

**MINISTRY OF RESOURCES AND ENVIRONMENT
VIETNAM INSTITUTE OF METEOROLOGY
HYDROLOGY AND CLIMATE CHANGE**

BUI DUC HIEU

**RESEARCH ON WATER SECURITY UNDER IMPACT
OF CLIMATE CHANGE – APPLICATION TO QUANG NGAI
PROVINCE**

Major: Climate change

Code: 9440221

**SUMMARY OF DOCTORAL THESIS IN
CLIMATE CHANGE**

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**LIST OF SCIENTIFIC WORKS OF THE AUTHOR
RELATED TO THE THESIS**

1. Bui Duc Hieu, Ta Dinh Thi, Huynh Thi Lan Huong, Dao Minh Trang (2018), “ Water security and challenges to water security in Vietnam ”, Journal of Climate Change Science , No. 8 - December 2018.
2. Huynh Thi Lan Huong, Bui Duc Hieu, Nguyen Thi Lieu, Quang Thinh Dang, Nguyen Dinh Hoang (2020), " Assessment of climate change on surface water resources Risks for Quang Ngai province " , Disaster Advances , Vol. 13 (7) July (2020).
3. Bui Duc Hieu, Huynh Thi Lan Huong, Nguyen Thi Lieu, Dang Quang Thinh, Be Ngoc Diep (2020), “ Research and assessment of risks to surface water resources due to climate change; applied to Quang Ngai province " , Journal of Meteorology and Hydrology , March 2020 issue.
4. Bui Duc Hieu , Ta Dinh Thi , Huynh Thi Lan Huong , Dang Quang Thinh , Nguyen Van Dai , Nguyen Thi Lieu , Nguyen Anh Tuan (2021), " Assessment of water security in Quang Ngai province in the context of climate change " , Journal of Hydrometeorology , No. 729, pp. 79-90. DOI: 10.36335/VNJHM.2021(729).79-90.
5. Bui Duc Hieu, Ta Dinh Thi, Nguyen Dang Huy Anh, Nguyen Anh Tuan (2021), “Effectiveness of measures to improve water security in Quang Ngai province in the context of climate change”, Journal of Climate change Science , No 19/2021 , pages 1-9.

INTRODUCTION

1. Necessity

Water is an essential part of life, a basic need and foundation for ecosystem and social activities, so water plays an important role in contributing to conflicts that can threaten human and environmental security [35]. Water security is not simply about “accessing water appropriately” – it is about sustainable access to water in an appropriate quantity and quality to meet the needs of survival, production and survival production, socio-economic development and protection of ecosystems.

Recently, water security in the world in general and Vietnam in particular is under threat due to the impact of climate change. In which, Quang Ngai is one of the provinces most heavily affected by climate change and sea level rise.

Facing that situation, many research topics and projects in the field of water resources, environment, climate change in Quang Ngai province have been carried out in order to contribute to the local management. To contribute more scientific and practical bases for the planning, exploitation and management of water resources for sustainable economic, social development and environmental protection in the province in the changing conditions. On climate change, the thesis topic "Research on water security under the impact of climate change - applied to Quang Ngai province" is very necessary, topical and scientific.

2. Research objective

(i) Determine the factors affecting water security, thereby developing a method for assessing water security at the provincial level.

(ii) Assess current and future water security in Quang Ngai province (with and without considering to climate change conditions).

(iii) Propose solutions to ensure and enhance water security in Quang Ngai province in the context of climate change.

3. Objects and scope of research

The research object of the thesis is the state of water security in the current conditions and in the context of climate change. The thesis focuses on researching methods to assess water security, applying calculations to Quang Ngai province, thereby determining effective and feasible solutions to ensure water security in the province.

Spatial scope: districts and cities of Quang Ngai province and the whole of Quang Ngai province.

Time range: the base period is determined from 1986 - 2005, the current period is the data collected from the years 2017 to 2020 to serve the calculation, the future period is determined with two periods 2046 - 2065 and 2080 - 2099.

Scope of research and calculation factors related to water security: quantity of surface water, water-related disasters and part of socio-economic factors.

4. Research question and thesis statement

4.1. Research questions

- How to assess the state of water security and the impact of climate change on water security?
- What is the level of water security in Quang Ngai province under current and future conditions (with and without considering to climate change)?
- What solutions are there to ensure and enhance water security for Quang Ngai province in the context of climate change?

4.2. Thesis statement

- Quang Ngai is currently facing the risk of water insecurity;
- Water security in Quang Ngai at present and in the future (with and without considering to climate change conditions) can be quantified through a set of indicators;

- It is possible to apply structural and non-structural solutions to ensure and improve water security in general and for Quang Ngai province in particular.

