). The surface overflow is considered as surface return flow (***RF_{sur}***) (Lawrence J. Schwankl et al. 2007). Based on water balance Eq. (1), the return flow variable can be estimated as follows:

$$P_e + IRR = WD + ET_{crop} + RF_{sub} + RF_{sur} \quad (2)$$

$$\Leftrightarrow IRR - (WD + ET_{crop} - P_e) = RF_{sub} + RF_{sur} \quad (3)$$

$$\Leftrightarrow RF_{sub} + RF_{sur} = IRR - IN \quad (4)$$

In Eq. (4), ***IN*** is the irrigation water need that will be explained more detail in next section 2.3. Consequently, return flow value is the difference between the actual quantity of supplied water and the irrigation water demand.

2.3. Indicators and parameterizations

2.3.1. Indicators

As previously mentioned, two major components of return flow are surface and sub-surface return flows. However, the prediction of sub-surface return flow is most complicated. There has been no previous detailed research on percolation and groundwater changes in VGTB basin. Furthermore, in comparison with sub-surface drainage, the surface return flow is available outflow that accounts majority proportion and can be captured by the local hydrologic system for reuse purpose (Phil King 2008). Therefore, this study is simplified by focusing on analysing the surface return flow.

Return flow coefficient (C_{RF}): refers to the ratio of surface return flow volume to the total amount of input water, including irrigated water and effective rainfall (if any). The equation of C_{RF} is defined as:

$$C_{RF} = \frac{RF_{sur}}{(IRR + P_e)} \ (0 \leq C_{RF} \leq 1) \quad (5)$$

Reuse potential (*r*): indicates the irrigating capacity of return flow. The potential here is evaluated under the hypothesis that all the surface return flow is cached and directly distributed to the reuse scheme. It is the ratio of surface return flow volume to the irrigation water need for one unit of the paddy area in a given duration:

$$r = \frac{RF_{sur}}{IN} \quad (6)$$

Irrigation efficiency (*e*): is considered as one of the important indicators to characterize the performance of an irrigation system (Howell 2003). The classical concept of irrigation efficiency (e_c), in other words, the crop consumptive use fraction indicates the efficient delivery into the root zone of irrigation water. It is usually defined as the ratio of the estimated irrigation water requirement and the actual water withdrawn (Israelsen 1932).

$$e_c = \frac{IN}{IRR} \quad (7)$$

Nevertheless, if the return flow is recycled for irrigation, the effective efficiency (e_e) of irrigation system is determined by the following equation (Keller & Keller 1995):

$$e_e = \frac{IN}{(IRR + RF_{sur})} \quad (8)$$

2.3.2. Parameterizations

Total pumping volume (*IRR*):

The measuring sites are irrigated through different sluices. Therefore the actual pumping volume of the measuring sites is the sum of pumping volume at their irrigation sluices:

$$IRR = \sum_i \bar{Q}_i t_i \quad (9)$$

where $\bar{Q}_i$ is the average pumping discharge (m^3/s) at sluice *i*, t_i is the operating duration of sluice *i*. $\bar{Q}_i$ is manually measured by SEBA Propeller.

Irrigation water need (*IN*):

The CROPWAT model, which is developed by FAO, is a practical tool for estimating the irrigation water requirement as well as the efficiency of irrigation practices (M. Smith 1992; Stancalie et al. 2010). Table 1 describes the input and output data of the CROPWAT model.

Table 1. Summary of data input and CROPWAT procedures

Input	Remarks	Output
Climatic data: • Temperature • Humidity • Wind speed • Sunshine	Average monthly (1976-2010) at Danang station	Potential evapotranspiration ET_o calculation based on FAO Penman – Monteith formula (Allen et al. 1998)
Rainfall distribution by Thiessen method	Average monthly (1978-2010) of 3 gauging stations	Effective rainfall P_e estimation by USDA soil conservation service method (M. Smith 1992)
Rice crops	Sowing date Average growth stage Crop coefficient (K_c) in FAO 56	Actual crop evapotranspiration $ET_{crop} = K_c \times ET_o$
Paddy soils	Initial soil moisture condition Maximum water depth (150-180 mm) Maximum root infiltration rate	Daily soil moisture deficit

The net scheme irrigation requirement (q) is computed according to climatic condition, different soil types and growth stages of paddy rice. It should be noted that the actual irrigation need for the whole irrigation scheme or at basin scale is higher than the paddy water requirement at field level because of water losses in transportation through the canal system. Therefore, if estimating efficiency at broader scales, it is necessary to take into account conveyance efficiency of the irrigation system. However, during the field measurement, most efficiency parameters were estimated at field level, as a result, the total irrigation water need can be computed as follows:

$$IN = q \times A \qquad (10)$$

where IN is the total irrigation need (m^3/day or m^3/month), q is the net scheme irrigation requirement (l/s.ha or mm/month) and A is the area of paddy farm (ha). In this steps, the unit conversion is employed.

