ASSESSING THE PERFORMANCE OF IRRIGATION SYSTEM IN THE DOMINANT PADDY RICE REGION OF THE VU GIA THU BON DELTA

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Abstract

Assessing irrigation performance plays an important role in improving irrigation efficiency and water resource management in the low land of Vu Gia – Thu Bon river basin where traditional irrigation practices are applied to a predominantly paddy rice cultivation. Relative Water Supply (RWS) and Relative Irrigation Supply (RIS) were selected as relevant indicators to assess the relationship between water supply and water demand of the irrigation system. About 120 primary and secondary pumping stations were visited during field trips. 13 large primary pumping stations were chosen to validate the actual irrigation supply. Annually there are two crops Winter-Spring and Summer-Autumn being cultivated in this region. Monthly RWS and RIS were calculated for 13 irrigation management schemes during the two crops in the years 2004 - 2005. The obtained results differ from scheme to scheme and were analysed individually. The result presents an under - irrigation supply at six irrigation management schemes including Tu Phu, Tu Cau, Xuyen Dong, Bich Bac, An Trach, Ai Nghia in both crop seasons Winter – Spring and Summer – Autumn, especially from February to July. Both RWS and RIS are high in December and August implying that there is considerable potential to save and use water more effectively during this period. At Ai Nghia and Chau Son irrigation management schemes, RIS values are zero while RWS is relatively high in May demonstrating that rainfall variability plays an important role in changing RWS and RIS. Reducing the irrigation supply should be considered for those periods, so that effective irrigation management can be achieved.

Keywords: *Water management, Water demand, Water supply, Irrigation performance, Relative Water Supply (RWS), Relative Irrigation Supply (RIS)*

1. INTRODUCTION

Irrigated agriculture is the major user of freshwater globally, accounting for 70% of total fresh water consumption (Fischer et al., 2007). To meet the demand of the increasing population, water development for agriculture is a priority (Geleto et al., 2019). With limited freshwater resources and increasing competition between different water users, irrigated agriculture efficiency needs to be improved (Molden et al., 1998). Therefore, assessment of irrigation performance is significantly important for improving irrigation water management (Abuzar et al., 2017), reducing competition in scarce water resources and enhancing food security.

The increasing population has also made the efficient use of irrigation water crucial, particularly in developing countries, where the economy mainly relies on agriculture (Beshir & Bekele, 2008). It is formidable to assess the performance of irrigation system since there are many factors that influence the performance of irrigation agriculture such as infrastructure, inputs, management, climatic conditions, socio-economic factors (Molden et al., 1998). Molden et al., 1998 also proposed a set of 9 indicators including Output per cropped area, Output per unit command, Output per unit irrigation supply, Output per unit water consumed, Relative water supply, Relative irrigation supply, Water delivery capacity, Gross return on investment, Financial self-sufficiency to assess the performance of irrigation system. These indicators allow the comparative analysis of irrigation performance across irrigation systems in term of land, water, production, finance. A relative comparison of values helps to examine how well the system is performing in relation to others. Input data collection for these indicators is feasible and they present sufficient information about the output of system. In the context of water scarcity, this study focuses only on the efficiency of water use by the irrigation system based on the two most important factors which are the availability of water supply and water demand (Sakthivadivel et al., 1993)

The Vu Gia Thu Bon (VG-TB) is the fifth largest river basin in Vietnam with 10.350 km2 of catchment area (MARD 2009). With a current population of approximately 3 million, the VG-TB is one of the most important food-producing regions in central Vietnam (Pedroso et al. 2017). The region is characterized by wide-scale paddy rice area in downstream and a strong development of hydropower in upstream. Thus, there is a conflict between water users in the region. As existing traditional irrigation practice is the largest water consumer in this region, it is critical to assess the relation between water supply and water demand in the irrigation system (Nauditt & Ribbe, 2017). Relative Water Supply (RWS) and Relative Irrigation Supply (RIS) are relevant indicators which highly illustrate the relationship between supply and demand (Al Zayed et al., 2015), and thus they were chosen as basic indicators to apply in this study. Furthermore, the performance of an irrigation system can be analysed and interpreted for different time intervals such as annual, seasonal, monthly or special periods, as well as to compare the performance of different systems within a region (Sakthivadivel et al., 1993). While RWS represents the condition of water abundance or scarcity, RIS represents how irrigation water supply is met (Levine, 1982).