5. Research Methods

- Data collection.
- Analysis, statistics, synthesis.
- Delphi.
- Experts.
- Mathematical model of hydrology, hydrodynamic.
- Calculation of water demand for industries.
- GIS technology.

6. New contributions of the Thesis

- Develop a set of indicators for assessing provincial water security in the context of climate change.

- Assess current and future water security in Quang Ngai province (with and without considering to climate change scenarios); also compares the difference between periods and conditions that take into account climate change with conditions that do not take into account climate change

- Propose solutions to ensure and enhance water security for Quang Ngai province; calculations to demonstrate the effectiveness of applying these solutions.

7. Scientific and practical significance

7.1. Scientific significance

Develop a scientific basis and methodology to assess water security in Quang Ngai province.

Proposed solutions to ensure water security in Quang Ngai province.

7.2. Practical significance

Proposed solutions to ensure water security in Quang Ngai province.

8. Structure of thesis

Besides the introduction, conclusion and recommendations, the content of the thesis consists of following three chapters:

Chapter 1. Overview of research on water security.

Chapter 2. Research methodology and data on water security in the context of climate change.

Chapter 3. Assessment water security and suggest solutions to ensure, enhance water security for Quang Ngai province.

CHAPTER 1: OVERVIEW OF RESEARCH ON WATER SECURITY

1.1. Some concepts of water security in the world

Committee on Water of the United Nations (UN-Water) [42] introduced a complete definition of water security as: when a community of people meet the country fundamentally in terms of both quantity and quality for life maintenance, socio-economic development, but not affected by water pollution and water-related disasters; and it is important that all the factors mentioned above must be maintained in the condition that the ecosystem is still preserved, life is peaceful and politically stable.

1.2. Studies in the world on water security in the context of climate change

Research by Hassan T.A. and nnk (2019) [30] on urban water security - in which the assessment framework on Water Security includes four main groups of indicators: Drinking water and people, ecosystems, climate change and water-related hazards, and socioeconomic factors. These indicators allow further analysis of the interrelationships between urbanization and water security, as well as between socioeconomic indicators.

Ludwig R. [37] has studied regional-scale climate change-induced water security in the Mediterranean, which focuses on three factors: (i) climate change and hydro-ecological factors literature related to hazardous factors such as floods and droughts; (ii) water economy, including virtual water economy; and (iii) social and political factors and factors that cause conflict or threaten human security.

1.3. Studies in Vietnam on water security

There are a number of studies on water security of Vietnam have been carried out, in which the Study on Water Security for Sustainable Development of the Ma River Basin by Dr. Nguyen Thi Mui [9] is one of the outstanding researches and has a goal close to the goal of this thesis. Research established a set of water security indicators in Vietnam's river basin including 18 indicators divided into 6 groups of water security indicators.

1.4. Studies related to water security in Quang Ngai

- In 2010, the Institute of Meteorology, Hydrology and Environment [19] implemented the project "Assessment of impacts of climate change on water resources and adaptation measures".

- In 2015, Huynh Thi Lan Huong [7] studied on assessing the impact of climate change on Quang Ngai province and proposing response solutions.

1.5. Thesis research diagram

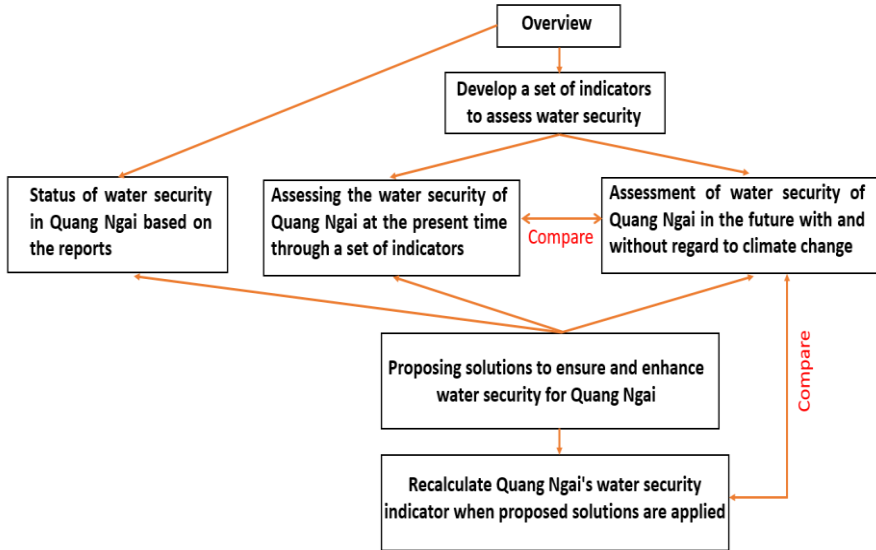


Figure 1.2. Thesis research diagram

CHƯƠNG 2. METHODOLOGY AND DATA RESEARCH WATER SECURITY IN THE CONTEXT OF CLIMATE CHANGE

2.1. Methods of assessing water security

2.1.1. Structure of the Water Security Assessment Indicator

Based on the review of documents in Chapter 1 and the definition of water security of UN-Water, the thesis has built a set of indicators to assess water security including 04 main groups of indicators showing 4 aspects. on the concept of water security to consult experts, specifically:

