Current situation, challenges and community perception for water security of Ben Tre provice

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Abstract

This study analyzes the current status of surface water resources in Ben Tre province in the context of climate change and upstream exploitation of the Mekong River. Findings indicate that Ben Tre faces major challenges, including deep and prolonged saltwater intrusion, increasing surface water pollution due to domestic, agricultural, and aquaculture wastewater; freshwater shortages during the dry season; strong impacts from climate change (sea level rise, reduced river flow); and pressure from urbanization and population growth. The research employs document review, field surveys, GIS applications, and SWOT analysis to assess risks and propose sustainable management strategies. Sociological surveys reveal that the community is aware of pollution and saltwater intrusion issues and is willing to engage in water protection measures, though limited by skills and resources. SWOT analysis highlights strengths such as water resource potential and policy support, but also points out weaknesses in management capacity and threats from climate change and upstream water exploitation. The paper proposes key solutions including integrated water resource management based on ecological zones, investment in climate-adaptive irrigation infrastructure, community awareness enhancement, and the development of multi-stakeholder water governance models to ensure long-term water security for Ben Tre province.

Keywords: *Surface water resources; saltwater intrusion; water security; Ben Tre province; community perception; climate adaptation.*

JEL Classification: *Q50, Q56, Q57.*

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1. INTRODUCTION

Surface water resources play a central role in ensuring water security, supporting socio-economic development, and maintaining the stability of ecosystems in coastal delta regions. Amid global challenges such as climate change, sea-level rise, and environmental degradation, provinces in the Mekong Delta - particularly Ben Tre province are facing mounting pressures on surface water resources [1].

Ben Tre is a coastal province located in the lower Mekong River system, with a dense network of rivers and canals directly influenced by tidal regimes and upstream water exploitation. In recent years, the quantity and quality of surface water in the province have been seriously threatened. One of the most significant challenges is the increasingly complex saltwater intrusion, which now occurs earlier, lasts longer, and reaches salinity levels well above the multi-year average. Severe saline droughts in 2015–2016 and 2019–2020 caused extensive damage to agriculture, aquaculture, domestic water supply, and public health [2][3]. Climate projections indicate that saltwater intrusion will intensify in both scale and severity in the coming decades, particularly during the dry season [2].

Simultaneously, surface water quality has declined significantly in many areas of the province, especially in rapidly urbanizing zones, industrial parks, aquaculture regions, and intensive agricultural areas. Surface water is increasingly impacted by untreated wastewater, agricultural chemical residues, and organic pollutants. Environmental monitoring results show that many river and canal sections fail to meet national surface water quality standards (QCVN 08-MT:2015/BTNMT), especially for domestic water use purposes [4].

In addition, population growth, urbanization, and the rapid development of economic sectors such as agriculture, industry, and tourism services have increased water demand, while surface water supply has become increasingly unstable and seasonal. During the dry season, many areas - particularly coastal districts like Ba Tri, Binh Dai, and Thanh Phu district regularly suffer from severe freshwater shortages, seriously affecting livelihoods and local living conditions [1][3].

These realities underscore the urgent need for a comprehensive assessment of the current status of surface water resources and the identification of critical challenges. This paper is highlights key issues requiring attention in order to formulate effective solutions and ensure water security for Ben Tre province in the future.

2. THEORETICAL FRAMEWORK AND METHODS

2.1. Sampling area

This study focuses on the surface water resource system of Ben Tre province, including natural and artificial rivers, canals, reservoirs, ponds, and irrigation structures used for domestic and production purposes. Ben Tre, a coastal province in the lower Mekong River basin, has low-lying terrain and a dense river network influenced by tides, saltwater intrusion, and climate change. The study categorizes the area into three main aquatic ecological zones:

a. *Freshwater zone:* Mainly located in the upper reaches of major rivers, supplying water for domestic use and production. The study evaluates water quality, discharge, and the risk of reduced storage during the dry season.

b. *Brackish water zone:* A transitional area between freshwater and saltwater, highly sensitive to tidal fluctuations and upstream flows. The study focuses on salinity-freshwater dynamics and the adaptability of aquatic ecosystems.

c. *Saltwater zone:* Concentrated in coastal districts, affected by saltwater intrusion. The study assesses the effectiveness of salinity control infrastructure and freshwater storage solutions.