2.4. Return flow estimation

An assessment of the return flow is a challenging task. Previous researches (Odhiambo & Murty 1996; Chen et al. 2002; A. K. Gosain et al. 2005; Dewandel et al. 2008; Chien & Fang 2011) indicated that the combination of field measurement and computing from water balance model could raise good results in estimating return flow. The general procedure for determining irrigation return flow from paddy fields is presented in Figure 2.

The surface return flow was measured at least four times per day in the period from 1st March to 10th

April 2013. This period coincides with the flowering stage of the Winter- Spring rice crop. SEBA Propeller was used to measure water flow at drainage outlets. The flow was measured at 0.2, 0.5 and 0.8 water depth.

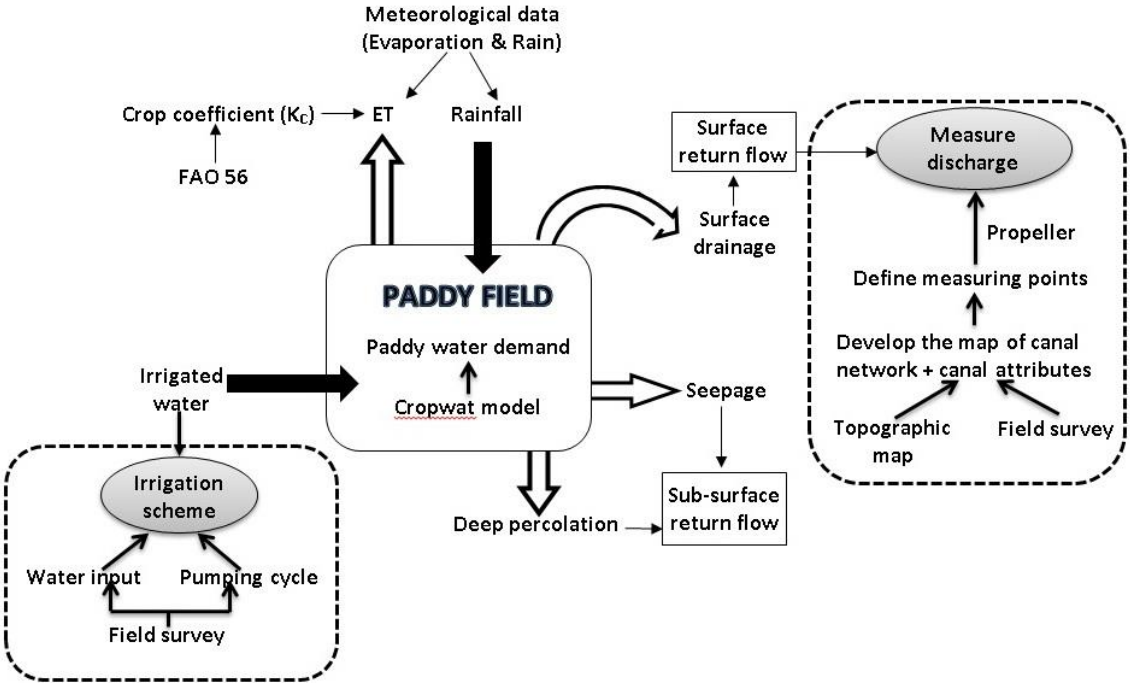


Figure 2. General procedure for estimating irrigation return flow

2.5. Assessment water quality of return flow

The parameters for return flow quality analysis were determined according to the Vietnamese irrigated water standards TCVN 6773:2000 and QCVN 39:2011 of MARD. The simple parameters were on-site tested and other parameters were tested in the laboratory of CHM. The pH meter PCE-PHD 1 was used for testing the pH value of the water, electrical conductivity (EC_w), dissolved oxygen (DO) and total dissolved solids (TDS). This device is portable with multi-function and suitable for measurement in situ.

