

Assessment of impacts of utilization on water resources in the basin of trans-boundary Red river system

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Received: 1 September 2019; Accepted: 6 December 2019

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Abstract

The Red river system is the large trans-boundary river system, there has been no united system of hydrology stations as well as integrated plan for the water use and management in the whole basin. The trend of water resources change in the Red river system basin has been assessed on the basic of statistic analyses of data observed during the studies, especially in the time when the exploitation of water resources has been intensified for the multisectoral development. This paper shows some of the results from considerations of the water use in the highlands that is influential in water resources in the Red river system basin and the planned reservoirs which are built in the basin of Red river system. The results include the assessment of the state and trend of water resources in the Red river system basin, the trend of water level lowering in the lowlands and its impacts.

Keywords: Yuan Jiang - Red river system, water resources, hydrology station, annual rainfall, water level.

INTRODUCTION

Red river system (RRS) is a large trans-boundary river system with a basin of 147,525 sq.km in area, among which 74,828 sq.km is in China's territory, with great potentials for the social economic development and meaningfully environmental and ecological functions in Northern Vietnam [1, 2]. However, the intensive exploitation of water resources in the basin in form of making reservoirs for electric generation, irrigation, domestic needs, mining for heavy minerals and deforestation has impacted water resource potentials in the basin which are inherently influenced by the global climate change [3, 4]. As the large trans-boundary river system, there has been no united system of hydrology stations as well as integrated plan for the water use and management in the whole basin. Based on identifying the state and the cause of impacts on water resources, measures for reducing

consequences from the water exploitation and use in the basin can be devised towards the sustainable development.

From the years of 1998 to 2017, the scientists from the Institute of Marine Geology and Geophysics in Vietnam and the Yunnan University in China discussed the natural hazards and trans-boundary pollution issue at the International Symposium on Resources Development and Environmental Protection of Yuan Jiang - Red river, Hanoi of Vietnam [5]. Up to the present, most researches in the upper Red River by the domestic scholars mainly focus on the hydrology characteristics of flood, runoff, sediment, pollutant distribution, water quality protection, soil erosion and controlling [6-9]. Most of the Vietnam's researches focus on the hydrology change between the upstream and downstream areas, the sediment transport, the river bank erosion and its trans-boundary impacts on the Red river delta.

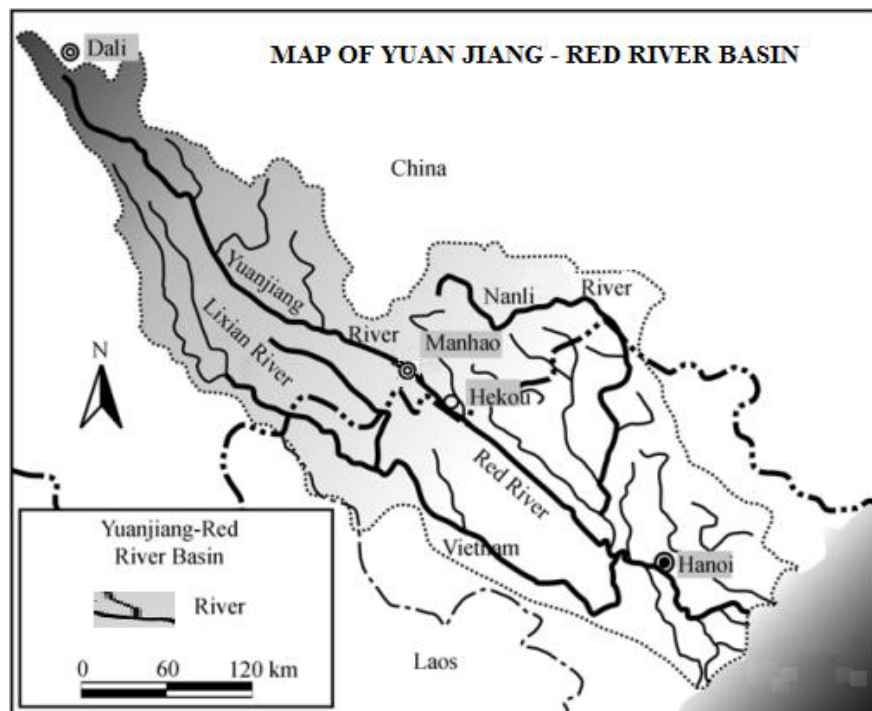


Fig. 1. The location of Yuan Jiang - Red river system

DATA AND METHOD

Data

In the RRS in Vietnam territory, the data were collected from the Ministry of Agriculture