The objective of this study is to assess the performance of the traditional irrigation practice in the low land of VG - TB river basin in order to understand the relation between water demand and supply in the context of water scarcity and conflict. The study has the potential benefit of improving irrigation efficiency and water resource planning for the region.

2. STUDY AREA

This study was conducted in the low land of the VG - TB (Figure 1). The total irrigated agriculture area is 16,084 ha, mainly for paddy rice, followed by maize and peanut (Pedroso et al. 2017). There are two crops being cultivated per year. The Winter-Spring Crop is usually from the middle of December to the middle of April and Summer-Autumn Crop is from middle of May to beginning of September. The irrigated agriculture area is categorized into 13 irrigation management schemes (IMS) according to their characteristics such as soil type, irrigation demand, topography, climatic impacts including, but not limited to weather events; salt intrusion; and flooding. The traditional irrigation practices are applied with 120 primary and secondary pumping stations installed along the rivers. The irrigation canal system is used to convey water to each scheme. The average temperatures vary from 20°C in December to 34°C in July (Firoz et al. 2018) and the annual rainfall ranges from 2000mm in the flood plain to 3500mm in the mountain area. About 80% of rainfall happens in the wet season from October to December (IMHEN 2010). The driest period is from February to April with only 3-5 % of the total annual rainfall (Souvignet et al., 2013), causing severe water shortages and problems with salt water intrusion in this area (Viet, 2014).