The water quality assay of return flow at the laboratory consists of total Nitrogen, total Phosphorus, total dissolved iron and the concentration of ions Na^+, Ca^{2+} and Mg^{2+}. While the first three parameters are used to assess the elements that may affect the growth of crops if irrigating by return flow, the cations of Calcium, Magnesium and Sodium are also needed to measure in order to calculate the sodium adsorption ratio (SAR). This ratio is useful for evaluating the influence of the concentration of sodium on soil and crop:

$$SAR = \frac{Na^+}{\sqrt{\frac{1}{2}(Ca^{2+} + Mg^{2+})}} \quad (11)$$

where the concentration of ions Na^+, Ca^{2+} and Mg^{2+} is meq/L and SAR is (meq/l)^1/2.

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Quantity of return flow

Measurement and calculation results indicated that the return flow coefficient in the Winter-Spring crop 2013 was relatively high, accounting for 0.57 and 0.29 for the Tu Cau and Thanh Quyt irrigation schemes respectively. The total volume of return flow in March 2013 of the Tu Cau investigated area was 16,176 m^3 and the amount of agricultural water surplus of the Thanh Quyt area was 13,100 m^3. This finding is consistent with another research in VGTB basin (Viet 2014) showing that the potential of irrigation return flow in this basin is considerable.

It can be seen from the graphs in Figure 3 that the discharge of the return flow is fluctuated to the change of total input water, including pumped water and rainfall. The amount of input water and pumping cycles plays an important role in adjusting the amount of return water and efficient water usage. Tu Cau irrigation scheme is also represented for the WMUs that extremely affected by salinity intrusion with typical characteristics of irrigation sequence, pumping duration and water regulation. Particularly, the water from river is massively pumped when the salinity below the threshold level (1‰), thus leading to surplus irrigation water. This may cause an increase of return flow.

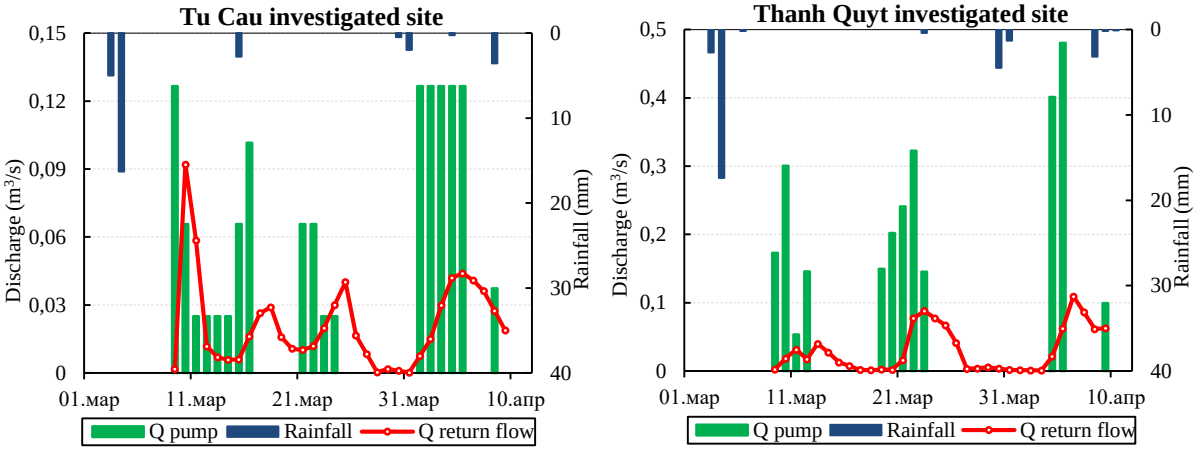


Figure 3. The correlation between return flow and input water, including pumped water & rainfall

3.1.2. Quality of return flow

Besides quantity, the quality of the return flow was also investigated to identify the applicability of return water for irrigating paddy farms. Selected parameters for sampling were pH, TDS, DO, total N, total P, sodium adsorption ratio (SAR) and salinity. The testing results were compared to the standard applied for irrigation issued by MARD. In overall, the parameters of the testing points were below the threshold of the standards.

