



# Performance Assessment of Irrigation Schemes and Water Pollution Issues Raised in the Red River, Vietnam

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## To cite this article:

Nguyen Duc Viet, Dao Trong Tu, Nguyen Tung Phong, Ha Hai Duong. Performance Assessment of Irrigation Schemes and Water Pollution Issues Raised in the Red River, Vietnam. *International Journal of Environmental Protection and Policy*. Vol. 6, No. 1, 2018, pp. 1-8.

doi: 10.11648/j.ijepp.20180601.11

Received: November 27, 2017; Accepted: December 11, 2017; Published: January 10, 2018

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**Abstract:** Irrigation schemes management in Red River Delta, Northern Vietnam has an extreme significance to ensure the multi-objective water supply and the health of the Red River. This study is drawn upon mostly primary data sources including results of water supply assessment of economic industries and the status quo of hydraulic works (pumping station, canals, gates, regulating reservoirs, etc.) along the Red river (study area inside the territory of Vietnam), then compare the results against the value of water supply capacity of irrigation schemes in the context of effectiveness of hydraulic works has not yet achieved as original designs (approximately 60%). From that point, identifying the relationships between - trade off - the water supply and healthy of the Red river. The results of the comparison show that the water supply for agriculture production will increase dramatically in 2020 approximately from 8 bill.m<sup>3</sup>/year compared to actual demand of about 13.65 bill.m<sup>3</sup>/year. And, more irrigation water may be more harmful for the Red river's health, which is absolutely correct in the context of irrigation schemes also supply for other sectors such as industry, drinking water, aquaculture farms, etc. The results of this study are conclusive evidence to promote the implementation of a number of water policies in the Red River Delta.

**Keywords:** Performance Assessment of Irrigation Schemes, Water Pollution Issues, Water Resources Management, Water Resource Protection, Irrigation Schemes Management, Water Quality and Quantity, Red River Delta, Red River Basin

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## 1. Introduction

Vietnam is a country located at downstream of major rivers, with 2,360 rivers, total reserve of surface water is estimated at about 830-840 bill.m<sup>3</sup>, in which three-quarters of the water flowing from abroad into the territory [1]. Currently, the two largest river basins of Vietnam are Mekong River (South) and Red River (North).

According to Ministry of Natural Resources and Environment (MONRE) of Vietnam, Red River Basin (RRB) is approximately 169,020 km<sup>2</sup>, of which 81,240 km<sup>2</sup> (48%) in China's territory, 1,100 km<sup>2</sup> (0.65%) in Laos and 86,660 km<sup>2</sup>

(approximately 51.35%) in Vietnam. Red river has a length of 1,149 km, in which, the length in the territory of Vietnam is about 328 km [2].

Rivers have played an important role in the economics society development of human life, since thousands of years, before the irrigation schemes exist, many delta regions have been formed naturally by the floodplains of the river. And, Red River Delta (RRD) is one such delta (approximately 23,336 km<sup>2</sup>) [3], account for 7.1% Vietnam's area.

The total amount of water of the Red River flowing to the territory of Vietnam has been estimated at about 82.54 bill.m<sup>3</sup>/year [4], [5], it carries a large amounts of sediment

estimated about 115 million tons/year [6], that has greatly contributed to the development of agricultural production.

In the RRD, the irrigation schemes is essential infrastructure, serving agricultural production, contributing to significantly increases productivity, yield and quality of agricultural products, fisheries, supplying water for people's living and other economic sectors, drainage, contributing to prevention and mitigation of damage caused by natural disasters, and promoting socio-economic development. So far, with the huge investment of the State, the contributions of the

people and the international organizations, the RRD has 140 dams, 500 reservoirs of different types and 5,500 pumping stations which are nodal taking water from the Red river for transmission and distribution through 61,300 km of canals of all levels (levels 1, 2, 3 and on-farm) [7]. The RRD also has some large irrigation schemes as Bac Hung Hai (110,000ha of irrigated area) and Bac Nam Ha (59,000 ha of irrigated area and 86,000 ha of drainage area) [8]. This system is considered "blood vessel" for development of 10 provinces in RRD with nearly 20 million people living [9].

