EFFECTIVENESS OF MEASURES TO IMPROVE WATER SECURITY IN QUANG NGAI PROVINCE IN THE CONTEXT OF CLIMATE CHANGE

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Abstract: *As one the countries most adversely affected by climate change and sea level rise, Viet Nam is facing many challenges threatening its water security. Currently, there have not been many studies assessing water security in the context of climate change, especially the quantification of the water security at national and provincial levels. The study used the method of developing a set of indicators to assess the water security in the context of climate change. On that basis, the study proposed measures to improve the water security in Quang Ngai province. The analysis results show that among the 17 proposed sub-indicators on water security, there are 5 sub-indicators that cannot be affected, namely: flood frequency; number of days of drought; ratio of flooded area; the average annual rainfall and the average annual temperature. The remaining 12 sub-indicators can be improved by measures and hence the study has selected prioritized measures to ensure water security in Quang Ngai in the direction of focusing on improving these 12 indicators.*

Keywords: *Water security; Climate Change; Set of indicators.*

1. Introduction

Water is an essential part of life, a basic need and foundation for the ecosystem and social activities, so water plays an important role in contributing to conflicts that can threaten human security and the environment [6].

Water security is not simply about "appropriate access to water" – it is about sustainable access to water in an appropriate quantity and quality to meet the needs of survival, production, socio-economic development and protection of ecosystems. Water security is central to achieving a broader sense of security, sustainability, development and human affairs [8]. Specifically, according to the United Nations Water (UN-Water), the most complete definition of water security is *"The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability"*.

Measuring the water security is not a simple task and many tools have been established to quantify it [10]. In an assessment for the Asia-Pacific region [7], the water security of 46 countries with different conditions on water resource and socio-economic development was assessed through 5 indicators including: basic needs, food production, environmental flows, risk management and independence. In the study of water security indicators [9], in order to calculate the water security, 03 groups of sub-indicators are needed including water

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resources, water environment and socio-economic conditions, which used 15 factors selected for establishing an integrated assessment of water security in the Yellow River basin. Specific targets include: (i) Water resource component; (ii) Water environment component; and (iii) Socio-economic component. The Asian Water Development Outlook Report of the Asian Bank (ADB) published in 2020 [18] has introduced a method to measure water security using five main indicators, including: (1) the water security of rural households, (2) economic water security, (3) security on urban water, (4) security on water environment, and (5) security on water-related disaster.

In Viet Nam, although there is not much research on water security, some research related to water security can be mentioned, including:

In 2015, the study on "Development and application of a framework for assessing water security for Ha Noi city" [4] showed the water security index of Ha Noi and the integrated water security index (WSI) in 2005, 2010 and 2015, with respectively. Thereby, the study showed that the water security index of Ha Noi City has increased gradually over time. Based on the arithmetic average method and weighting of indicators for groups, and regions, the research has divided Ha Noi into 4 areas (Center, North, West and South) and categorized 5 groups of indicators according to the following criteria: Household; Economy; Environment; Disasters and governance, management.

One of the recent studies on water security in Viet Nam [5] is the study on water security for sustainable development of the Ma river basin. The study developed a set of water security indicators in Viet Nam's river basin, which includes 18 indicators divided into 6 groups of sub-indicators: (i) Water flowing to the river basin; (ii) Clean water supply for people; (iii) The economic level of water use of the river basin; (iv) Protection of river ecosystems and environment; (v) Risks and damages caused by natural disasters; (vi) Management of water resource and river basin, and decentralization of water security assurance levels in the basin. On that basis, the study proposed a number of structural and non-structural measures to ensure water security in the basin.

Therefore, it can be seen that it is possible to evaluate and quantify the level of water security and apply a set of indicators in the assessment, which serves as a basis for proposing measures to ensure the water security. Regarding Viet Nam's situation, although numerous issues on water security have arisen nationwide in general and in Quang Ngai in particular. Viet Nam has a few studies on water security, even in the State's legal documents, especially in the context of climate change. From that perspective, this study was conducted to assess the level of water security in the context of climate change in Quang Ngai through a set of indicators, which also serves as a basis for proposing and selecting response solutions.