The Figure 4 shows the results of water quality tests. The average pH value is about 6 for all sampling points. This value complies with irrigation water quality standard of Vietnam - QCVN 2011 (within the range from 5.5 to 8.5). The threshold of dissolved oxygen for irrigation is 2 mg/L. The dissolved oxygen in water samples is higher than the threshold. High concentration of dissolved oxygen indicates the low residence time of the water inside the farms. Low total dissolved solids (TDS) expresses the purity of the return flow. Most of the samples has TDS values under 400 mg/L meanwhile the QCVN 2011 standard is 2000 mg/L. Total nitrogen and total phosphorus are not mentioned in the irrigation standard but they need to be considered. The present of these elements in water results from applying fertilizers and may cause eutrophication for the aquatic systems.

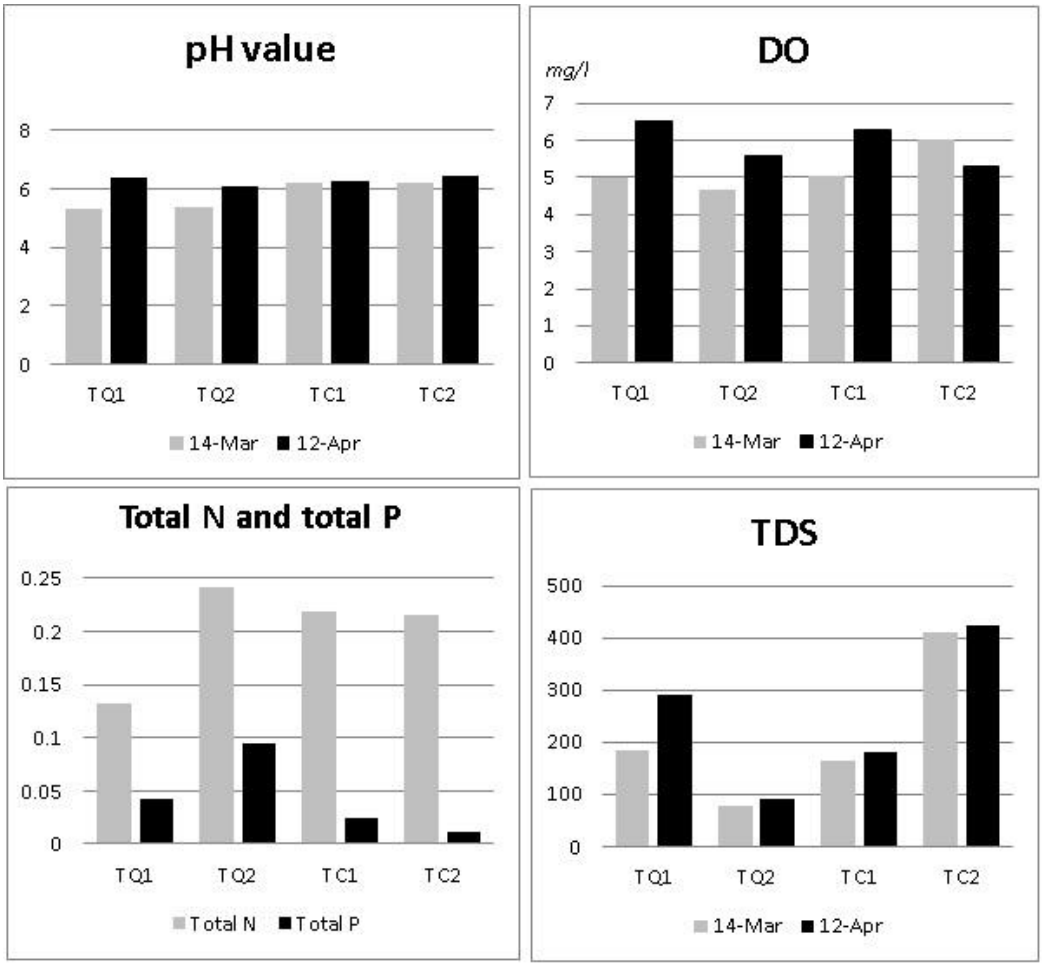


Figure 4. The results of water quality parameters

As specified in QCVN 39:2011, the threshold value of the sodium adsorption ratio (SAR) for irrigation water is under 9.0. In the study area, this ratio ranges from 0.37 to 0.52, which is much lower than the threshold value.