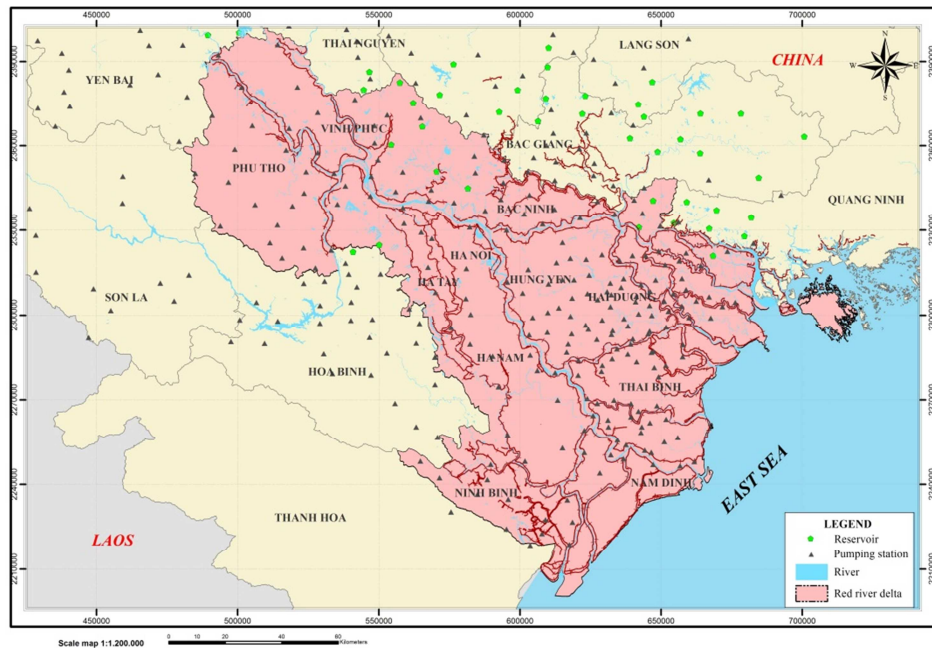


Figure 1. Red river and Red River Delta in Vietnam.

According to forecasts by 2020 of the previous researches [10]–[12], the capacity of the irrigation schemes in RRD will not be enough to meet domestic demand for the economic sectors due to low effectiveness of management and exploitation of irrigation works. Some main reasons are: (i) management institution of RRB; (ii) the degradation of the irrigation works; and (iii) regime of deficiency funding of irrigation fees. Anticipated consequences of irrigation water shortage by 2020 combining with the negative impacts of climate change and sea level rise will cause serious impacts to the development of agricultural production and other economic sectors such as industry, transport waterway, tourism, etc. leading to the degradation of the aquatic ecosystem and local people's livelihood of the Red River.

In this research, first step is determine the water demand at the research time (2015) and forecasts up to 2020, then, compare this results with the water supply capacity of all the irrigation schemes of the Red River Delta. The irrigation schemes efficiency assessment will be implemented through the Benchmarking Index (including 22 indicators), then, these results will be discussed before proposing specific policies regarding management of irrigation schemes for the RRD.

## 2. Research Methods

### 2.1. SWOT Analysis Method

SWOT is the abbreviation of Strengths – Weaknesses – Opportunities – Threats. SWOT analysis is a very effective tool to determine the advantages and disadvantages of a policy, both opportunities, challenges and risks that such policies must face when it is established (Table 1) [13]. Based on the results analysis, managers (national or regional level) will make the appropriate policy choices.

Table 1. SWOT analysis template.

	Strengths	Weaknesses
Internal	1.	1.
	2.	2.
	3.	3.
	...	...
External	Opportunities	Threats
	1.	1.
	2.	2.
	3.	3.
	...	...

Source: International Journal of Innovative and Applied Research, 2014.

## 2.2. Method of Water Demand Calculation

Demand for water use is the total water required of economic sectors such as crops, breeding, aquaculture, industry, and living and environment, etc; specifically as follows:

### 2.2.1. Water Demand for Crops

Water demand for crops is calculated by CROWAT software. Evapotranspiration of crop (ET<sub>c</sub>) is calculated by the formula:

$$ET_c = K^c \times ET^o \text{ (mm/day)}$$

In which:

- i) ET<sup>o</sup>: Potential evapotranspiration, is calculated by the formula of Penmam - Monteith.
- ii) K<sup>c</sup>: Crop coefficient, is identified in Table 2.