- (1) Ecosystem indicators group: ecosystem conditions are still preserved;
- (2) Indicators group of Water-related disasters and hazards: Water resources are not affected by water-related disasters;
- (3) Socio-economic indicators group: ensuring enough water to use for life, daily activities, eating and serving socio-economic development;

(4) Water resources and people: water quality is guaranteed, using unpolluted water.

Each main indicators group will include sub-indicators. There are total 27 sub-indicators. This set of indicators will be consulted by experts to choose the right indicator.

2.1.2. Methods of analysis and selection of water security indicators

The method of consulting experts is the method of choice to determine the set of indicators on water security. The process of selecting water security indicators is carried out specifically through 8 small steps, 3 stages before, during and after consultation. The obtained results include 04 main indicators and 17 sub-indicators to calculate water security as shown in Table 2.5.

Table 2.5. The indicators for calculating water security

Main indicators	Final indicators after consulting experts
Ecosystem	Pollution status
	Water resource pressure
	Water resource indicators
	Green coverage ratio
	Coefficient on ecosystem degradation
Water-related disasters and hazards	Flood frequency
	Number of days of drought
	Rate of flooded area
	The average annual precipitation
	The average annual temperature
Socio-economy	Cost of water and sanitation
	Payment for water and wastewater services

Main indicators	Final indicators after consulting experts
Water resources and people	Water scarcity coefficient
	The coefficient of water change to the river basin
	Water extraction coefficient
	Population with access to clean water
	Percentage of people who have access to a standard wastewater collection system

2.1.3. Determination of indicators and classification of water security values

The set of water security indicators for Quang Ngai province includes sub-indicators (Table 2.5), the value of the water security indicator is calculated by the formula shown below:

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

In which:

ANN: Water Security Indicator

ANN_i : i^{th} sub-indicator; n is the total number of indicator groups.

Values of water security range from [0-1] as they are determined from standardized indicators, so the value of water security also ranges from [0-1]. Specifically:

Table 2.7. 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. Methods of mathematical modeling

The thesis uses the MIKE model set copyrighted by the Institute of Meteorology, Hydrology and Climate Change, including hydrological and hydraulic mathematical models to calculate the data to serve the construction of the indicators to assess the impact of climate change on surface water resources. Specifically:

- Model MIKE-NAM
- Model MIKE11
- CROPWAT.

2.3. Method of calculating water demand for sectors

The demand for irrigation water for agriculture is used CROPWAT model (as shown above). Demand for irrigation water for domestic, industrial and service sectors is based on statistical analysis methods based on water supply criteria. Specifically:

- Calculation of water demand for industry: according to TCXDVN 33:2006 "Water supply - Pipeline network and standard design works" issued by the Ministry of Construction in 2006.

- Calculation of water demand for daily life: according to TCXDVN 33:2006 "Water supply - Pipeline network and standard design works" issued by the Ministry of Construction in 2006.

- Calculation of water demand for services: to calculate the demand for water use for industrial and service activities in urban areas, the thesis uses the norms of water supply for industrial and service activities in urban areas according to the following criteria: TCXDVN 33:2006 of the Ministry of Construction, the demand for water use for industrial and service activities in urban areas is taken as 10% of the demand for water use for daily life.

2.4. Data used in the thesis

2.4.1. Meteorological and hydrological data

Daily rainfall data at rain gauge stations and daily water discharge at Son Giang and An Chi hydrological stations are used to calibrate and verify the MIKE-NAM hydrological model.

2.4.2. Data of climate change scenarios

The thesis uses the results of simulated temperature and rainfall at Quang Ngai, Ba To and Ly Son meteorological stations according to the scenarios RCP4.5 and RCP8.5 developed by the Institute of Meteorology, Hydrology and Climate Change implemented in accordance with the scenario of climate change and sea level rise for Vietnam announced by the Ministry of Natural Resources and Environment in 2016.

These data are used to calculate water resources in Quang Ngai province under climate change scenarios (RCP4.5 and RCP8.5).

2.4.3. Socio-economic data

The thesis uses a number of documents and socio-economic data of Quang Ngai province, including socio-economic planning, construction, transportation, water resources and Provincial Statistical Yearbook.