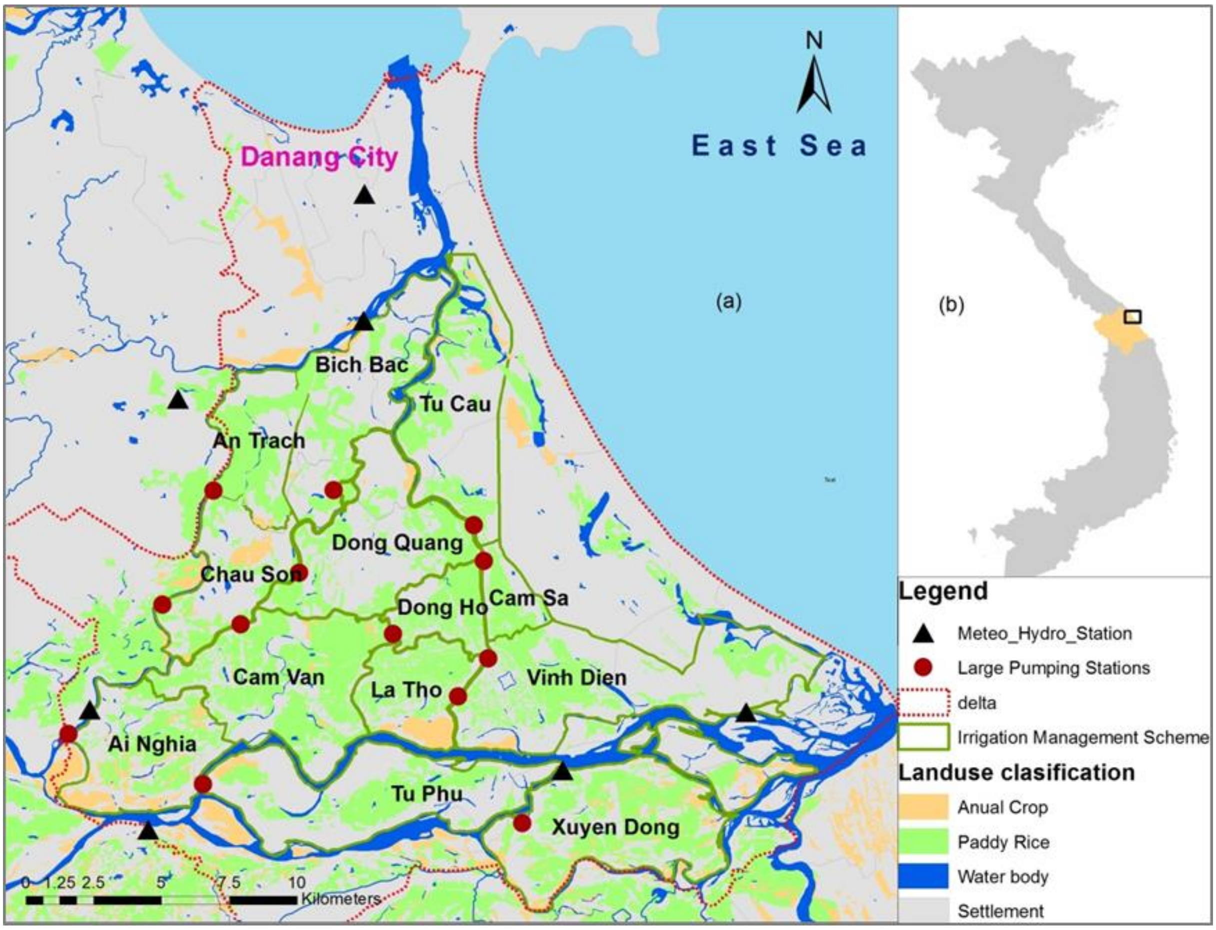


Figure 1. (a) VG-TB Delta, irrigation management schemes, pumping stations and river network (b) Location of VG-TB Delta in Vietnam

3. MATERIALS AND METHODS

3.1 Data

Data used for estimating performance indicators were collected for the period of 2004 - 2005. Rainfall data from 5 other stations (Da Nang, Ai Nghia, Cau Lau, Cam Le and Hoi An) which cover the basins lowlands was also obtained and analysed.

Meteorological parameters applied to compute Reference Evapotranspiration (**ET_o**) in CROPWAT model were latitude, longitude and altitude of the station, maximum and minimum temperature (^oC), relative humidity (%), wind speed (km/day) and sunshine hours. This data was provided by the Regional Centre for Hydro-Meteorological (RCHM).

Daily operation data from 13 large primary pumping stations for the calculated year were provided by Irrigation Management Company (IMC) during the field research to estimate the total irrigation water abstract.

The crop schedules, cultivated area, soil types, land-use data and crop yield data were obtained from Department of Agricultural and Rural Development (DARD)

Those data were validated for quality in the scope of the research project “Land Use and Climate Change Interactions in Central Vietnam” (LUCCI) from 2010 to 2015.

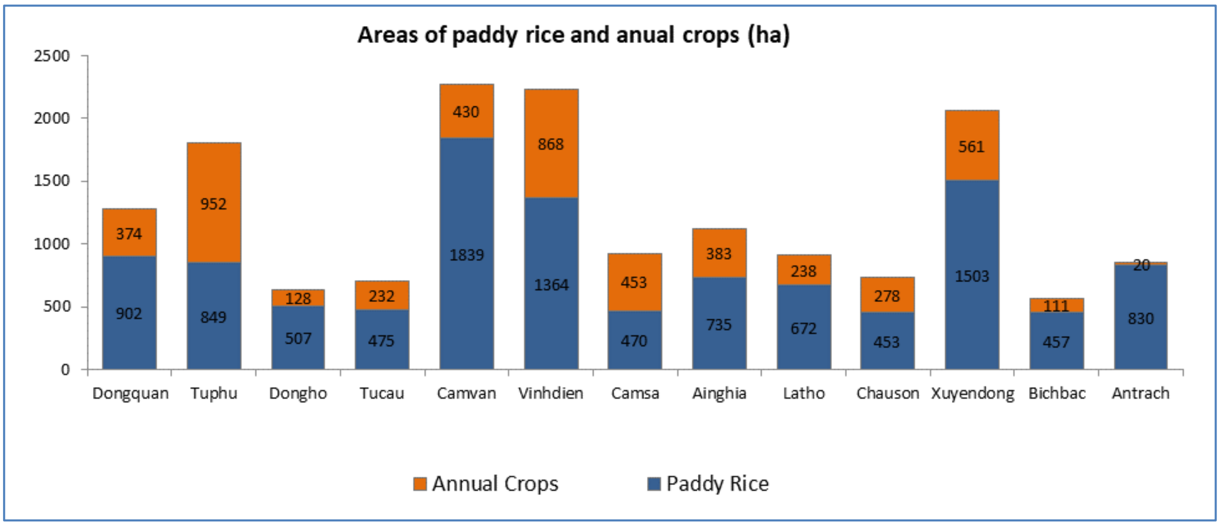


Figure 2. Area of Irrigation Management Schemes in the VG – TB delta

3.2 Methods

Water supply and water demand are two critical factors for assessing the performance of irrigation scheme. Relative Water Supply (RWS) and Relative Irrigation Supply (RIS) were selected to apply in this study. They are useful to analyse and interpret the performance of irrigation system for different spatial and temporal (Sakthivadivel et al., 1993). In this study, we calculated monthly RWS and RIS for 13 different irrigation management schemes in the low land of the VG – TB and the results were analysed and interpreted.