2. Research method and used data

2.1. Method of selection and calculation of water security indicators

2.1.1. Preliminary index selection

Through a literature review and based on the UN-Water's definition of water security, the study identified the factors that need to be achieved to ensure water security, including: (i) The community has enough water for domestic use and serving socio-economic development; (ii) Guaranteed water quality, using clean water; (iii) Not affected by water-related disasters; (iv) All of the above factors must be maintained in the condition that the ecosystem is still preserved, the community lives in peace, and the political system is stable.

The study has preliminarily identified indicators to assess water security (before consulting experts) including 04 main groups of indicators showing 4 aspects of UN-Water's water security concept, specific:

(1) Ecosystem indicator group: Ecosystem conditions are still preserved;

(2) Indicator group of Natural disasters and water-related hazards: Water resources are not affected by water-related disasters;

(3) Socio-economic indicators group: Ensuring enough water for domestic use and serving socio-economic development;

(4) Water resources and people: Water quality is guaranteed, using unpolluted water. Each main group of indicator includes sub-indicators, there are 27 sub-indicators in total. This set of indicators will be consulted by experts to choose appropriate indicators.

2.1.2. Applying the expert method to choose the right indicator

The method of expert consultation was selected to determine the set of indicators on water security [3].

The process of selecting water security indicators was carried out specifically through 8 steps, categorized into 3 stages including before, during and after consultation as follows:

- Stage before expert consultation:

+ Step 1: Select a group of experts related to the consultation process. The number of experts was 10 people (including scientists and managers working on the relevant research content from the Institute of Hydrology, Meteorology and Climate Change, Institute of Water Resources Science, Ha Noi University of Natural Resources and Environment, Department of Water Resources Management, Department of Climate Change, Viet Nam Meteorological and Hydrological Administration and Department of Natural Resources and Environment in Quang Ngai Province).

+ Step 2: Develop indicators of water security based on literature review and conformity assessment.

+ Step 3: Develop questions to consult experts and relevant scientists.

- Stage of expert consultation:

+ Step 4: Conduct the first round consultation. An expert consultation meeting was held. Experts were asked to assess the level of consensus with the given set of indicators. The consensus level is ranked from 1 - 5 as follows: (i) Very irrelevant; (ii) Not relevant; (iii) More or less relevant; (iv) Relevant; and (v) Very relevant.

+ Step 5: Analyze the data from round 1. After collecting data by Delphi method, each group of authors selected different rules to synthesize and analyze results, two commonly used rules are KAMET and DPSIR framework (Kendal value was used to assess the appropriateness of the indicators that need being consulted. The level of consensus was scored according to the thresholds 0.0 - 0.1; > 0.1 - 0.3; > 0.3 - 0.5; > 0.5 - 0.7; > 0.7 - 1.0, which means very weak; weak; moderate; strong; very strong consensus, with respectively).

Based on the evaluation results, the Median values (Md); Quartile deviation (Q); Mean (qi) and Variance (%) according to KAMET rule were calculated.

+ Step 6: Apply the method of expert consultation in round 2. The questionnaire was sent to experts in round 2 to consult the level of consensus or stability in the answers of the members. Indicators were not used when an expert could not answer the questions with certainty [2].

- Stage after expert consultation:

+ Step 7: Analyze data in round 2. After the data was collected in round 2, the results were analyzed. The analysis was based on the above-mentioned KAMET rule. The value of Median (Md); Quartile deviation (Q); Mean (qi) and Variance (%) were recalculated at this step.

In case all questions were approved or rejected; or the Mean value was higher than 3.5 and the Variance value was less than 15%, the method of expert consultation finalized [2].