2.4.4. Survey data

In order to provide information for the assessment of water security through a set of indicators, the thesis has conducted a survey to collect data and information from the study area.

2.5. Information about the study area

2.5.1. General information

Quang Ngai province is located in the coastal plains, hills and low valleys with an average annual temperature of 25.5 - 26.5°C, in the high mountains below 500m, with an average annual temperature of 23.5 - 25, 5°C, high mountain areas from 500 - 1,000 m have an average annual

temperature of 21 - 3.5°C, in mountainous areas over 1,000 m, the annual average temperature can be below 21°C.

2.5.2. Characteristics of water resources in Quang Ngai province

The annual surface water resource of Quang Ngai province is about 14 billion m³, mainly from rain water stored in 4 main river systems. The largest flow usually occurs in October - December every year, the driest month usually occurs in May - August every year. Currently, in Quang Ngai province, 723 irrigation works for agricultural production have been put into management and operation (including: 123 water reservoirs; 464 surge dams, 06 salt-prevention dams and 130 pumping stations).

2.5.3. Current status of water security in Quang Ngai

- In general, during the dry season months, the amount of water that can be exploited is not enough to meet the water demand. The months that are often in short supply are February-August, especially in Son Tinh district and Quang Ngai city, the water shortage occurs in all months in the dry season, even the shortage occurs in December (2020).

- Shortage of mining system of surface water: 230/671 works exploitation of surface water was built in 1989 or earlier, but because investors are not synchronized and executed by hand. Therefore, there are 108 damaged and degraded buildings need to be repaired and upgraded soon; of which 28 reservoirs are severely damaged or degraded, which should be prioritized for repair and upgrading.

- Quality and evolution of surface water: monitoring results in 2019 at some points show that areas with serious water pollution in the province include 7 areas (Quang Ngai city 03 areas, Mo Duc, Duc Pho, Binh Son, Son Tinh 01 area each). The cause of pollution is that these locations receive wastewater in production, daily life and livestock activities of people in the province.

2.5.4. Past Trends and Climate Change Scenario in Quang Ngai

- Trends of climate change in the past in Quang Ngai province: all indicators of annual rainfall, annual mean maximum temperature, annual mean minimum temperature, annual absolute maximum temperature, and annual temperature The year's absolute minimum, the number of hot days of the year, the largest single-day rainfall and the largest five-day rainfall have all tended to increase in recent years.

- Climate change scenario of Quang Ngai province, scenarios: change in temperature, precipitation, maximum one-day rainfall (Rx1day), precipitation for 5 consecutive days with the largest (R5xday) in Quang Ngai will likely increase over the base period in the whole province, scripted RCP8.5 extreme scenarios than RCP4.5. Sea level rise scenarios in early 50th century slower rate than 50 years of the century (about 13-25 cm). Flood risk change scenario: based on the calculation results under the climate change scenario, the largest flooded area is in districts and cities in Quang Ngai province in all periods of the climate change scenario. After RCP4.5, all increased compared to the baseline period (1986 - 2005) with an increase of 21.0 - 2,214 ha.

CHAPTER 3. WATER SECURITY ASSESSMENT AND PROPOSED SOLUTIONS TO GUARANTEE , ENHANCE WATER SECURITY FOR QUANG NAI

3.1. Assessment of water security in Quang Ngai province

3.1.1. Impact of climate change on water resources and water demand for Quang Ngai

- Impact of climate change on flow: in the future, under the impact of climate change, annual flow and flood season will tend to increase while dry season flow tends to decrease compared to the previous period in all areas of Quang Ngai province. Regarding the impact of climate change on

surface flows: in all districts and cities of Quang Ngai province, in the future under the impact of climate change, annual flow and flood season flow will be tending to increase, while the flow in the dry season tends to decrease compared to the baseline period.

- Impact of climate change on water demand:

- + For agricultural irrigation demand: most of the future periods of the two scenarios RCP4.5 and RCP8.5 will see a sharp increase in agricultural irrigation demand compared to the baseline period in most districts and cities of Quang Ngai province.

- + For industrial water demand: many districts and cities of Quang Ngai province have industrial land areas expected to increase significantly in 2020 compared to the current land use status in 2015, therefore, the demand for industrial land use will increase significantly. Industrial water also increased sharply. Particularly some districts do not have industrial land as Ly Son, Minh Long, Shanxi, west Tea; or in some districts with insignificant increase in industrial land area like Tra Bong and unchanged like Tu Nghia, the demand will not increase.

- + For the impact of climate change on water demand for daily life: According to the results of the future population forecast of Quang Ngai province, the urban and rural population of districts and cities has increased quite a lot compared to the status quo in 2017, so it will also be affected by climate change.