**Table 2.** Determination of growth-stage crop coefficients.

Crop	Growth stage specific crop coefficients				
	Begin	Growth	Middle	End	Growth
Rice	1.1 - 1.15	1.1 - 1.3	1.1 - 1.35	1.05 - 1.3	0.95 - 1.05
Potato	0.4 - 0.5	0.7 - 0.9	1.05 - 1.2	0.8 - 1.05	0.7 - 0.8
Peanut	0.4 - 0.5	0.7 - 0.85	0.95 - 1.1	0.95 - 0.8	0.85 - 0.7
Sugar	0.4 - 0.5	1.05 - 1.1	1.05 - 1.1	0.8 - 0.95	0.8 - 0.9

Source: Institute for Water and Environment, 2014.

### 2.2.2. Water Demand for Breeding

Water demand for breeding: in accordance with standards of Ministry of Construction of Vietnam in 2020 for:

- i) Residents in rural areas is 70 (l/day/person).
- ii) Residents in urban areas is 120 (l/day/person).
- iii) Buffalo, cattle is 135 (l/day/unit); pig is 60 (l/day/unit) and poultry is 11 (l/day/unit).

### 2.2.3. Water Demand for Fishery

Water demand for fishery: this demand depends on the form of fisheries:

- i) Freshwater aquaculture: including in rivers and reservoirs, two of this type do not need freshwater.
- ii) Aquaculture in ponds: needs regular supply of fresh water for deacidification and creating environment for aquatic growth and development.

Deacidification water is calculated by the equation as follows:

$$W = 10 \times (a_i + E_i) \text{ (m}^3/\text{ha)}$$

In which:

- W: Deacidification water of each month (m<sup>3</sup>/ha);
- a<sub>i</sub>: Water layer needs to be replaced (mm);
- E<sub>i</sub>: Evaporation amount between 02 times of the water changes (mm).

On average, in the Red River Delta, water demand for aquaculture is estimated at 8,000 - 12,000 m<sup>3</sup>/ha/year.

### 2.2.4. Water Demand for Industry

Water demand for industry: for concentrated industrial zones, the amount of water is calculated at (50 - 80) m<sup>3</sup>/ha/day

or by specific products:

- i) Food industry: 1,000 m<sup>3</sup>/ 1,000 USD.
- ii) Light industry: 400m<sup>3</sup>/ 1,000 USD
- iii) Heavy industry: 200m<sup>3</sup>/ 1,000 USD

### 2.2.5. Water Demand for Drinking Water

Water demand for drinking water: depends on each area, specifically as following:

- i) Urban area: in the city is 150 (l/person/day) and suburban is 100 (l/person/day).
- ii) Rural area: 60 (l/person/day).

### 2.2.6. Water Demand for Environmental Flow

Environmental flow is water demand for ecological environment is the amount of water used for processing, dilution of the effluent from the water demand for crops, breeding, living, industries and aquaculture.

Therefore, to maintain the environmental flow of the river basin in the development phase until 2020, it will need 15-20% of the water demand for irrigation throughout the Red River Basin.

## 2.3. Methods of Performance Assessment of Irrigation Scheme Management

Applying the assessment of irrigation schemes in RRD by the Benchmarking Evaluation Index, including 22 indicators and 29 component parameters [14].

The meaning of each indicators as Table 3.

**Table 3.** Meanings of Benchmarking indicators.

Construction management criteria (C)	
C1	Cost for operating, maintenance and repairs (VNĐ/ha)
C2	Rate of solidification canals (%)
C3	Water monitoring (%)
C4	Construction saftify (%)
Water management criteria (N)	
N1	Irrigation levels (m <sup>3</sup> /ha)
N2	On-farm irrigation water use (m <sup>3</sup> /ha)
N3	Efficient agricultural water use (VNĐ/ha)
N4	Irrigation efficiency compare with original designs (%)
N5	Irrigation efficiency compare with plan (%)
N6	External demand for agricultural production (%)
N7	Drainage efficiency for agriculture (%)
Economic management criteria (K)	
K1	Number of labor management (ha/person)
K2	Management skills of Irrigation and Drainage Management Company (IDMC) (%)
K3	Management skills of workers (%)
K4	The cost ratio of irrigation scheme (%)
K5	The cost ratio of labor of irrigation scheme (%)
K6	The cost ratio of operation and maintenance of an irrigation scheme (%)
Water environment management criteria (M)	
M1	Irrigation water quality
Water user organization management criteria (T)	
T1	Density of on-field channel (km/ha)
T2	Farmers participation in water management (VNĐ/ha)
T3	The cost ratio of water fee subsidy of WUO (%)
T4	The cost ratio of water fee collection (%)

Source: Decision No. 2212/QĐ-BNN-TCTL, MARD Vietnam.