and Rural Development of Vietnam, the Ministry has built 3 different scenarios of water resources utilization in the basin. The trend of water resources change in the RRS basin has

been assessed on the basis of statistic analyses of data observed during the studies, especially in the time when the exploration and exploitation of water resources have been intensified for the multisectoral development [10, 11]. At the same time, Kendall statistic norms are used to identify the variation of data chains. The average flow was observed at the Yen Bai hydrology station, Vu Quang hydrology station, Son Tay hydrology station and Hanoi hydrology station [1, 2]. The data also came from the series of reservoirs planned to construct in Tuyen Quang, Son La, Nam Chien, Ban Chac, Huoi Quang, Nam Nhun, Van Lang, Na Lanh, Nam Na, Bac Muc, Bao Lac, Hung Thi.

In the RRS in China, most data available in this work were the monthly average data at Manhao hydrology station and daily precipitation at 19 meteorological stations in the catchment from 1956 to 2017, so we could calculate the arithmetical monthly average precipitation at Manhao, in comparison to synchronous annual average runoff and discharge data, sediment changes were analyzed and its driving factors were diagnosed by using statistical methods, and some relevant data were also cited from the research and investigation such as the Comprehensive Survey Report on Yunnan Province Land Resources Remote...

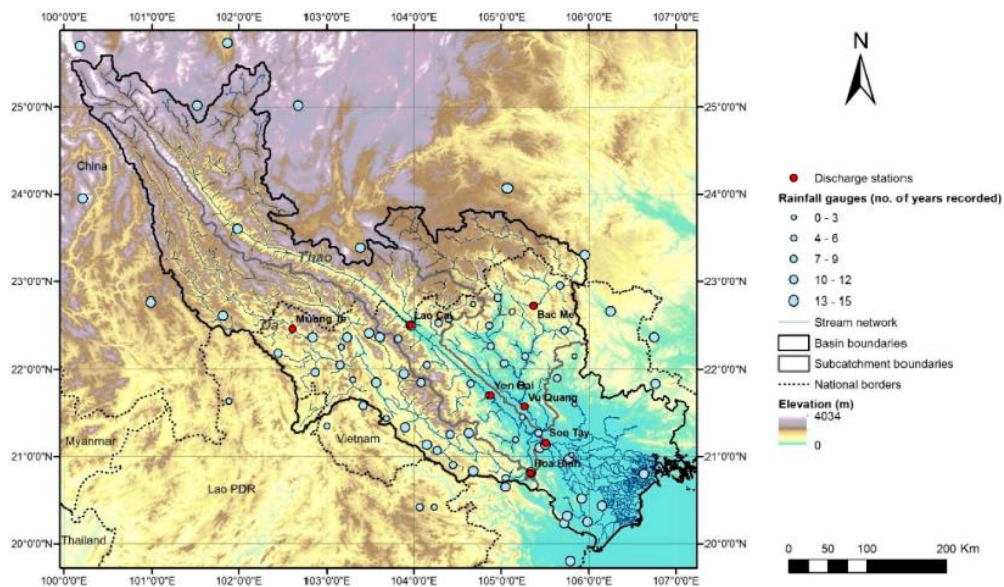


Fig. 2. The observation station system in the RRS

Methods

The data used in this research are all typical time series, so some conventional methods as correlation analysis and linear regression analysis are usually adopted to study the relationship among several time series. Linear regression analysis requests that the time series would be stable or have no unit roots. If regression analysis is directly performed between the unstable time series, wrong conclusions will be drawn; furthermore, as more samples are taken, fault regression will not disappear but even become more serious.