- + Regarding the impact of climate change on water demand for other types of surface water use (industrial activities, urban services): most of the future periods will have water demand for industrial and service activities in urban areas increased compared to the current situation in 2017, although the increase was not much, the increase was quite large.

3.1.2. Calculating water security for Quang Ngai

3.1.2.1. Results of Quang Ngai water security at the present time

- The water security indicator for the whole year for the current time of the whole Quang Ngai province is assessed at a high level (0.61).

Table 3.10. Water security indicator for the whole year at the present time

NO	District	Ecosystem	Water-related disasters and hazards	Socio-economic	Water resources and people	Water security indicator
1	Ba To	0.81	0.92	0.1304	0.74	0.65
2	Binh Son	0.66	0.91	0.0586	0.75	0.60
3	Duc Pho	0.65	0.77	0.1488	0.75	0.58
4	Ly Son	0.45	0.86	0.1222	0.41	0.46
5	Minh Long	0.78	0.91	0.1241	0.73	0.64
6	Mo Duc	0.68	0.74	0.1709	0.75	0.59
7	Nghia Hanh	0.83	0.84	0.1760	0.76	0.65
8	Son Ha	0.90	0.92	0.1122	0.71	0.66
9	Son Tay	0.83	0.92	0.0503	0.68	0.62
10	Son Tinh	0.78	0.82	0.1179	0.75	0.61
11	Tay Tra	0.76	0.92	0.1073	0.65	0.61
12	Quang Ngai City	0.68	0.86	0.0657	0.76	0.59
13	Tra Bong	0.79	0.92	0.1363	0.72	0.64
14	Tu Nghia	0.75	0.79	0.1569	0.75	0.61
	ALL PROVINCE	0.74	0.86	0.1198	0.71	0.61

- The dry season water security indicator calculated for the present time of the whole Quang Ngai province is assessed at the average level (0.59), 0.02 lower than the whole year water security indicator.

Table 3.11. Current dry season water security indicator

NO	District	Ecosystem	Water-related disasters and hazards	Socio-economic	Water resources and people	Water security indicator in dry season
1	Ba To	0.80	0.82	0.1304	0.73	0.62
2	Binh Son	0.65	0.84	0.0586	0.74	0.57
3	Duc Pho	0.61	0.66	0.1488	0.65	0.52
4	Ly Son	0.44	0.93	0.1222	0.39	0.47

NO	District	Ecosystem	Water-related disasters and hazards	Socio-economic	Water resources and people	Water security indicator in dry season
5	Minh Long	0.78	0.82	0.1241	0.73	0.61
6	Mo Duc	0.65	0.69	0.1709	0.72	0.56
7	Nghia Hanh	0.82	0.77	0.1760	0.75	0.63
8	Son Ha	0.90	0.84	0.1122	0.70	0.64
9	Son Tay	0.84	0.83	0.0503	0.68	0.60
10	Son Tinh	0.77	0.78	0.1179	0.74	0.60
11	Tay Tra	0.77	0.83	0.1073	0.65	0.59
12	Quang Ngai City	0.68	0.79	0.0657	0.76	0.57
13	Tra Bong	0.80	0.84	0.1363	0.72	0.62
14	Tu Nghia	0.75	0.77	0.1569	0.75	0.61
	ALL PROVINCE	0.73	0.80	0.1198	0.69	0.59

- The flood season water security indicator calculated for the present time of the whole Quang Ngai province is assessed at the average level (0.56), lower than the whole year water security indicator of 0.05.

Table 3.12. Indicator of water security in flood season at the present time

No	District	Ecosystem	Water-related disasters and hazards	Socio-economic	Water resources and people	Water security indicator in flood season
1	Ba To	0.87	0.74	0.1304	0.74	0.62
2	Binh Son	0.68	0.73	0.0586	0.76	0.56
3	Duc Pho	0.74	0.70	0.1488	0.76	0.59
4	Ly Son	0.62	0.67	0.1222	0.41	0.45
5	Minh Long	0.88	0.72	0.1241	0.73	0.62
6	Mo Duc	0.62	0.66	0.1709	0.76	0.55
7	Nghia Hanh	0.63	0.70	0.1760	0.76	0.57
8	Son Ha	0.70	0.76	0.1122	0.71	0.57
9	Son Tay	0.80	0.74	0.0503	0.68	0.57
10	Son Tinh	0.58	0.69	0.1179	0.75	0.54
11	Tay Tra	0.79	0.75	0.1073	0.65	0.57
12	Quang Ngai City	0.48	0.74	0.0657	0.76	0.51

No	District	Ecosystem	Water-related disasters and hazards	Socio-economic	Water resources and people	Water security indicator in flood season
13	Tra Bong	0.88	0.74	0.1363	0.72	0.62
14	Tu Nghia	0.56	0.65	0.1569	0.76	0.53
	ALL PROVINCE	0.70	0.71	0.1198	0.71	0.56

3.1.2.2. Results of Quang Ngai water security in the future period (2046 - 2065) with and without considering to climate change

- Considering the whole province, the water security indicator in the future period excluding climate change is on average (0.60), lower than the current water security indicator, but the difference is only 0.01 (0.61 vs. 0.60) minimum.