Relative Water Supply is defined as the ratio of the total water supply to the total water demand as originally defined by (Levine, 1982). Higher values of RWS indicate that there is excess water for supplying.

$$\text{Relative water supply} = \frac{\text{Total water supply}}{\text{Total crop water requirement}} \tag{1}$$

The total water supply is actual irrigation water supply by pumping system via irrigation canals plus the total rainfall.

In this study, the term crop water requirement is defined as the amount of water needed to compensate the evapotranspiration loss from the cropped field for a specific time (USDA Soil Conservation Service 1993). Crop water requirement is estimated by CROPWAT model simulation (Allen et al., 1998). It uses the FAO (1992) Penman - Monteith equation for estimating reference crop evapotranspiration. The input data for this model is presented in section 3.1.

Relative irrigation supply is defined as the ratio of irrigation supply to irrigation demand (total demand less effective rainfall) and it is the inverse of irrigation efficiency.

$$\text{Relative irrigation supply} = \frac{\text{Irrigation supply}}{\text{Irrigation demand}} \tag{2}$$

Irrigation supply is actual irrigation water abstracted and supplied by pumping systems via irrigation canals. During the field research, we decided to select 13 large primary pumping stations which represent 13 irrigation management schemes. The actual irrigation water supply is calculated using the daily operational data of these pumping stations.

Irrigation demand is understood as the net irrigation water requirement and calculated as below:

$$\text{NIWR} = \text{CWR} - \text{P}_{\text{eff}} \tag{3}$$

Where: $\mathbf{P_{eff}}$ is effective rainfall. **CWR** is the crop water requirement.

The method used to compute effective rainfall was United States Department of Agriculture (USDA) soil conservation service (Smith, 1991) following below equations:

$$P_{eff} = P_{tot} \times \frac{125 - 0.2P_{tot}}{125} \quad \text{for } P_{tot} < 250mm \tag{4}$$

or

$$P_{eff} = 125 + 0.1 \times P_{tot} \quad \text{for } P_{tot} > 250mm$$

Where $\mathbf{P_{eff}}$ denotes the effective rainfall; $\mathbf{P_{tot}}$ the measured (or generated) total daily rainfall.

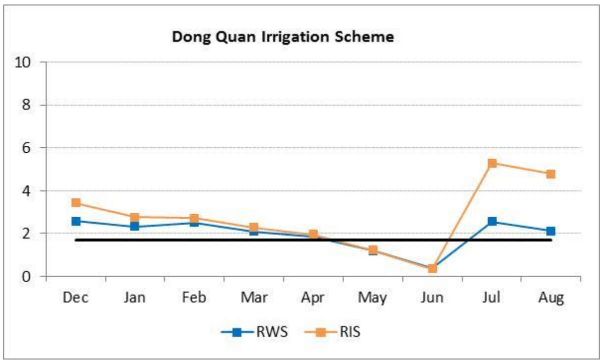
By that definition, effective rainfall in some period of times can be equal to or exceed the crop water requirement. In cases where effective rainfall equals or exceeds crop water requirement, there is no irrigation water requirement and the RIS value is zero and the higher RIS, the lower irrigation efficiency of system.

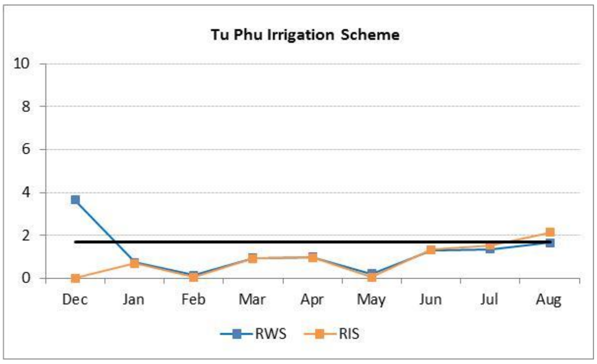
When the irrigation water supply equals the crop water demand, both RWS and RIS have a value is of 1.00. This implies 100% irrigation efficiency, which is not possible under field conditions (Salvador et al., 2011). The Irrigation Management Company in charge of pumping and irrigation in the area defines irrigation efficiency at about 60% (RIS ≅1.7). Therefore, an RWS or RIS value below 1.7 implies under-irrigation, whereas a value above 1.7 implies over-irrigation for surface irrigation systems.