The research also examines risk factors such as saltwater intrusion, pollution, dry season water shortages, and climate change impacts, while investigating community awareness regarding water resource protection.

2.2. Research methods

The study combines document review, field surveys, and data analysis to evaluate the current state of surface water resources in Ben Tre province. Specific methods include:

Collection and analysis of secondary data: Data was sourced from reports by the Department of Natural Resources and Environment, Department of Agriculture, Statistical Office, and academic studies to establish a basis for analyzing the status and challenges related to water resources.

Field surveys: Conducted in freshwater, brackish, and saltwater areas to observe water flow, levels, salinity, pollution, and irrigation infrastructure, as well as to interview local residents and officials. This information validates the data and reflects issues such as saltwater intrusion and freshwater scarcity.

GIS application: Geographic Information Systems (GIS) were used for spatial analysis and thematic mapping of aquatic zones, salinity fluctuations, and pollution risk areas to support effective water resource management.

SWOT analysis: Used to assess strengths, weaknesses, opportunities, and threats in water resource management, helping to identify barriers and potential improvements for enhancing water security.

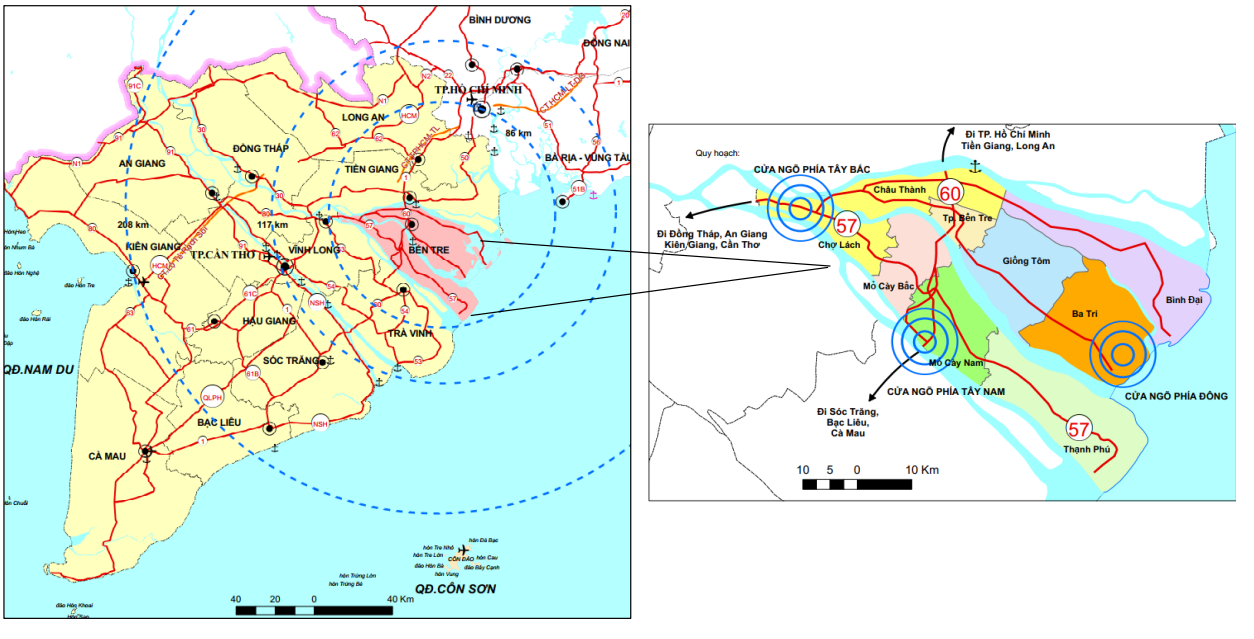
Sociological surveys: Conducted with 200 residents from saltwater intrusion-affected districts to assess community awareness of water resources, impacts of salinity, and current mitigation measures, thereby supporting decision-making and sustainable development.

3. RESULTS AND DISCUSSION

3.1. Surface water status

Ben Tre province possesses a diverse hydrological system with major rivers such as the Tien, Ham Luong, and Co Chien river. These rivers are crucial for agriculture, domestic use, and aquaculture but face challenges including saltwater intrusion and water pollution. Covering an area of approximately 2,400 km² with a population of over 1.2 million, the province's dense river network helps regulate the climate and supports ecotourism development.