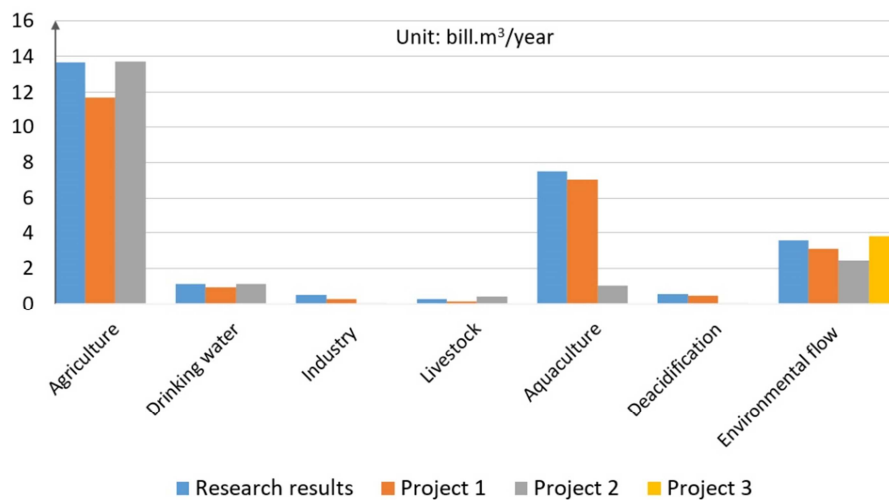
### 3. Research Results

#### 3.1. Water Demand Calculation Results

The calculation results for water consumption of major economic sectors in RRD as Table 4.

**Table 4.** Water demand forecast of RRD by 2020.

No.	Water Demand Forecast to 2020	
A	Water consumption	
1	Agriculture	13.65 bill.m <sup>3</sup> /year
2	Drinking water	1.15 bill.m <sup>3</sup> /year
3	Industry, handicraft villages	0.55 bill.m <sup>3</sup> /year
4	Livestock	0.32 bill.m <sup>3</sup> /year
5	Aquaculture	7.5 bill.m <sup>3</sup> /year



**Figure 2.** Comparing calculation results regarding the water demand on charts with data from different three projects.

Comparative charts as Figure 2 show that the results of calculations on water demand for economic sectors in the RRD of this study did not differ significantly from the previous studies.

These results show that total water demand of the economic sectors in the RRD by 2020 is estimated at 23.77 bill.m<sup>3</sup>/year. In comparison with water demand of other sectors, agriculture production is largest; it is about 13.65 bill.m<sup>3</sup>/year, accounted for 16.4% of total annual flow of Red river in Vietnam.

No.	Water Demand Forecast to 2020	
6	Deacidification, desalination	0.6 bill.m <sup>3</sup> /year
Total A		23.77 bill.m <sup>3</sup> /year
B	Red river's health	
1	Environmental flow (15% A)	3.56 bill.m <sup>3</sup> /year

Compare the results of three study researches: (i) Project 1: Planning using integrated water Red River Basin [10]; (ii) Project 2: Scientific basis and operating practices for water supply in dry season of RRD [11]; (iii) Project 3: 2<sup>nd</sup> Red River Basin [12] regarding water demand of economic sectors in the territory of Vietnam by 2020 as Figure 1.

#### 3.2. Assessing the Status Quo of the Performance Assessment of Irrigation Schemes in RRD

The Benchmarking Index (as Table 3) was conducted for 33 irrigation schemes in the whole RRD including 10 provinces: Hanoi, Hai Duong, Hai Phong, Thai Binh, Nam Dinh, Ninh Binh, Hung Yen, Ha Nam, Vinh Phuc and Bac Ninh; The results are shown in Table 5.

**Table 5.** Assessment results of efficient management of irrigation schemes according to the Benchmarking Index (2015).