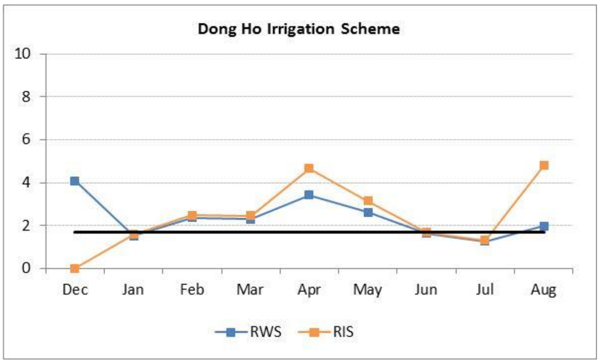
4. RESULTS AND DISCUSSION

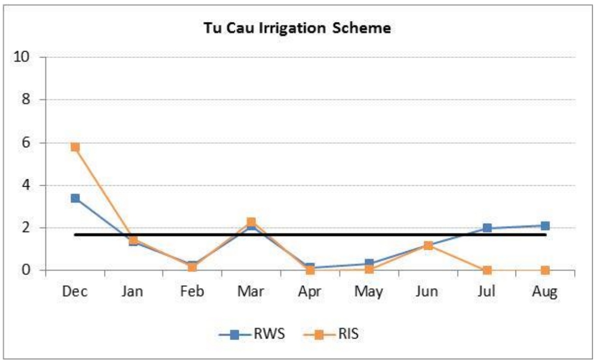
4.1 Results

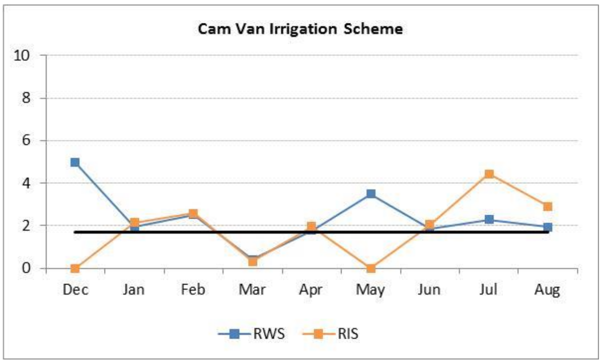
Figure 3 presents the monthly RWS and RIS of 13 irrigation management schemes in the region. The results differ from scheme to scheme. To understand the performance of each irrigation system, the results were analysed individually. It can be seen that six irrigation schemes including Tu Phu, Tu Cau, Xuyen Dong, Bich Bac, An Trach, Ai Nghia suffered from under water supply most of the time during crop seasons. In December and August both RWS and RIS are high, except in some cases the RIS values are zero and RWS relatively high such as Tu Phu, Dong Ho, Cam Van, Vinh Dien, Cam Sa, Ai Nghia, La Tho, Chau Son, Xuyen Dong. At Ai Nghia and Chau Son in May, RIS values are zero while RWS relatively high.