Figure 1. Map showing Ben Tre's location within the Mekong Delta region



However, it is also highly vulnerable to saline intrusion from the East Sea, particularly during the dry season [5].

Surface water reserves in Ben Tre province mainly depend on the upstream flow of the Mekong River, with an average annual volume ranging from 12.5 to 15 billion m^3. The rainy season (June - November) accounts for about 80% of the water supply, while the dry season (December - May) often experiences water shortages and saline intrusion, affecting over 200,000 households, especially in coastal areas [6].

Surface water in Ben Tre is categorized into three zones: freshwater, brackish, and saline. Freshwater zones are primarily used for domestic and production purposes, but during the dry season, reduced flows can lead to saline intrusion. Brackish zones mainly serve aquaculture but face difficulties in salinity control [7]. Saline zones, especially in coastal districts such as Thanh Phu and Ba Tri district, support shrimp farming but are severely affected by saline intrusion, hindering domestic water supply and agriculture [8].

Saline intrusion is a major challenge, particularly during extreme events like the 2015–2016 drought. The province has invested in hydraulic works such as the Ba Lai sluice to prevent salinity and protect freshwater sources, but their effectiveness still needs improvement, especially in water monitoring and coordination [9][10].

Surface water quality in Ben Tre is seriously polluted, mainly due to domestic and aquacultural wastewater. Organic and microbial pollution reduces water quality, affecting livelihoods and production [6]. Water demand is increasing sharply and is projected to exceed 1.6 million m^3/day by 2030. However, current water exploitation lacks proper planning and data infrastructure, leading to overexploitation and reduced water replenishment capacity [10].

3.2. Challenges to water security in Ben Tre

a. Surface water quality

Ben Tre currently has 20 monitoring stations for salinity and water quality (WQ) along major rivers such as Ham Luong, Co Chien, Ba Lai, and Tien river, along with hydrological stations and 3 automatic wastewater monitoring stations. In 2021, three more wastewater monitoring stations were added in industrial zones, and the province conducted periodic monitoring at 53 points with a frequency of once per year.

For domestic water supply, surface water is the main source. There are 67 plants with a total capacity of 240,000 m^3/day-night, meeting 72% of the demand. Groundwater is used less, with four plants; the largest, Son Dong, provides 31,900 m^3/day from the Ham Luong river. The rate of households using hygienic water reaches 99.8%, with 78.4% using standard clean water. The rate of households with clean water access varies from 42.3% (Thanh Phu district) to 99.3% (Ben Tre city).

Table 1. Percentage of households supplied with clean water in Ben Tre

No.	Administrative unit	Rate (%)
1	Ben Tre city	99,3
2	Chau Thanh district	90,9
3	Cho Lach district	76,6
4	Binh Dai district	74,0
5	Ba Tri district	70,6
6	Mo Cay Bac district	66,8
7	Mo Cay Nam district	65,8
8	Giong Trom district	57,4
9	Thanh Phu district	42,3

However, surface water quality (SWQ) is being affected by industrialization and urbanization, with multiple sources of pollution. While indicators such as pH, $N\text{-}NO_3^-$, and $P\text{-}PO_4^{3-}$ meet the standards, others like Fe, BOD5, COD, and TSS exceed limits, and some areas show DO, NH_4^+-N, and Coliform levels above permissible thresholds [11]. Compared to the 2011–2015 period, pollution indicators have increased [12].

In agriculture, the province has an irrigation system with 68 main canals totaling 363.52 km and 1,537 sluices, serving irrigation for 181,821 ha of farmland. In 2021, total freshwater usage for agriculture was approximately 500.3 million m^3, with aquaculture consuming about 83.5 million m^3 annually [13][14].

b.Saltwater intrusion

According to the Southern Institute of Water Resources Research, Mekong upstream flows to the delta have declined from 2000 to 2020, with major floods becoming rare and potentially absent by 2050. Severe saline intrusion has occurred earlier in the dry season (December–January), penetrating 60–70 km inland, causing freshwater shortages in coastal regions [15]. Ben Tre is heavily affected due to reduced rainfall and upstream inflow. From 2015 to 2024, 4‰ salinity has intruded 50–143 km inland depending on the area, severely damaging fruit trees and aquaculture [16].