Table 2. Sodium Adsorption Ratio of return water

Concentration	**TQ1**	**TQ2**	**TC1**	**TC2**
Ion Ca (mg/l)	7.014	4.509	9.018	12.525
Ion Mg (mg/l)	3.605	2.128	24.016	7.6
Ion Na (mg/l)	6.255	5.381	9.42	8.293
SAR*	**0.48**	**0.52**	**0.37**	**0.45**

*conversion between mg/l and meq/l, eg. 1 mg/l Ca = 1/20 meq/l

It is obvious that, the purification function of paddies would produce acceptable quality and stable return flow. Therefore, return flow water can be recognized as supplement sources for irrigation.

The electrical conductivity of irrigation return water at the sampling sites was low, except a sample on

Tu Cau site (Table 3). The impact of saline intrusion in this irrigation area caused the increase of the drainage water conductivity. According to the report of FAO (1985), the higher the electrical conductivity is, the lower the productivity of paddy rice is. If using the return water for irrigating, this issue should be considered in correlation with economic analysis and the salinity tolerance of paddy rice.

Table 3. Conductivity of return water in the study area

Conductivity (uS/cm)				
Date	**TQ1**	**TQ2**	**TC1**	**TC2**
14-Mar	276	116.85	2500	606
12-Apr	436	137.4	2730	634
The sensibility of rice to conductivity (FAO 1985)				
The influence level		No	Mild	Severe
Productivity		**100%**	**50-90%**	**<50%**
Conductivity thresholds		<2000	2000-4800	>4800

3.1.3. Reuse potential

The two investigated areas can be considered as the source schemes of return flow. Considering the availability of return flow from paddy fields in relation to the irrigation demand for the paddy cultivation area is necessary for comprehensive assessment of its reuse potential.

Table 4. Reuse potential of irrigation return flow (results was calculated for March 2013)

Investigated area	**Tu Cau**	**Thanh Quyt**
Area (ha)	33.0	58.6
Return flow ratio to input water	0.57	0.29
Effective rainfall (mm)	25.5	25.4
Pumping volume (m^3)	19,979	30,440
Surface return flow volume (m^3)	16,176	13,100
Actual irrigation water need (m^3/day)	1,026	1,823
Actual irrigation water need (m^3/month)	32,109	57,076
Potential reuse duration (day)	**15.8**	**7.2**
Potential reuse area (ha)	**16.6**	**13.4**

At the Thanh Quyt pumping station, during the Winter-Spring crop 2013, there were totally 9 irrigation periods (6-9 days per each irrigation period) with the total volume of 1.8 million m^3. In which, the total input water (including effective rainfall) the Thanh Quyt investigated site (during the measuring period) was more than 45,000 m^3. Accounting for 29% of the total input water, the return flow of this scheme can be ideal reused for irrigating 13.4 ha of paddy in about 7 days (in one irrigation period).

At Tu Cau irrigation scheme, the total pumping volume of 3.3 million m^3 was distributed in 7 irrigation periods (8-11 days per each period). As explained above, the return flow from paddy fields in this scheme is considerable. The surface return flow volume was estimated at around 16,176 m^3. This amount of return flow has potential to irrigate the agricultural area of 16.6 ha in about 16 days (in one and a half irrigation periods).

In the Tu Cau irrigation area, the reuse of return flow plays a significant role, especially in the context of salinity intrusion and drought. In 2012, the first on-farm irrigation structure was initially implemented in the Tu Cau WMU. The existing Bau Sen Pond was enlarged for storing return flow. A temporary diesel-run pumping station was also installed to pump water from this storage tank into the irrigation canal system. This measure can minimise the damage to agricultural production caused by excess salt during the dry periods. Recycling return flow helps to extend the irrigation sequence and increase the irrigation efficiency. In the other words, the pumping station just needs to operate in 6 to 8 irrigation periods, instead of 7 or 9 irrigation periods per crop season. Consequently, the energy consumption of the main pumping station will be reduced. The overall efficiency of the irrigation system will be significantly improved.

3.1.4. Irrigation efficiency

Table 5 demonstrates that the flooded irrigation method applied for both investigated sites provides a low irrigation efficiency. However, if considering the reuse potential of return flow, the efficiency of irrigation system can be improved. Accordingly, the effective efficiency is estimated to increase by 1.4 times in the Tu Cau and Thanh Quyt irrigation schemes.