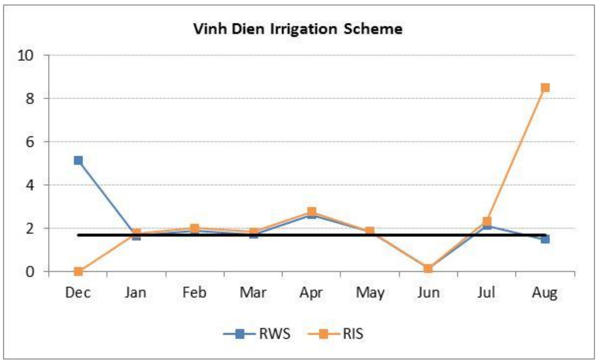


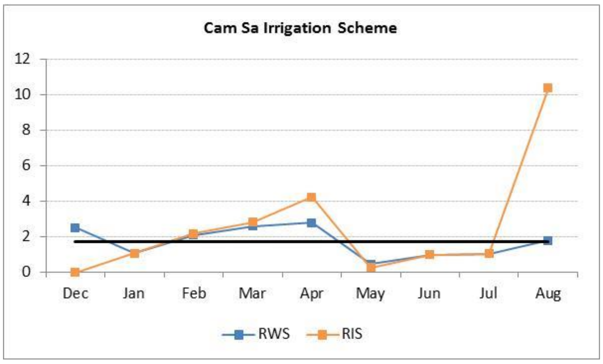


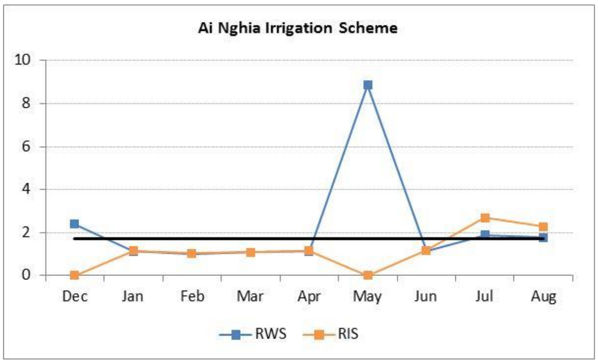

Dong Ho Irrigation Scheme
RWS
RIS

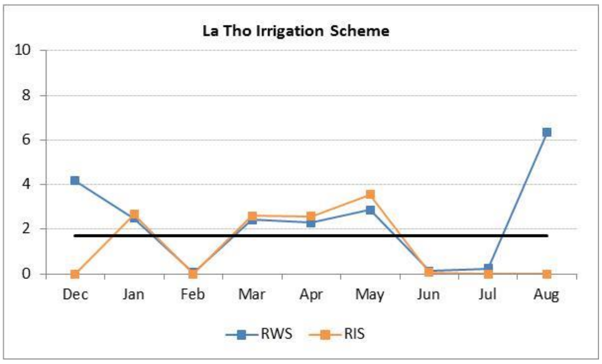

Tu Cau Irrigation Scheme
RWS
RIS

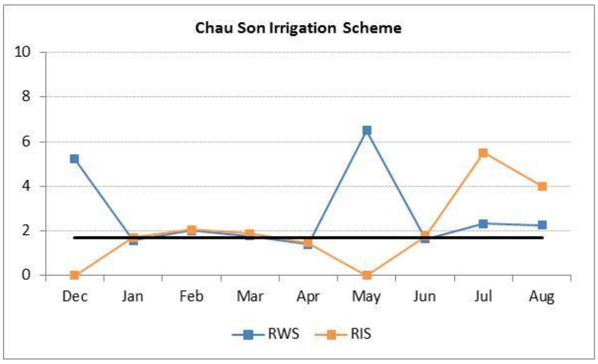

Cam Van Irrigation Scheme
RWS
RIS


Vinh Dien Irrigation Scheme
RWS
RIS


Cam Sa Irrigation Scheme
RWS
RIS


Ai Nghia Irrigation Scheme
RWS
RIS


La Tho Irrigation Scheme
RWS
RIS


Chau Son Irrigation Scheme
RWS
RIS

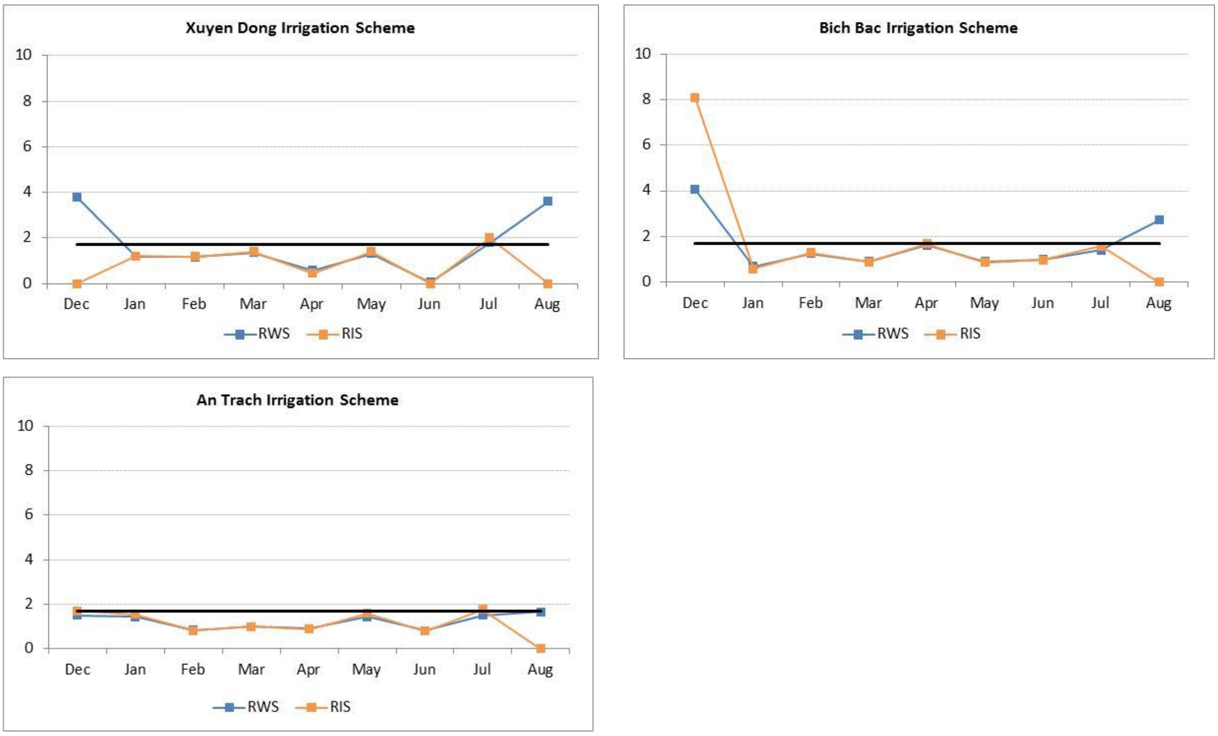


Figure 3. Monthly Relative Water Supply (RWS) and Relative Irrigation Supply (RIS) for Irrigation Schemes in the Vu Gia – Thu Bon Delta

4.2 Discussion

Analysing the RWS and RIS calculated from the results, six irrigation schemes including Tu Phu, Tu Cau, Xuyen Dong, Bich Bac, An Trach, Ai Nghia reveals that these irrigation schemes suffered from under water supply. This implied an under-irrigation supply in both seasons Winter – Spring and Summer – Autumn, especially from February to July. Salt-water intrusion occurred early in February and heavily in May, June and July. The research on salt-water intrusion by (Viet, 2014) revealed that the operation of those pumping stations was seriously affected during this period of time.

Generally, RWS and RIS follow the same trend (Al Zayed et al., 2015) except in some cases where the RIS value is zero and RWS relatively high. This can be explained by understanding that during this timeframe the system is in a condition of water abundance, and effective rainfall is equal or greater than crop demand. For example RWS and RIS of Ai Nghia, Cam Van and Chau Son soared to a peak in May as a high rainfall was reported that month