So, a general method is that stability would be tested in the time series before the linear regression analysis. If the time series is unstable or contains a unit root, it can be analyzed by the means of linear regression only after processing the first difference test [5, 6].

The traditional analytical methods, such as correlation analysis and regression simulation, do not have the function to analyze the causality between time series. Methods have to be introduced to solve this difficult question cooperatively when performing the traditional regression analysis [8, 9].

PRINCIPAL RESULTS

Trend of water resources change in the RRS basin

The trend of water resources change in the RRS basin has been assessed on the basis of statistic analyses of data observed during the studies, especially in the time when the exploitation of water resources has been intensified for the multisectoral development. At the same time, Kendall statistic norms are used to identify the variation of data chains [12].

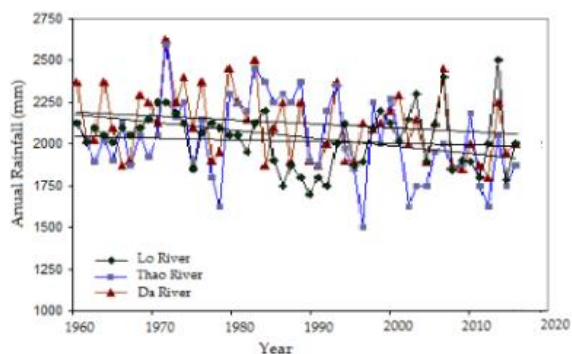


Fig. 3. The trend of annual rainfall in the basins of Da, Thao and Lo rivers

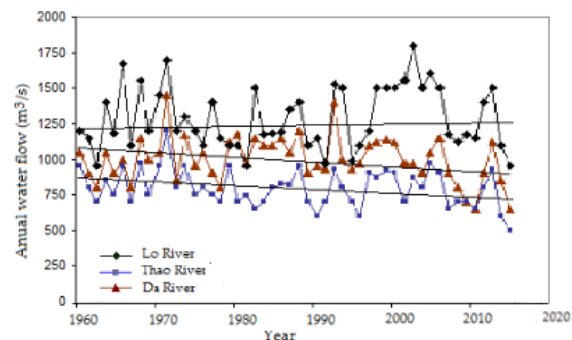


Fig. 4. The trend of annual flow in the basins of Da river, Thao river and Lo river

The trend of flow lowering of the Thao and Lo rivers is apparent. The average flow of the Thao river observed at the Yen Bai hydrology station during the years 2001–2017 was 8.22% lower than the annual value and that of the Lo river at the Vu Quang hydrology station during the same time - 14.9%. The reason for flow lowering of rivers is due to the reduction of rainfall in the sub-basins. The average rainfall in the Thao river sub-basin during the years

2001–2017 was 172 mm (8.2%) lower than the annual value and that of the Lo river sub-basin during the same time - 103 mm (4.6%).

As a result of flow lowering in the highlands, the flow recorded at the Son Tay hydrology station during the years 2001–2017 was 7.3% lower than the annual value and that at the Hanoi hydrology station during the same time was 13.4% lower than the annual value.

The water level at the Son Tay hydrology station and other downwards stations has lowered since 2001. The mean water level at the Hanoi hydrology station during the years 2001–2017 was 112 cm lower than that during the years 1978–1990. The level lowering has recently tended to be more intensive and influential in the management of water supply, flood and inundation control, dyke and environment protection in the lowlands.