The historic 2015–2016 drought led to 160,000 ha of land being salinized, causing losses of over VND 5,500 billion. In 2020, drought and saline intrusion lasted over six months, damaging 43,000 ha of rice and affecting 80,000 households, with losses nearing VND 11,800 billion [16]. Currently, saltwater has intruded 70 km inland, affecting 4,000 ha of seedlings and fruit trees, threatening drinking water sources for around 25,000 households. The anti-salinity irrigation system remains incomplete, limiting control effectiveness and increasing the risk of erosion and freshwater shortages during the dry season [16].

c.Climate change

Climate change (CC) severely affects water resources (WR) in Ben Tre province, especially in coastal areas that suffer from extreme freshwater shortages during the dry season. Saltwater intrusion (SWI) in major rivers such as the Tien, Ba Lai, Ham Luong, and Co Chien river is increasing due to climate change and excessive upstream water exploitation, significantly impacting domestic water supply.

During the dry season, saline water from the East Sea intrudes deep inland, causing over two-thirds of the province to experience salinization. River and canal water sources become heavily polluted, significantly affecting residents' lives. Although groundwater is available, it often does not meet the Ministry of Health's standards for domestic use due to high salinity levels (0.35–0.8‰ compared to the 0.3‰ standard). The incomplete irrigation canal system further aggravates SWI into the interior fields [17].

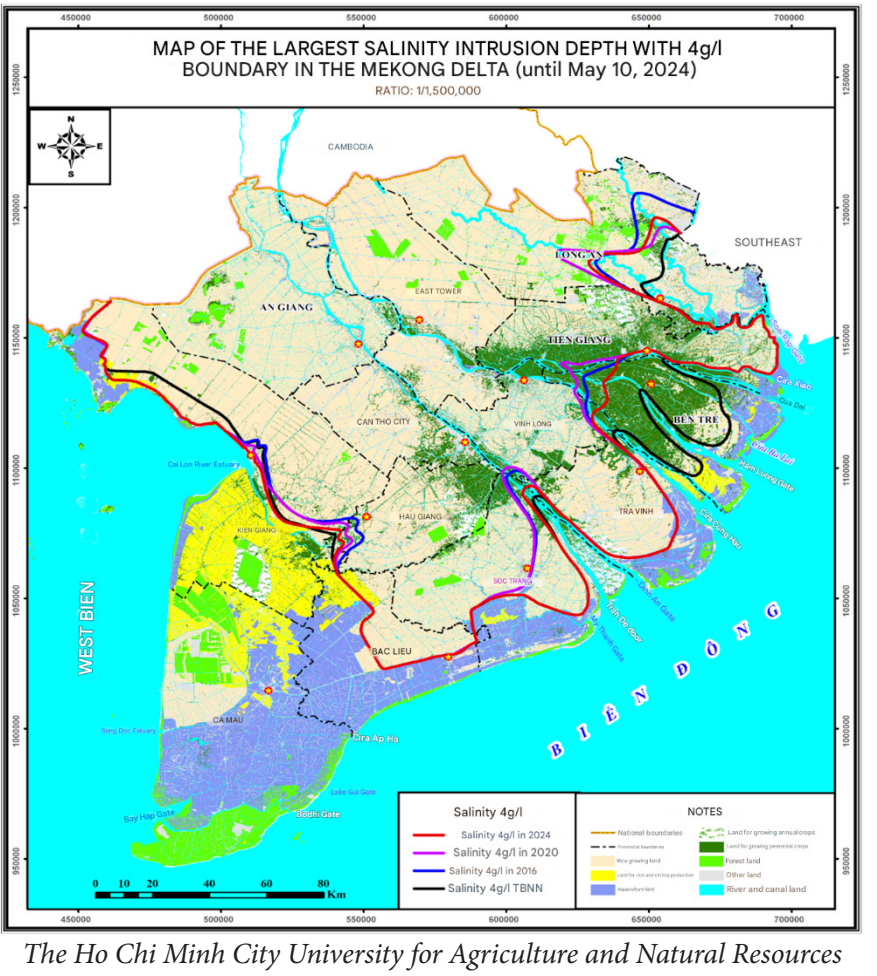
Salinity boundary calculations based on climate change scenarios indicate that SWI intensifies in brackish areas, especially during the dry months (February–May), with April being the most severe. The saltwater penetrates 23–35 km inland, primarily through the Ham Luong and Co Chien river mouths. The extent of SWI depends on tidal levels and upstream flow rates [17]. Specifically, maximum salinity during the dry season is measured at 29.1‰ at the Tien River estuary, 33.3‰ at Ham Luong River (An Thuan station), and 32.1‰ at Co Chien River (Ben Trai station) [18].