Table 5. Irrigation efficiency (in investigated period)

Parameters	***Tu Cau***	***Thanh Quyt***
IRR (m^3)	19,979	30,440
RF_{sur} (m^3)	16,176	13,100
IN (m^3/month)	32,109	57,076
e_c	**62%**	**53%**
e_e	**89%**	**76%**

3.2. Discussion

3.2.1. Return flow calculation

Theoretically, the correlation between irrigation return flow and irrigation water is determined based on the principle of matter or mass conservation. Defining correlation among two or many variables requires ensuring the highest possible independent. Meanwhile, there are many hypotheses in applying the water balance approach due to the high amount of unknown variables compared to the equations. There are several uncertainties in estimating return flow. They may result from the limitation of data, interference of external parameters or measurement error (Lorefice 2009).

Basically, in this study, the irrigation return flow is the variable depending on the total amount of irrigation water. The peak discharge of return flow occurs soon after the pumping discharge reaches the maximum value. In this case, the uncertainties in estimating surface return flow are caused by relatively high uncertainties of irrigation inflow and storage change, which are often not reported or documented. However, these uncertainties are reasonable in the context of relatively complicated conditions in the quantification of dynamic flows for one month without modern and automatic equipment. Therefore, in order to more precisely estimate and analyze the return flow to enhance water management in the reuse system of the rice-based irrigation area, it is necessary to establish an appropriate and adequate

measuring and monitoring system of irrigation inflow and drain outflow.

Although both selected WMUs have similar climatic conditions, the differences of soil type, storage capacity and irrigation method are major factors influencing the quantity of return flow in both WMUs. Firstly, the difference in soil texture will affect the horizontal and vertical infiltration capacity. The findings summarized from the researches of Jo & Um (1990), Tuong et al. (1994) and Bell & Seng (2005) are used to determine the average infiltration rate of the paddy area in both WMUs. Accordingly, the mean value of infiltration rate of Tu Cau (3.6 mm/d) is higher than Dong Quang (3.1 mm/d). Another influence factor is the storage capacity or the residence time of water in paddy fields and on-farm canal system. In this case, the paddy field is considered as a tank or a reservoir. If the paddy area is large and the embankment is regularly reinforced, the residence time of water may be longer. In addition, the graphs in Figure 3 also indicate that there is a lag time between the peak of pumping discharge and the peak of return flow discharge. For both measuring sites, it takes almost 1 day for the return flow discharge to reach the maximum value after the peak of pumping discharge.

3.2.2. Use of return flow for irrigation

Return flow would be possible for reuse purpose only when it is available and captured through the storage structure or drain which is hydraulically linked to the source scheme. An integrated management framework for the reuse system consisting of both hydraulic and institutional links should be established. In this paper, the WMU is understood as an integrated irrigation and drainage system consisting of four components: (i) hydraulic catchment, (ii) the source scheme of return flow, (iii) the reuse scheme, and (iv) drainage system. The hydraulic linkage can be expressed in the following diagram:

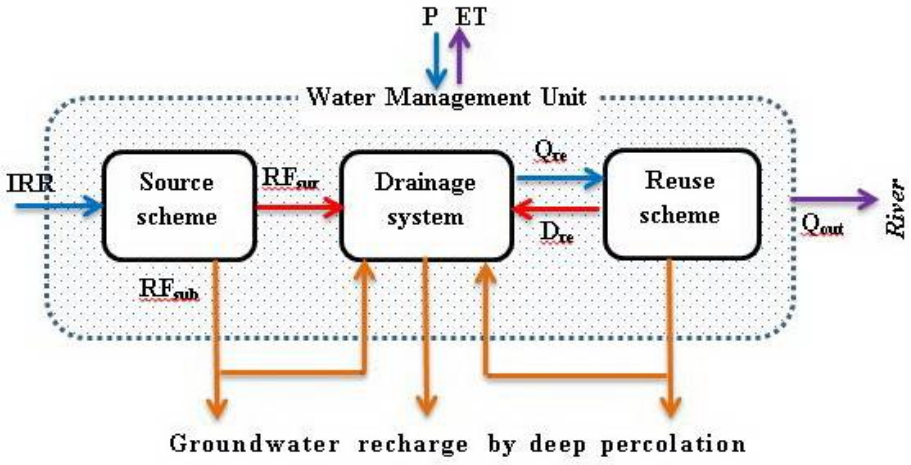


Figure 5. A reuse framework for using return flow

Note: IRR, RF_{sur}, RF_{sub}, P& ET are explained in previous section; Q_{re} & D_{re} are inflow and drainage from reuse scheme and Q_{out} is the outflow of the whole catchment.