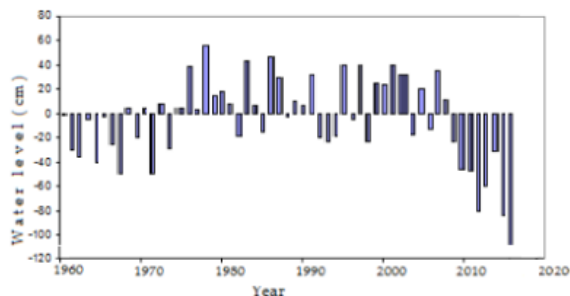


Fig. 5. The average change of water level in Hanoi hydrology station (period of 1956–2017 in comparison with 1956–1990)

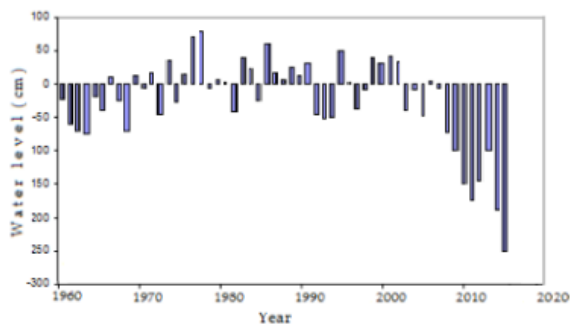


Fig. 6. The average change of water level in Hung Yen hydrology station (period of 1956–2017 in comparison with 1956–1990)

Causes of water level lowering in the lower part of the RRS

Data from sediment monitoring periods show that there is an apparent decrease in the suspended sediment discharge in the Da, Thao and Lo rivers during the years 2001–2017, especially the years 2006–2017. The cause of this is the building of a large number of

reservoirs in the highlands since 2000, many of which have come to operation since 2005. As a result of damming in Hoa Binh and several built reservoirs, the suspended sediment discharge from the river downwards reduced rapidly during the years 1987–1990 and has tended to decrease intensively since 2001.

Table 1. Characteristics of sediment monitoring (kg/s) at the hydrology stations in main flow of Red river by the years

Observed time	Da river (at Lai Chau station)		Thao river (at Lao Cai station)		Thao river (at Ha Giang station)	
	Average	Percentage %	Average	Percentage %	Average	Percentage %
Period of years	1485	100	1438	100	104	100
2001–2017	1186	–22	1185	–26	78	–23
2006–2017	869	–43	724	–53	61	–41

The change in the flow, water level and entrance is compatible with the difference in

the water level at hydrology stations in the lower part of the RRS.

Table 2. The change of water level in each part of Red river in downstream region

Period of years	At Son Tay - Hanoi	At Son Tay - Thuong Cat	At Hanoi - Hung Yen
1957–1990	284	232	252
1991–2000	282	259	271
2001–2017	268	262	167

Assessment of the water resources utilization and its state in the RRS basin

Statistic analyses of data from the discontinuous and incomplete meteorology observations show that the annual rainfall in the Ly river (confluent) sub-basin is 1,790 mm, in the Nguyen river sub-basin - 1,090 mm, in the Ban Long river sub-basin - 1,190 mm, and in the whole RRS basin - 1,590 mm, equal to the total water amount of 232.78 bil.m³ (not including the rainfall in Laos's territory), among which 97.7 bil.m³ (accounting for 42%) is in China's territory and 133.9 bil.m³ (57.5%) is in Vietnam's territory. The annual rainfall water in the Nguyen-Thao river sub-basin is 62.25 bil.m³ (holding 36.7% of the total annual rainfall water in the RRS basin), in the Ly Tien-Da river sub-basin - 90.8 bil.m³ (39%), and in the Ban Long-Lo river sub-basin - 59.23 bil.m³ (25.4%). The total surface water resources in the RRS basin are about 122.5 bil.m³, provided with another annual water discharge of 47.2 bil.m³ from China's territory, among which 22.8 bil.m³ is in the Da river sub-

basin, 15.0 bil.m³ in the Nguyen river sub-basin, and 9.4 bil.m³ in the Ban Long river sub-basin. The annual flow distribution from China's territory has a seasonal change with only 13.2 bil.m³ in dry season, holding 26.1% of the annual total or 3.3 bil.m³ in the 3 driest months (February-April), holding 7% of the annual total (table 1).