Step 8: Analyze and summarize the results. Based on the results from the above steps, the final indicators were selected to perform the calculation.

2.1.3. Determination of water security indicator

The set of water security indicators for Quang Ngai province includes sub-indicators, the value of the water security indicator is calculated by the formula shown below:

$$\mathrm{ANN} = \frac{1}{\mathrm{n}} \sum_{i=1}^{n} ANNi$$

where:

ANN: Water Security Indicator

ANNi: Ith sub-indicator; n is the total number of indicator groups.

The water security hierarchy is divided by regular intervals (Table 1).

Table 1. Water security classification applied to Quang Ngai province

Range	Classification
0 < ANN ≤ 0.2	Very low water security
0.2 < ANN ≤ 0.4	Low water security
0.4 < ANN ≤ 0.6	Moderate water security
0.6 < ANN ≤ 0.8	High water security
0.8 < ANN ≤ 1	Very high water security

2.2. Data used for the calculation

The used data for the calculation of this study included:

- The climate change scenario of Quang Ngai province was extracted from the scenario of climate change and sea level rise for Viet Nam updated in 2016 by the Institute of Meteorology, Hydrology and Climate Change [1]. The scenario was developed according to two scenarios of greenhouse gas concentration, namely the medium scenario RCP4.5 and the high scenario RCP8.5.

- The climate data measured up to 2014 were used for model calibration and comparison of calculated results with actual measured data. This data was from the following stations: An Chi, Ba To, Ly Son, Quang Ngai, and Son Giang.

- The natural, economic and social data were analyzed from the results of surveys, investigation and related collected documents.

3. Results and Discussion

3.1. A set of indicators on water security

The final set of indicators after expert consultation includes 04 main indicators and 17 sub-indicators. These indicators have closely followed the UN–Water definition as presented in the Introduction section. Specifically, the indicators were described and interpreted according to the calculation formulas as Table 2.

Table 2. The indicators on water security index for the whole year at present

Main indicators	Sub-indicators
Ecosystem	Pollution status
	Water resource pressure
	Water resource indicators
	Green coverage ratio
	Coefficient of ecosystem degradation
Water-related disasters and hazards	Flood frequency
	Number of days of drought
	Portion of flooded area
	Average annual precipitation
	Average annual temperature
Socio-economy	Cost of water and sanitation
	Payment for water and wastewater services
Water resources and people	Water scarcity coefficient
	Coefficient of change of water coming to river basin
	Water extraction coefficient
	Population with access to clean water
	Percentage of people having access to a standard wastewater collection system

3.2. Application of a set of indicators to evaluate the effectiveness of measures to ensure water security in Quang Ngai

3.2.1. Analyze, evaluate and select suitable measures

Among the above-mentioned 17 indicators of water security, there are 05 indicators that cannot be affected, namely: flood frequency, number of days of drought, rate of flooded area, the average annual precipitation and the average annual temperature. The remaining 12 indicators can be improved by measures and hence the selection of prioritized measures to ensure water security in Quang Ngai should focus on improving these 12 indicators. On that basis, the study proposed measures to prioritize implementation until 2030, with a vision to 2050 as follows:

- Measures to maintain and expand the forest area in order to achieve the goal of maintaining the current forest coverage:

+ Focus on investigation, planning, zoning and protection of existing forest areas, reducing forest degradation and promoting new plantation, ensuring the improvement of the ecological environment. In the near future, in addition to the management and protection of special-use forests, the province needs to mainly develop protection forests and production forests; renew production plans and implement measures to develop planted forests, ensuring a sufficient number of laborers to participate in afforestation.

+ Implement synchronously measures on science and technology and human resources as well as policies to attract investment; encourage all economic sectors to participate in forest development effectively; strengthening the capacity of state management, administrative reform, as well as clearly defining the functions and tasks of managing forestry activities in the locality.