Table 3.13. Future water security regardless of climate change

NO	District	Ecosystem	Water-related disasters and hazards	Socio-economic	Water resources and people	Water security for the whole year
1	Ba To	0.77	0.92	0.1277	0.74	0.64
2	Binh Son	0.64	0.91	0.0582	0.75	0.59
3	Duc Pho	0.63	0.77	0.1488	0.75	0.58
4	Ly Son	0.44	0.86	0.1195	0.41	0.46
5	Minh Long	0.75	0.91	0.1208	0.73	0.63
6	Mo Duc	0.67	0.74	0.1713	0.75	0.58
7	Nghia Hanh	0.81	0.84	0.1756	0.76	0.65
8	Son Ha	0.87	0.92	0.1121	0.71	0.65
9	Son Tay	0.80	0.92	0.0493	0.68	0.61
10	Son Tinh	0.76	0.82	0.1173	0.75	0.61
11	Tay Tra	0.74	0.92	0.1048	0.65	0.60
12	Quang Ngai City	0.67	0.86	0.0650	0.76	0.59
13	Tra Bong	0.76	0.92	0.1379	0.72	0.63
14	Tu Nghia	0.74	0.79	0.1561	0.75	0.61
	ALL PROVINCE	0.72	0.86	0.1189	0.71	0.60

- The case of climate change

+ Scenario RCP 4.5 with period of 2046 - 2065: The level of water security for the whole year of Quang Ngai province is assessed at an average level (0.58), compared with the current period, it is lower than 0.03 (between 0.61 - high and 0.58 - average).

Table 3.14. Water security for the whole year according to the RCP4.5 scenarios for the period 2046 - 2065

NO	District	Ecosystem	Water-related disasters and hazards	Socio-economic	Water resources and people	Water security for the whole year
1	Ba To	0.72	0.79	0.1277	0.84	0.62
2	Binh Son	0.55	0.76	0.0582	0.81	0.54
3	Duc Pho	0.58	0.71	0.1488	0.82	0.56
4	Ly Son	0.45	0.91	0.1195	0.41	0.47
5	Minh Long	0.71	0.80	0.1208	0.81	0.61
6	Mo Duc	0.55	0.67	0.1713	0.84	0.56
7	Nghia Hanh	0.66	0.74	0.1756	0.87	0.61
8	Son Ha	0.74	0.82	0.1121	0.79	0.62
9	Son Tay	0.73	0.77	0.0493	0.76	0.58
10	Son Tinh	0.66	0.72	0.1173	0.82	0.58
11	Tay Tra	0.66	0.84	0.1048	0.76	0.59
12	Quang Ngai City	0.67	0.75	0.0650	0.85	0.58
13	Tra Bong	0.73	0.80	0.1379	0.78	0.61
14	Tu Nghia	0.68	0.69	0.1561	0.84	0.59
	ALL PROVINCE	0.65	0.77	0.1189	0.79	0.58

- The RCP8.5 scenarios for the period 2046 - 2065 of the whole Quang Ngai province is assessed at an average level (0.57), compared with the current period, it is lower than 0.04 (between 0.61 - high and 0.57 - medium).

Table 3.15. Water security for the whole year according to the RCP8.5 scenario for the period 2046 - 2065

NO	District	Ecosystem	Water-related disasters and hazards	Socio-economic	Water resources and people	Water security for the whole year
1	Ba To	0.72	0.78	0.1277	0.81	0.61
2	Binh Son	0.55	0.75	0.0582	0.80	0.54
3	Duc Pho	0.58	0.71	0.1488	0.80	0.56
4	Ly Son	0.45	0.91	0.1195	0.41	0.47
5	Minh Long	0.71	0.78	0.1208	0.80	0.60
6	Mo Duc	0.55	0.65	0.1713	0.82	0.55
7	Nghia Hanh	0.66	0.73	0.1756	0.84	0.60
8	Son Ha	0.74	0.81	0.1121	0.78	0.61
9	Son Tay	0.73	0.77	0.0493	0.75	0.57
10	Son Tinh	0.66	0.69	0.1173	0.81	0.57
11	Tay Tra	0.66	0.84	0.1048	0.75	0.59
12	Quang Ngai City	0.67	0.72	0.0650	0.84	0.57
13	Tra Bong	0.73	0.81	0.1379	0.77	0.61
14	Tu Nghia	0.67	0.65	0.1561	0.83	0.58
	ALL PROVINCE	0.65	0.76	0.1189	0.77	0.57