The results obtained from studying the temporal and spatial distributions of rainfall and flow are considered to be coincident with those from doing the same aspects by Chinese colleagues in the Nguyen-Hong river sub-basin in China's territory [5–7].

In order to assess the need of water resources utilization in Vietnam territory's Red river basin in the period of 2010–2020, the Ministry of Agriculture and Rural Development of Vietnam has built 3 different scenarios of water resources utilization in the basin [13–16], as follows:

The first scenario (KB1) is built in accordance with the normal trend, almost

similar with the statistic results in some previous years.

The second scenario (KB2) is built in accordance with meeting the demand of the sustainable development of the social and economical sectors, and suitable to the master plans of Vietnamese governmental ministries.

The third scenario (KB3) is built in accordance with the unstable developments of society and economy, and following the negative trend.

The volumes of water balance in accordance with different scenarios are calculated.

Table 3. The total water amount of Red river from China's territory to Vietnam

River name	Along the river	Area of basin (km ²)	Total water amount (km ³)			
			Year	Flood season	Dry season	Months II-IV
Ly Tien	<i>Main flow and Nam Khe</i>	38074	14.91	10.39	4.52	1.33
	Main flow	18390	17.48	13.98	3.50	0.94
	Dang Dieu	4220	5.36	3.60	1.76	0.37
	<i>Total</i>	22610	22.84	17.58	5.26	1.31
	Main flow	6413	3.72	2.62	1.10	0.31
Ban Long	Gam	2622	1.80	1.37	0.43	0.09
	Pho Mai	3190	1.98	1.67	0.31	0.10
	Nam Ninh	1920	1.89	1.35	0.54	0.15
	<i>Total</i>	14145	9.40	7.01	2.38	0.66
Red	Total	75968	47.15	34.98	12.30	3.30

Table 4. The calculated results of the water balance for scenarios of 2010–2020 in Vietnam's RRS basin

Scenario	Frequency	In Son Tay station	Water use	Balance
				Unit: bil.m ³
2010-KB1	75% (10/41 years)	20.79	18.75	2.03
	85% (6/41 years)	20.15	19.08	1.07
2010-KB2	75% (10/41 years)	20.22	20.07	0.16
	85% (6/41 years)	19.66	20.39	-0.73
2010-KB3	Year of 1980	18.74	21.27	-2.52
2020-KB1	75% (10/41 years)	20.30	18.72	1.58
	85% (6/41 years)	19.69	19.04	0.65
2020-KB2	75% (10/41 years)	19.64	19.76	-0.12
	85% (6/41 years)	18.95	20.05	-1.10
2020-KB3	Year of 1980	18.05	21.56	-3.51

Table 5. The reservoirs are planned to build in the period of 2010–2020

No.	Name of reservoir	Building time	River name	Efficient volume (10 ⁶ m ³)
1	Tuyen Quang	2010	Gam river	1,684
2	Son La	2010	Da river	5970
3	Nam Chien	2010	Nam Chien river	132
4	Ban Chac	2010	Nam Mu river	1615.8
5	Huoi Quang	2010	Nam Mu river	16.3
6	Nam Nhun	2020	Da river	760
7	Van Lang	2020	Cau river	113
8	Na Lanh	2020	Luc Nam river	56
9	Nam Na	2020	Nam Na river	196
10	Bac Muc	2020	Lo river	2006
11	Bao Lac	2020	Gam river	1699
12	Hung Thi	2020	Boi river	...

In accordance with the certain scenarios in period of 2010–2020, Vietnamese government has planned to build reservoirs to meet the demand of basin's water utilization. The names of reservoirs are listed in table 5.