at Ai Nghia station with 128mm compared to less than 20mm of previous months. The result also demonstrates that rainfall variability plays an important role in changing RWS and RIS. Reducing the irrigation supply should be considered for those periods, so that effective irrigation management can be achieved.

Both RWS and RIS are high in December and August. In some cases, the RIS values are zero and RWS relatively high such as Tu Phu, Dong Ho, Cam Van, Vinh Dien, Cam Sa, Ai Nghia, La Tho, Chau Son, Xuyen Dong irrigation management schemes in December. This can be explained by high rainfall and land preparation stage for the winter-spring growing season. Similar to December, August also was reported with high rainfall in the whole region. The values imply that there is considerable potential to save and use water more effectively during this period.

5. CONCLUSION

Two indicators RWS and RIS were calculated for two crops of the year 2014 – 2015 in the VG – TB delta. The results were deeply analysed for the better understanding of the irrigation system performance. The interpretation of the results was also presented. The intermittent shortage of water and inefficient irrigation system are revealed after analysing 2 indicators RWS and RIS. The efficiency of water use in this irrigation system is presented. The results can be used by local stakeholders to improve irrigation water management over schemes as well as enabling water planners and policy makers better rely on in their integrated water resource planning. The irrigation schedule adjusting and efficient rainfall using could be considered to enhance the irrigation system efficiency.

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