Under the RCP4.5 scenario, rainfall is projected to increase by 17.1% by 2030, with significant rises during the dry season

Table 2. Saline intrusion patterns in recent years (4g/l salinity front distance in km)

River mouth	2013–2019	2015–2016	2019–2020	2023–2024
Vam Co Dong	74	111	91	100
Vam Co Tay	74	123	143	130
Cua Tieu	39	48	91	55
Cua Dai	40	50	91	55
Ham Luong	50	73	78	65
Co Chien	45	65	68	58
Hau River	45	60	62	54
Cai Lon	55	68	62	61

Figure 2. Land use and saline intrusion boundary map in the Mekong Delta Region [16]



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(30.8%) and the rainy season (16.6%). Sea level is expected to rise by 12.1 cm in 2030 and 22.3 cm by 2050, increasing the risk of flooding. The districts expected to experience the most inundation by 2030 include Cho Lach (18%), Mo Cay Nam (12%), and Thanh Phu district (10%) [18].

d.Impact of population growth

Population growth increases the demand for water for domestic use, sanitation, and agriculture. Agriculture requires large amounts of water to meet food needs, which can lead to resource depletion. Rapid urbanization also puts pressure on infrastructure and water supply systems; if not properly planned, this may cause shortages. High population density leads to competition among water users, exacerbating water scarcity. In many

areas, water infrastructure lags behind population growth and climate change, making problems like drought and irregular rainfall even more severe.

By 2030, 90% of Ben Tre city's population is expected to live in urban areas, requiring high-quality surface water to meet residential and service needs. Urbanization reduces vegetative cover, affecting groundwater recharge and ecosystems. The growing population also increases solid waste; if improperly collected, it can contaminate surface water. A key challenge lies in raising awareness about waste sorting, water conservation, and protecting water resources from domestic pollution.

Figure 3. Dry season and annual salinity boundaries under climate change scenarios [17]

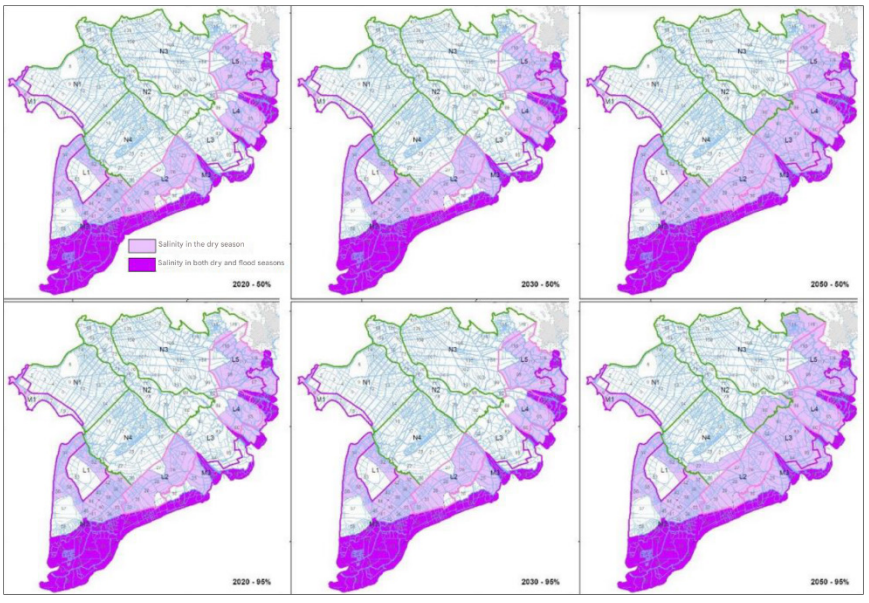
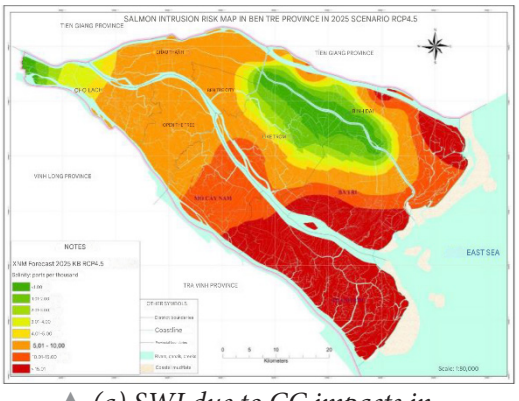
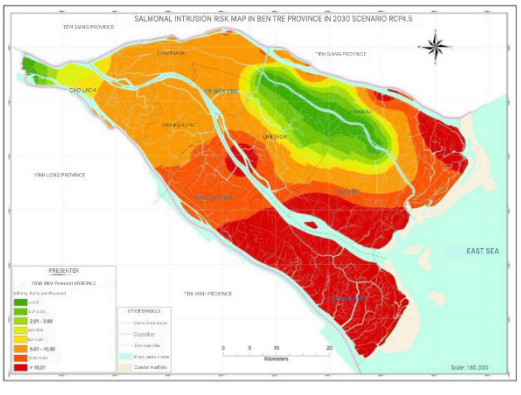