Assessment of impacts of the water use in the highlands on water resources in the RRS basin

From 2010 up to 2020, a total of 74 larger and smaller reservoirs were built in the highlands of the RRS basin for water use and electric generation with 6 reservoirs in the Ly Tien river (the upper part of the Da river) and 8 in its confluents, 2 reservoirs in the Nguyen river (the upper part of the Thao river) and 38 in its confluents, and 8 reservoirs in the Ban Long river (the upper part of the Lo river) and 12 other in the territory of Vietnam. Most of the reservoirs in the RRS basin are medium and small in size and in detail, 17 reservoirs have a dam below 100 m in length and 33 reservoirs have a dam over 300 m in length. The followings are their impacts on the water balance in the whole basin:

The flow in upstream and downstream regions has become unstable. Based on the results from processing data at hydrology stations in the Da river belonging to China's territory in early rainy season during the years 2008–2017, China's reservoirs caused the flow reduction of 200 m³/s, equal to 630 mil.m³/month. The flow reduction of the Thao and Lo rivers caused by reservoirs in early and late rainy season is in a range of 50–100 m³/s lower than that of the Da river. The unusual fluctuation of the water level and flow at hydrology stations in the upper part of rivers leads to the deformation of entrances, the erosion of river banks, the difficulty in flow regulation and flood control.

Due to the climate change, flood-generating heavy rains have occurred in the Ly Tien and Nguyen rivers in October when a large amount of water is reserved in reservoirs and resulted in the anthropogenic flood in the Da river in October 2006.

Assessment of drought status in Red river delta (RRD)

Based on the statistic data in RRD and main researched results of national project

(KC08-23/06–10) by Nguyen Lap Dan from 1980 to 2010 [17], the area of rice fields which suffered drought has nonlinear trend from year to year. In recent ten years, the drought affects the large area in RRD. In accordance with scientific researches in the area, the main reasons which cause serious drought in RRD are global climate change and unreasonable operation of reservoirs in upstream region of RR. These reasons cause the lack of water in downstream rivers [15]. Because the needs of living water, industrial water, cultivating water, aquaculture water and so on are raising more and more annually, the shortage of natural river water resources is more serious. In 2003, because the river water level in Red river and Thai Binh river is very low, almost all the area of 300.000 ha of rice field among 500.000 ha in RRD suffered serious drought. In 2004, the drought situation was the most serious in 40 recent years. In spite of applying synthetic ways to anti-drought solutions, the drought situation is still serious, the statistic number showed that there are 50% area in Bac Ninh province and 56% drought area in Hung Yen. In 2005, runoff volume in RR decreased 30–40% in comparison with previous time. Some reservoirs of hydro-electric stations has provided water to prevent drought, which makes the heavily reducing electric generation of these stations. In 2006, the river water level in Hanoi reduced to 1.66 m, much lower than the minimum level that is needed to water the rice field area (+2.5 m), which causes 150,512 ha of drought. In 2010, the total precipitation reduces about 30% in comparison with previous time. The water level at hydrology monitoring station in Hanoi is only 0.1 m, the lowest level recorded in history.

CONCLUSION

The followings are the assessed impacts of the water use in the highlands on water resources in the whole basin:

- (1) The instability of flow in the whole basin;
- (2) The decrease in inflow in early and late rainy season;
- (3) The water release from the reservoirs generates the human-made flood that may be

more severe than that in nature in early October when a large amount of water is reserved in reservoirs;

(4) The decrease in sediment discharge. These impacts of building reservoirs in the basin of RRS are lowering the water level in the RRS basin in relation to breaking the sediment discharge (both suspended and bed loads) balance, in response to which measures of non-construction, construction and operation have been proposed. In the context of global climate change and intensive needs of the water use, however, other potential impacts may not be identified.

On the basis of the use of the rain-flow model to simulate the natural flow at some of the main hydrology stations in the Da and Lo rivers in relation to the downwards stations and in comparison with the regulated flow, the impacts of reservoirs on the flow regulation and water resource use in the RRS basin have been shown. Based on the newly obtained results, the measures for the reduction of impacts of the unsuitable water use on the water resources in the RRS basin can be proposed, consisting of three groups of non-construction, building a high capacity of meteo-hydrological observation at upper stations and water resource management. Vietnam and China should have more cooperation on water resource management in the basin of Yuan Jiang river and Red river.

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