Generally, for being able to reuse the return flow for irrigation in agriculture, the particular irrigation and drainage model has to change from a linear to a cycle system. The reuse of return flow can be applied in all WMUs, particularly where the drainage canals connecting with storage tanks such as ponds, drainage canals, reservoirs or depressed places. In order to collect return flow for irrigation, the drainage systems, storage tanks, in-farm irrigation scheme are suggested to reform.

The surface return flow can be captured by the local hydrologic system for reuse purposes. Water drained from paddy farms is collected by drainage canals and stored in reservoirs. As the salinity of river water is over the threshold, water from the reservoirs is pumped back into irrigation canals. Return flow is proposed as a short-term measure to deal with water shortages in the urgent case.

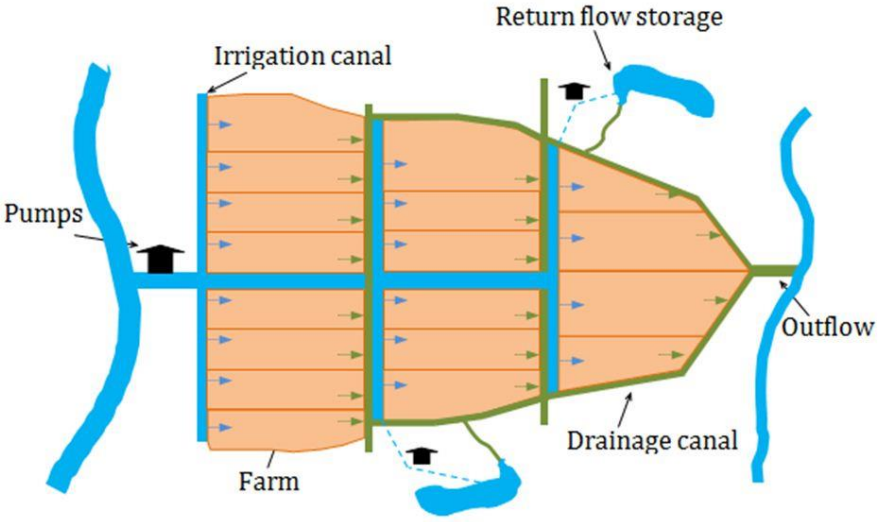


Figure 6. Suggested irrigation scheme to collect return flow (*Source: Viet, 2014)*

Regarding irrigation management, the main structures, including dynamic head, primary and secondary irrigation canals and irrigation facilities, are managed by Irrigation Management Company (IMC) through operational branches called Irrigation Management Enterprise (IME). Meanwhile, the whole on-farm canal networks and the small scale pump stations are under the management of local institutions, such as Water use association and Agricultural cooperatives. The institutional link between IMC and other institutions is implemented through seasonal service contracts on irrigation supply. However, the linkage and sharing responsibility in irrigation management between IMC, local institutions and the farmers is not strong enough. Moreover, the drainage issue didn't receive the consistent concern from irrigation management agencies. As return flow is the part of drainage flow, it is necessary to enhance the institutional link to develop the reuse framework for the study area. Think about the reforming IMC to IDMC with D is the drainage option.

4. CONCLUSION

In conclusion, return flow water can be recognized as supplement sources for irrigation. The amount of extracting water for irrigation and the cost of operating an irrigation system can be reduced. Moreover, the most important role of recycling return flow in the study area is saving the part of paddy area affected by drought and reducing salinity intrusion.

Further detailed investigation and discussion on the institutional issues for the reuse system should be required. In addition, the model applied in this study is based on assumptions of steady inflow conditions to the drain while neglecting the recirculation of the return flow of the reuse schemes and dynamics in the system. Thus, further studies should focus to identify the effect of these assumptions and to minimize of uncertainty for better development of the water balance approach in quantification of return flow and water reuse analysis.

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