Through the results of calculation and comparison, it can be seen that the general picture is: 1- the water security indicator in future periods is lower than in the present period; 2- the indicator of future water security taking into account climate change is lower than the indicator without climate change; 3- the water security indicator in the RCP8.5 scenarios is lower than that in the RCP4.5 scenarios in the same period 2046 - 2065 (Figure 3.19)

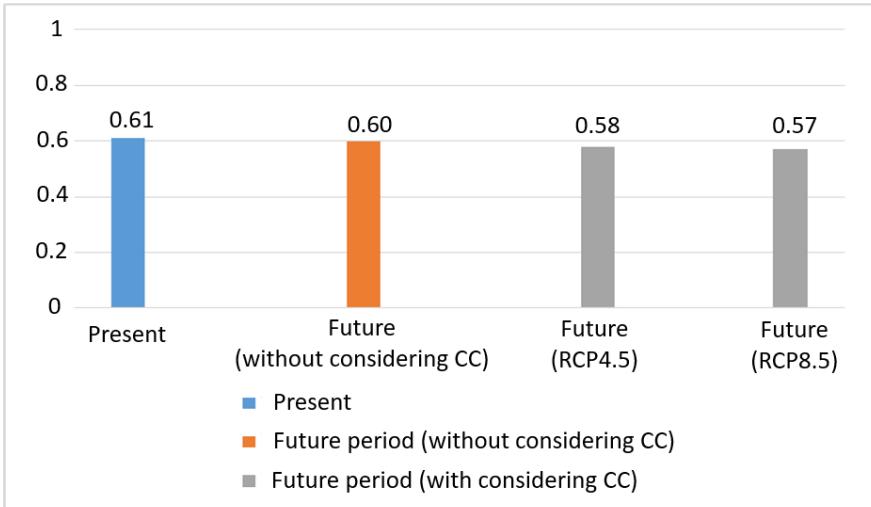


Figure 3.19. Comparison of water security levels across periods and scenarios

3.2. Comments on the impact of climate change on water security in Quang Ngai province

Through the results of calculating and comparing the level of water security in Quang Ngai in the future, with and without considering to climate change, it is clear that the level of water security of Quang Ngai province is affected by climate change. In particular, the more extreme climate change scenario has a stronger impact than the average scenario, as shown by the following water security indicators: (1) The water security indicator in the future when taking into account to climate change is lower than the indicator of no climate change; (2) The water security indicator under the RCP8.5 scenario is lower than that of the RCP4.5 scenario in the same period 2046 - 2065. Specifically: the water security indicator in the period 2046 - 2065 does not take into account changes climate indicator reached 0.6, while the water security indicator in the period 2046 - 2065 scenarios RCP4.5 and RCP8.5 is 0.58 and 0.57 respectively.

3.3. Solution

3.3.1. Scientific basis and practice of proposing solutions

Proper assessment of the risks of water supply and access of water-using industries is the basis for proposing appropriate solutions to ensure water security. In addition, the proposed solutions must be suitable for the region and feasible in order to bring into full play the available potential of a particular region, region or locality. In addition, the proposed solutions need to be consistent with regional and local planning orientations to ensure sustainability in the implementation process; and important and should be done overall. These are important principles that need to be implemented in the process of proposing solutions to ensure water security in general and Quang Ngai province in particular.

3.3.2. Analyze and select priority and suitable solutions for Quang Ngai province

The water security indicator includes 17 component indicators, but of these, there are 5 natural indicators that cannot be affected: Frequency of floods, Number of days of drought, Rate of flooded area, Average rainfall year, Average temperature of the year; remaining 12 indicators can be improved by solutions. Thus, the selection of priority solutions to ensure water security in Quang Ngai should focus on actions to improve these 12 indicators. On that basis, the thesis proposes solutions that need to be prioritized and implemented in parallel and synchronously to 2030, with a vision to 2050 as follows:

- Maintain and improve the forest area: the goal is to maintain the current coverage

- Wastewater management and treatment: the goal is that 100% of wastewater is collected and treated before it is discharged into lakes, rivers and streams.

- Ensuring the population of Quang Ngai is at an appropriate level in terms of both quantity and structure: the goal is to maintain the current fertility level.

- Ensuring water demand for daily life, agriculture, industry and services: the goal is 100% to meet demand in both quantity and quality.

- Overall solutions to raise incomes and improve people's lives: the goal is to reach 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 Party Congress of Quang Ngai province for the 20th time.