Figure 4. Saltwater intrusion due to climate change impacts in 2025 and projected to 2030 under RCP4.5 [18]



▲ *(a) SWI due to CC impacts in 2025 under RCP4.5*



▲ *(b) SWI due to CC impacts by 2030 under RCP4.5*

e.Impact of pesticides

Residues of pesticides on agricultural products and in the environment (soil, water, air) can enter the food chain and cause both acute and chronic poisoning, such as birth defects and cancer. The main exposure route is ingestion (97.3%), with lesser contributions from skin contact (1.9%) and inhalation (1.8%) [19]. Common toxic pesticides include Volfatoc (77.3%), 66 (14.7%), and DDT (8%) [20].

Pesticides disperse into the environment, polluting soil and water, killing beneficial organisms, and persisting for long periods. Chemicals may flow into water sources due to runoff, erosion, or uncontrolled disposal. Water pollution occurs from field runoff, equipment washing, and stormwater carrying chemicals from storage sites [19]. Pesticide management in remote areas remains inadequate, with users failing to comply with regulations on dosage and pre-harvest intervals, increasing environmental risks and reducing agricultural product quality. The collection and treatment of pesticide containers is also ineffective, causing serious pollution in provinces like Ben Tre [20].

f. Assessment of overall challenges

Despite having a legal framework in place at both the national and provincial levels for water resource management in general, and surface water management in particular, Ben Tre still faces many challenges. These are analyzed using the SWOT (Strengths – Weaknesses – Opportunities – Threats) model, as presented in Table 3.

Table 3. Harmful effects of pesticides on human health

HEALTH EFFECTS OF PESTICIDES ON HUMANS AND ANIMALS								
Toxicity			**Genetic Effects**			**Allergic Reactions**		**Premature Birth**
Chronic	Subacute	Acute	Embryotoxicity	Biotoxicity	Mutagenicity	Benign Tumor	Malignant Tumor	

Table 4. Assessment of surface water management challenges in Ben Tre province using the SWOT model

1. S - Strength	2. W - Weakness
Abundant water resources from both surface and groundwater sources, especially large groundwater reserves in coastal sand dunes. A relatively comprehensive legal framework for surface water management at both central and local levels, with clear guidelines and directives.	Limited resources for water resource management and environmental protection, especially human resources, due to recent restructuring of management agencies. Weak inter-sectoral coordination among management agencies and lack of synchrony. Limited budget for surface water protection, insufficient for meeting socio-economic development needs.
3. O - Opportunity	**4. T - Threat**
The Government's sustainable development policy for the Mekong Delta has been established, fostering more effective water management. Ben Tre receives support from many international cooperation projects such as those by the World Bank, JICA, GIZ, and others, enhancing resources and infrastructure development.	Surface water is frequently threatened by pollution and increasing saltwater intrusion. Climate change and sea level rise pose serious risks to water quality and quantity. The decline in flow from the Tien and Hau rivers driven by climate change - further complicates water resource management.