Symbol	Benchmarking	Average Value in RRD	Average Value in Vietnam	Unit
C1	Cost for operating, maintenance and repairs	1,138,000	758,000	VND/ha
C2	Rate of solidification canals	35.22	48.74	%
C3	Water monitoring	52.56	59.52	%
C4	Construction saftify	20.10	30.18	%
N1	Irrigation levels	6,117	8,455	m <sup>3</sup> /ha
N2	On-farm irrigation water use	4.697	5.510	m <sup>3</sup> /ha
N3	Efficient agricultural water use	3.392	6.700	VND/ha
N4	Irrigation efficiency compare with original designs	63.46	54.88	%
N5	Irrigation efficiency compare with plan	100	100	%
N6	External demand for agricultural production	11.10	14.61	%
N7	Drainage efficiency for agriculture	94.71	92.72	%
K1	Number of labor management	125	1.090	ha/person
K2	Management skills of IDMC	70.17	71.06	%
K3	Management skills of workers	69.78	63.67	%

Symbol	Benchmarking	Average Value in RRD	Average Value in Vietnam	Unit
K4	The cost ratio of irrigation schemes	101	98.33	%
K5	The cost ratio of labor of irrigation schemes	41.45	42.63	%
K6	The cost ratio of O&M of irrigation schemes	21.89	64.58	%
M1	Irrigation water quality	-	-	-
T1	Density of on-field channel	125	1.090	km/ha
T2	Farmers participation in water management	70.17	71.06	VND/ha
T3	The cost ratio of water fee subsidy of WUOs*	69.78	63.67	%
T4	The cost ratio of water fee collection	101	98.33	%

\* WUOs: Water user organizations.

### 3.3. Assessing the Drainage Water Quality at Two Drainage Gates Along the Red River

According to the monitoring results of the Centre for Evaluation and Monitoring (CEM) belongs to Ministry of Natural Resources and Environment (MONRE) of Vietnam [15], showed at some points near the drainage gates of irrigation schemes along the Red river have some characteristics:

i) Pollution by suspended solids, organic matter ( $BOD_5$ , COD reached from 1.3 - 3.7 times the permitted standard), dissolved oxygen (DO reached 1:11 1.02 - fold), nutrients (Ammonium), microorganisms (Coliform reached 1.17 - 2 times), chemicals and heavy metals (such as Phenol, As, Fe) and plant protection chemicals (Aldrin, 4.4 'DDT).

ii) Indicators  $NO_2$  and  $NO_3$  also tend to increase and reached the highest levels in the drainage position of the irrigated area.

- Indicators phosphate, oil exceeded the permitted level 1.1 - 1.5 times compare with QCVN 08:2008/BTNMT regarding "National technical regulation on surface water quality".

## 4. Discussion

The value of N4 indicator at the Table 5 has value is 63.46%, mean that is the irrigation efficiency of irrigation works is estimated at about 60% compared with design. Beside that, the

N2 indicator is present the on-farm water use level (about 4,700  $m^3/ha$ ) of existing irrigation works reach approximately 77% of the total volume of N1 indicator - irrigation water supplied at the beginning of system (reaching 6,100  $m^3/ha$ ); thus, the loss of water during water transmission from the head works to the farms is still relatively high, up to 23%. The effectiveness of irrigation schemes in RRD has not yet achieved as original designs due to some reasons:

i) Most of hydraulic works have been built about 40 years ago, therefore, these works has now been degraded over time.

ii) Poor management and operation of the Irrigation and Drainage Management Companies (IDMCs).

iii) Lack of budgets to upgrade, repair and maintenance the hydraulic works.

According to calculation results at Table 4, to forecast in 2020, only for agricultural production, the Red River needed to be supplied amount of water is about 21.5 bill. $m^3/year$ , increase 8 bill. $m^3/year$  compared to actual demand (13.65 bill. $m^3/year$ ); and millions of cubic meter of irrigation water for other economic sectors (such as fisheries, industry, handicrafts, livestock, etc) will also create a lot of pressure on the irrigation schemes along the Red river. To meet the increasing water demand for agriculture production and other economic sectors by 2020, hydraulic works will have to receive more water from the Red River (Figure 3), this trade-offs would be a negative impact of the Red river health.