+ Continue to maintain and promote the investment policy to develop concentrated material afforestation areas, in which clearly define the rights to use land and forest resources for forestry companies, forestry enterprises, other economies and households, ensuring long-term production investment. Land is allocated to each household for use, and a part of the area is allocated for agro-forestry production, ensuring for the planting, maintenance and protection of forests. Communes with special difficulties when allocating land to households must allocate capital and investment in techniques and seedlings so that people can feel secure in forestry development.

- Measures for wastewater management and treatment to achieve the goal of 100% of wastewater is collected and treated before being discharged into lakes, rivers, and streams:

+ Focus on monitoring and controlling key waste sources. Continue to invest in and build a monitoring system to monitor continuously, automatically and virtually the water discharge activities of large wastewater discharge facilities that are at risk of polluting water sources.

+ Strictly control projects, works, industrial, agricultural, medical, craft villages, mining zones and clusters... with strict regulations on environmental impact assessment, compliance with the regulation of synchronously constructing the wastewater discharge system with the non-discrete drainage system, avoiding increased pollution and having a policy to increase discharge fees for waste dischargers. Specifically, it is necessary to thoroughly implement Decree No. 53/2020/ND-CP dated May 5, 2020 of the Government on regulations on environmental protection fees for wastewater, which have new articles on the subject of charge as well as the fee level. Particularly, according to the regulation the organizations, households and individuals that discharge wastewater are the payers for environmental protection fees for wastewater. In case organizations, households, and individuals discharge wastewater into the centralized wastewater treatment system and pay for wastewater treatment services to the managing and operating unit of that centralized wastewater treatment system following the service price mechanism, the managing and operating unit will be the one to pay the environmental protection fee for wastewater.

+ Actively propagate to raise the awareness of water saving and water reuse in order to reduce the amount of direct wastewater, in parallel with the awareness of environmental protection.

- Measures to ensure the population of Quang Ngai is at an appropriate level in both quantity and structure to achieve the goal of maintaining the current fertility rate: In fact, the fertility rate in Quang Ngai is decreasing sharply, particularly, the rate of delivering the third child tend to decrease continuously from 2015 to present, with the current value of 11.63%. From that perspective, it is necessary that the province urgently changes its communication, advocacy, and planning strategies, in line with the focus of population work in the new situation. Therefore, Quang Ngai must have its own plan on population work, in which the most important thing is to shift the focus of policy from family planning to population and development, comprehensively solving problems of population size, structure, quality, and distribution in relation to socio-economic development, and ensuring national defense and security of the province.

- Measures to ensure water demand for daily life, agriculture, industry, and services to achieve the goal of ensuring 100% demand in terms of quantity and quality:

+ Regarding domestic water supply: focus on upgrading and repairing concentrated rural clean water supply works. Particularly, the priority i s given to the repair of clean water works in rural areas and areas contaminated with alum and lacking clean water. The pipeline system is upgraded, with modern filtering technology, ensuring that the water meets the standards to be supplied to the people. At the same time, there is a plan to protect and manage clean water supplying works. It is necessary to improve the efficiency of using clean water works in rural areas to ensure the supply of clean water to the people. In the long term, there are incentive mechanisms and policies to encourage enterprises to invest in rural clean water supply systems according to Decree No. 57/2018/ND-CP dated April 17, 2018 of the Government on mechanisms and policies to encourage enterprises to invest into agriculture and rural areas and Decision No. 131/2009/QD-TTg dated November 2, 2009 of the Prime Minister on a number of policies to encourage investment and management and exploitation of rural clean water supply works.

+ About ensuring water for agriculture (especially in the dry season): The first important measure to avoid burden on the irrigation water in the dry season is to appropriately rearrange the structure of crops, livestock, actively change the structure of crops (from rice to upland crops that use less water in areas with water shortages), and not to produce in areas where water supply is not guaranteed during the crop season. It is necessary to conduct research and apply new techniques and technologies for water-saving irrigation, particularly application of modern irrigation technologies such as sprinkler irrigation, drip irrigation to supply the right amount of water for growth and development. In addition, water resources should be prioritized for critical periods of productivity, and be limited in other periods. The construction of irrigation works should be complete to promptly put them into use and serve production. It is important to monitor regularly the meteorological and hydrological forecasts, weather trend and inventory of water sources to have a reasonable water use plan.