3.3.3. Evaluating the effectiveness of solutions in improving the level of water security for Quang Ngai province

In case of the proposed solutions are implemented synchronously and effectively, the water security indicator in all districts and the whole province will be improved with the difference ranging from 0.08 to 0.04. Specifically: the water security indicator in 03 districts of Ly Son, Tay Tra and Tra Bong improved the most with a difference of 0.08; next, the districts of Ba To, Duc Pho, Minh Long, Mo Duc, Nghia Hanh, Son Ha, Tu Nghia reached the difference of 0.07; the whole province improved from 0.55 - the average level of water security to 0.62 - the high level of water security (reaching a difference of 0.07).

CONCLUSIONS AND RECOMMENDATIONS

1. Conclusion

- *Quang Ngai Water Security Assessment Indicator*: Through analyzing and evaluating domestic and foreign studies on water security, it can be seen that there is a gap in research on water security in the development and application of a set of indicators to assess water security under current conditions and under climate change scenarios. The thesis has built a methodology and a set of indicators for assessing water security

including 4 components (17 sub-indicators) which are: (1) ecosystem; (2) natural disasters and hazards related to water; (3) socio-economic; (4) water and human resources. These four components cover the full range of factors that affect water security, including climate change. This set of indicators can be applied in other localities.

- *Water security issues in Quang Ngai in the present:* Water security in Quang Ngai is facing many risks of deterioration. Specifically: lack of water supply and increasing demand for water for industries, typically water used for agriculture and domestic use; water pollution due to direct discharge of untreated water into major water sources. There are also some indirect factors such as low per capita income, leading to limited access to clean water sources, ensuring standards; impacts of climate change on water security in particular and environmental - economic - social issues in general.

- *Water security in Quang Ngai in the future:* The level of water security in Quang Ngai province will be reduced in the future. Climate change has an impact on water security of Quang Ngai province, the high scenario has a stronger impact than the medium scenario. The water security indicators for the periods show that: (1) The water security indicators in the future periods are lower than in the present period; (2) The indicator of water security in the future taking into account climate change is lower than the indicator without climate change; (3) The water security indicator under the RCP8.5 scenario is lower than that of the RCP4.5 scenario in the same period 2046 – 2065.

- *Proposed solutions to ensure water security for Quang Ngai:* From the results of calculation and detection of Quang Ngai's water security problem in the present, in the future, and analyzing the specific conditions of Quang Ngai. Ngai, some specific solutions are proposed by the thesis to apply, including: (1) Maintaining and improving the forest area - the goal of maintaining the current coverage; (2) Wastewater management and

treatment - the goal is that 100% of wastewater is collected and treated before being discharged into lakes, rivers, streams; (3) Ensure Quang Ngai's population is at an appropriate level in terms of both quantity and structure - the goal is to maintain the current fertility rate; (4) Ensuring water demand for daily life, agriculture, industry and services - the goal is to ensure 100% demand in terms of quantity and quality; (5) Raise incomes, improve people's lives - the goal is to reach 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 Quang Ngai Provincial Party Congress.

- *Effectiveness of proposed solutions*: If the solutions are implemented, water security of Quang Ngai province will be ensured, even in the case of climate change impacts. Specifically, when the solution is implemented: (1) the water security indicator of the whole province is significantly improved, from the average water security level to the high water security level (0.55 to 0.62 level, reaching the level of high water security level (0.55 to 0.62). difference 0,07); (2) The water security indicator in all districts also improved similarly, increasing from 0.04 to 0.08 depending on each district.

2. Recommendation

Within the framework of the thesis, due to the limitations of time and resources, the thesis also has the following shortcomings:

- The set of indicators for assessing water security is not really comprehensive because there are many indicators that require a lot of data but are difficult to collect. For example, data on water pollution, waste water, and groundwater.

- The weights of the indicators as well as the groups of indicators for assessing water security have not been calculated, which leads to the undetermined level of which component indicators affect the final water security indicator more or less.

- Input component indicators related to many industries and fields, calculated data for the entire period of nearly 100 years, must be divided into periods, so some indicators use models to calculate or extrapolate. Although in fact, Quang Ngai is a locality with a rich set of data, which is collected methodically and updated more frequently and periodically than many other provinces.

- The reliability distribution function has not been built yet, but using an even scale to divide the water security level.

The above mentioned shortcomings of the thesis can be the subject for further research directions, focusing on:

- Research to identify all indicators affecting current water security in Vietnam (including provinces), thereby assessing water security in Vietnam and provinces, ensuring practicality and topicality.

- Research on the weighting of indicators and groups of indicators to improve practical applicability when using a set of indicators to assess water security;

- Research and build an efficient and realistic data collection system and toolkit to get more accurate outputs./.