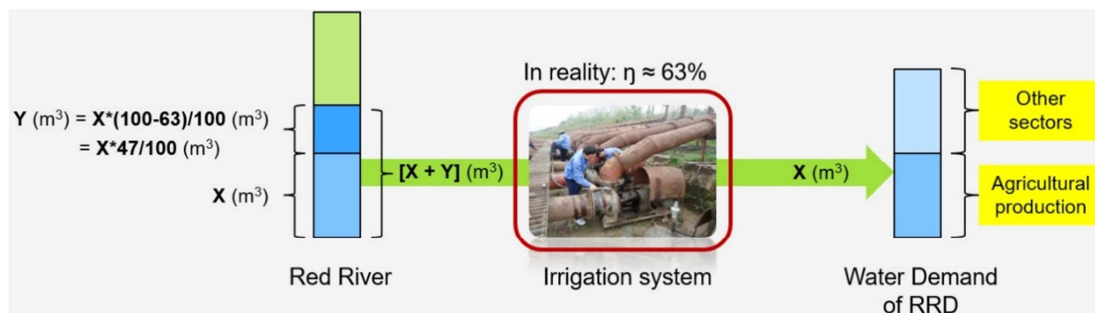


Figure 3. The actual water requirements to be taken from the Red river to provide future agriculture water demands (2020) in the RRD.

Continued from analyzing as mentioned above, not all the irrigation water will be "disappear" completely, after being used partly for human productive activities, especially agriculture production, majority of irrigated water will be back to the Red River by many ways, such as via the

drain-age canals or groundwater. Unfortunately, most irrigation supplies contain very high concentrations of these toxic and are generally quite big problems, which are the water quality and salinity intrusion as Figure 4.



*Edited by: Nguyen Duc Viet (MK33 - WLE)*



**Figure 4.** Relationship between irrigation schemes and Red river.

A more detailed analysis of water pollution issues raised in the Red river as follows:

1) The water quality: after water is used in the irrigated lands, it will drain back to the Red river, and irrigated water carries a lot of the residual of plant protection products, fertilizer on the field, waste discharge from handicraft villages, industry parks, etc.; these results show through the BOD<sub>5</sub>, COD, DO, Coliform, etc. indicators exceeds the permissible standards in the drain gates of irrigation schemes along the Red river (Item 3.2); in consequence, poor water quality and pollution have negative impact on ecological characteristics of the Red river. It's also leading to the affecting the livelihood of local people, the fishery resources decline will directly affects all fishermen in fishing villages, furthermore, those living along the two sides of the Red river, when their crop production will be reduced due to irrigation water pollution. Furthermore, which is affecting human health, if the communities living along the Red river used contaminated water for domestic purposes will cause serious diseases related to stomach, nervous system, reproductive, skin, etc especially cancer diseases.

2) The salinity intrusion: use more water for irrigation systems along the Red river leads to lack of water to push salinity in the estuaries, so the combined effects of salinity intrusion and sea level rise (due to climate change) resulted in degradation of coastal ecosystems.

In summary, more irrigation water may be more harmful for the Red River health, that is absolutely correct in the context of the hydraulic works also supply for other economic sectors such as industry, drinking water, aquaculture farms, etc. Frankly, there is an assumption, many environmental protection agencies of Government and NGOs will protest, therefore, this trade-off usually involves the irrigation systems will have to use less water from the Red

River, in consequence, not getting enough water to service agriculture production and other economic sectors lead to impact on development of RRD.

Therefore, to harmonize the benefits between the sustainability of water supply and the Red river health, one of the approaches to solve these problems, which is improving irrigation water use efficiency of the irrigation schemes in RRD. The solutions group to repair, upgrade, and modernize irrigation schemes often require a huge cost, up to billions of US\$, which surpasses the affordability of the national budget, but if the delay in the repairing and upgrading, the hydraulic works will continue to deteriorate.

Every year, the Vietnam Government has a policy to support irrigation fees for water users (focus on the farmer) in the RRD through the IDMCs, estimated at 2,100 billion VND [16]. However, the budget above-mentioned is fixed over a long time period (normally, 3 - 5 years), therefore, with unfavorable weather factors (storms, floods, cyclones, etc.) and wage costs up to 70% of the irrigation fee subsidy for a large number of officers and employees (14,000 people) of IDMCs in the RRD, after deductions other expenses, normally, only 18-21% of the total water service charge (about 420 billion VND - 200 million US\$) is used to repair and upgrade thousands of irrigation works, this is an impossible mission and this vicious circle will lead to a deeper impact on the ecosystems and livelihoods of the people living along the Red river as analyzed above. Thus, the nature of the problem to be solved is need to ensure financial resources for the IDMCs (including operation, maintenance, upgrading, repairing and modernization of irrigation schemes).