+ According to the calculation, the demand for water use in the industry now and in the future up to 2030 will be fully satisfied.

+ Regarding water demand for tourism and services, in fact, in Quang Ngai, the area with the highest water shortage is Ly Son district (both for domestic and tourism purposes). In order to meet the demand for fresh water in the future, it is necessary to have solutions to provide sustainable fresh water to the island, especially to conserve natural groundwater. Specifically, in addition to strictly protecting groundwater sources, it is very important and urgent to research and invest in one of the two following technological solutions: a purifier of seawater into fresh water and installation of a system to bring fresh water from the mainland to the island. However, each solution has advantages and disadvantages. Regarding utilization of the sea water purifier into fresh water, although the initial investment is not significant, the process of operation and maintenance is quite expensive. In terms of the investment into the water supply pipeline system from the mainland to island, although

the initial investment is high, it is less expensive to operate. Therefore, local authorities need to calculate specifically to both save money and ensure the water demand for people and tourists.

- The overall solution to raise incomes and improve people's lives in order to achieve the goal of reaching USD 4,400/person/year by 2030, with an orientation to reach USD 33,400/person/year by 2050 according to the Resolution of the 20th Party Congress of Quang Ngai Province:

+ Continue to promote administrative reform, particularly improving the ranking of indicators on administrative reform, efficiency in public governance and administration, and provincial competitiveness. In addition, it is necessary to promote tourism development, gradually becoming a spearhead economic sector as well as foster the socio-economic development and sustainable poverty reduction in mountainous districts.

+ Mobilize and effectively use resources to promote the industrial development, in which, the proportion of high-tech industries must be increased and the attraction and development of supporting industries and non-oil industries must be fostered. Besides, it is important to comprehensively review mechanisms and policies, consider renewing investment promotion methods and reform the operating model of economic zones.

+ Harmonious and sustainable development among economic regions.

3.2.2. Calculation results of water security indicators after applying measures

After proposing the above-mentioned measures, the study conducted a recalculation of the water security indicators to evaluate the effectiveness of the measures. The evaluation results are as follows:

In case the measures mentioned in Section 3.2.2 are implemented synchronously and effectively, the water security indicators in all districts and the whole province will be increased with the difference ranging from 0.08 to 0.04. Specifically, the water security indicators in 03 districts of Ly Son, Tay Tra and Tra Bong improved with a difference of 0.08. Besides, Ba To, Duc Pho, Minh Long, Mo Duc, Nghia Hanh, Son Ha, Tu Nghia districts reached the difference of 0.07. Overall, water security of the the whole province was improved from the average level of 0.55 to the high level of 0.62 (the difference of 0.07) (Table 3).

Table 3. Comparison of water security in case of application of measures

No.	District	Water security indicators without measures	Water security indicators with measures	Difference
1	Ba To	0.59	0.66	0.07
2	Binh Son	0.53	0.57	0.04
3	Duc Pho	0.53	0.59	0.07
4	Ly Son	0.44	0.52	0.08
5	Minh Long	0.58	0.65	0.07
6	Mo Duc	0.52	0.59	0.07
7	Nghia Hanh	0.57	0.64	0.07
8	Son Ha	0.59	0.66	0.07
9	Son Tay	0.57	0.63	0.06
10	Son Tinh	0.55	0.61	0.06
11	Tay Tra	0.57	0.65	0.08
12	Quang Ngai city	0.57	0.61	0.04
13	Tra Bong	0.58	0.65	0.08
14	Tu Nghia	0.55	0.62	0.07
	PROVINCE	**0.55**	**0.62**	**0.07**