Therefore, need a breakthrough policy to break the barriers of current irrigation policy. Accordingly, the policy proposed in this study is to make a transition from public irrigation

services to irrigation service pricing, to convert irrigation water into a commodity, and to be influenced by market factors. The water pricing of irrigation services is a new approach in Vietnam, if applied, it will open up a new financing mechanism in the field of irrigation sector; It also requires IDMCs to collect the enough water fees from the water users (WUs). WUs also have the right to refuse to pay irrigation services if the IDMCs fail to meet the terms and conditions in the contract. However, there should be a roadmap to collect the irrigation service pricing of the WUs, the hypothesis of 03 options as follows:

i) Option 1A: To maintain and continue implementing the irrigation fee support policy.

ii) Option 1B: Immediately turning to the principle of market economy for irrigation service pricing is "correctness calculation - adequacy calculation" and "proper collection - enough collection" of WUs.

iii) Option 1C: Conversion from irrigation fee subsidy to irrigation service pricing, but the State still partly subsidizes irrigation service.

The SWOT analysis for three options above-mentioned shows that policy change from irrigation fees to irrigation services is an indispensable trend that needs to be made to access the market mechanism. Although some IDMCs also commented that the continuation of the irrigation support policy under Option 1A was the optimal solution to maintain the irrigation systems with minimum funding to service agricultural production, ensuring food security for the whole region. However, the results of the SWOT analysis for both options 1B and 1C show the high feasibility of applying irrigation service pricing in the Red River Delta, but the new mechanism should be implemented along a roadmap as suggested in Option 1C, the reason is that to avoid the risk of implementing the irrigation service pricing regime such as a sharp increase in input costs in agricultural production, it would be a shock for millions of WUs or the WUs will seek to break the crop planning, switch to super-profitable crops. Forecasting impacts under Option 1C is clearly illustrated by the fact that when IDMCs have sufficient funds to maintain the operation, repair and upgrading of hydraulic works, besides saving about 2,100 billion VNĐ annually for the State budget, irrigation systems would also reduce 8 billion cubic meters of irrigation water (for agricultural production) from the Red River compared to actual demand by 2020, therefore, it is also reduce the water pollution from irrigation schemes, contributing to minimize negative impacts on the environment and ecosystems of the Red river.

Expected results will motivate: (i) IDMCs will be achieved self-control in managing and operating costs; (ii) Ensuring budget for maintenance, repairing and modernization of hydraulic works, improving the operational efficiency of RRD's irrigation schemes compared to the current rate (63%); (iii) WUs are aware of economical and efficient use of irrigation water; (iv) Meet multi-purpose water supply requirements for non-agricultural production sectors; (v) Reducing negative impacts on the Red river ecosystem; (vi) Reduce the annual burden from the State budget to support

irrigation fees for WUs.

## 5. Conclusions

Compare the values of the water use demand and effectiveness of irrigation schemes in RRD shows that water supply for agriculture production will increase dramatically in 2020 approximately 8 bill.m<sup>3</sup>/year compared to actual demand is about 13.65 bill.m<sup>3</sup>/year; more irrigation water may be more harmful for the Red River health. That is absolutely correct in the context of the hydraulic works not only provide irrigation water for agriculture production, which also supply for other economic sectors such as industry, drinking water, aquaculture farms, etc. Therefore, to harmonize the benefits between the sustainability of irrigation water supply and the Red river health, one of the approaches to solve these problems, which is transfer from irrigation fees policy to irrigation services mechanisms.

However, if Vietnam Government immediately replaces the irrigation fees policy by the irrigation services mechanisms, it can cause major disturbances in the production activities of millions of farmers; the increasing in input costs, particularly the cost of irrigation services in agricultural production. Through the SWOT analysis, the study suggests that Vietnam Government should continue to support a part of irrigation service fees; the irrigation service pricing will be reduced over the next years follows a roadmap and it will be ended when WUs have enough economic conditions to pay for all the cost of irrigation water in agricultural production.

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