It can be seen from the table that water security of all 10 districts changes from medium to high level, particularly: Ba To (from 0.59 to 0.66), Minh Long (from 0.58 to 0.65), Nghia Hanh (from 0.57 to 0.64), Son Ha (from 0.59 to 0.66), Son Tay (from 0.57 to 0.63), Son Tinh (from 0.55 to 0.61), Tay Ninh Tra (from 0.57 to 0.65), Quang Ngai city (from 0.57 to 0.61), Tra Bong (from 0.58 to 0.62) and Tu Nghia (from 0.55 to 0. 62) (Figure 1).

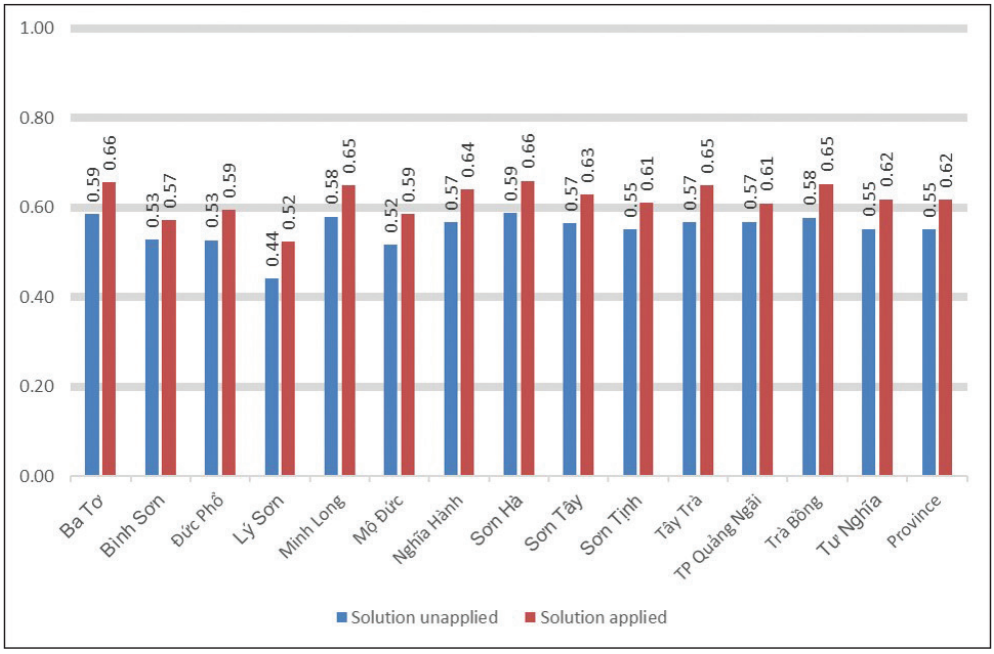

Figure 1. Comparison of water security indicators with and without solution

4. Conclusion

Based on the results of the water security assessment using a set of indicators, the following measures have been proposed to improve the state of water security in Quang Ngai:

(1) Measures to maintain and improve the forest area in order to achieve the goal of maintaining the current forest coverage;

(2) Measures for wastewater management and treatment to achieve the goal of 100% of wastewater is collected and treated before being discharged into water bodies;

(3) Measures to ensure the population of Quang Ngai is at an appropriate level in both quantity and structure to achieve the goal of maintaining the current fertility rate;

(4) Measures to ensure water demand for daily life, agriculture, industry and services to achieve the goal of ensuring 100% demand in terms of quantity and quality;

(5) The overall solution to raise incomes and improve people's lives in order to achieve the goal of reaching USD 4,400/person/year by 2030, with an orientation to reach USD 33,400/person/year by 2050 according to the Resolution of the 20th Party Congress of Quang Ngai Province.

Once all above-mentioned solutions are implemented synchronously and effectively, the water security indicator will be significantly improved, from medium to high level (0.55 to 0.62), reaching a difference of 0.07.

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