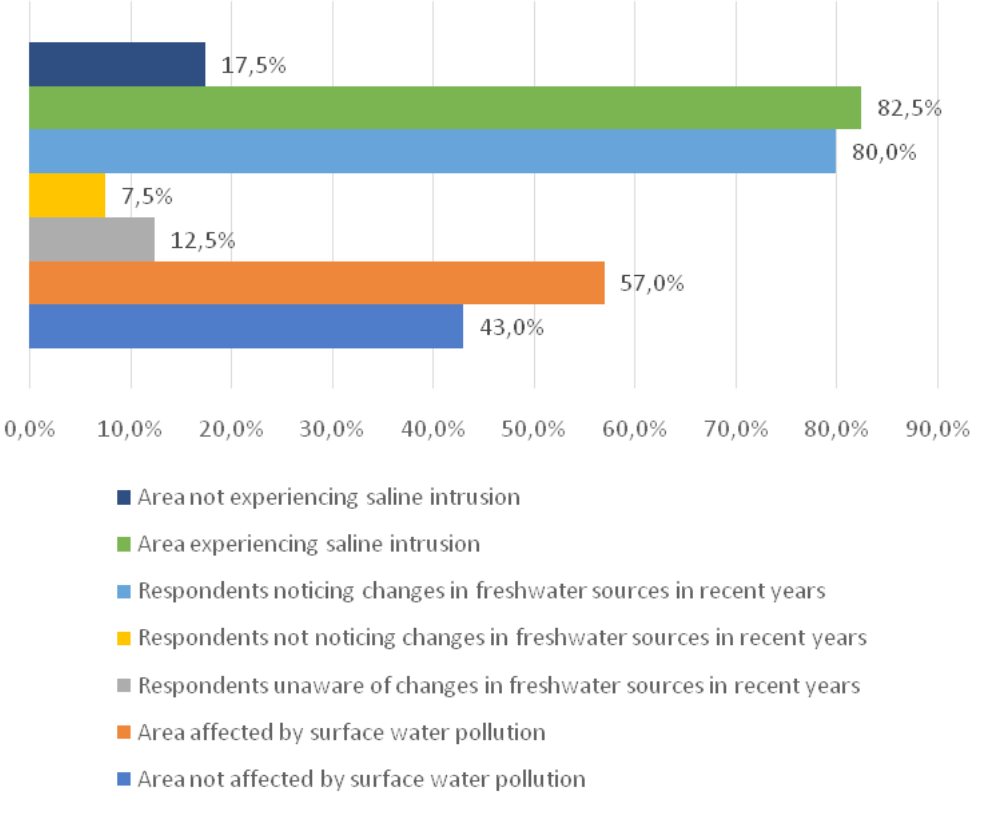
The key challenges in surface water management in Ben Tre stem from both internal factors (e.g., human and financial resources) and external ones (e.g., climate change, saltwater intrusion, and upstream activities in the Mekong River basin). Addressing these issues requires improving coordination, enhancing resources, and implementing climate adaptation measures.

3.3. Community awareness and willingness to participate

a. Community awareness

A survey of 200 questionnaires on public awareness in Ben Tre province revealed that 57% of respondents believed that surface water sources in their area were polluted. Residents reported that the water was often turbid, had an unpleasant odor, and caused itching when used for bathing. The causes were identified as indiscriminate littering, untreated wastewater discharge from livestock farms, and the dumping of animal carcasses into rivers. However, thanks to training sessions and awareness campaigns, public consciousness regarding environmental protection has somewhat improved.

Figure 6. Public awareness of pollution and saltwater intrusion in Ben Tre



In addition to pollution, residents also reported difficulties in accessing and using water resources due to saltwater intrusion and freshwater shortages during the dry season. This situation has seriously affected daily life and production, particularly in urban and densely populated areas. Nevertheless, local authorities have made efforts to raise community awareness through various communication channels, including mass media and social networks, helping residents stay informed and develop better environmental protection habits.

b. Community readiness

According to the survey, residents noted that local authorities had launched strong campaigns to address serious environmental issues. Communication activities, guidance on protecting water resources, prohibiting untreated wastewater discharge, and enforcement of penalties have been intensified. In addition, campaigns such as building embankments to prevent saltwater intrusion, cleaning up waste, unclogging waterways, and constructing drainage systems have also been implemented. These measures to protect surface water in Ben Tre are illustrated below.

Regarding the adaptability of local people, the campaigns have helped raise awareness and foster responsible behavior toward protecting surface water. Residents are applying context-specific environmental practices depending on their living conditions, such as refraining from littering, not discharging untreated wastewater, conserving water, and sorting household waste. A portion of the population also participates in environmental protection activities with the support of local authorities. These practices are reflected in the following statistical illustrations.

Figure 7. Community perception of water pollution, treatment methods and local authority guidance

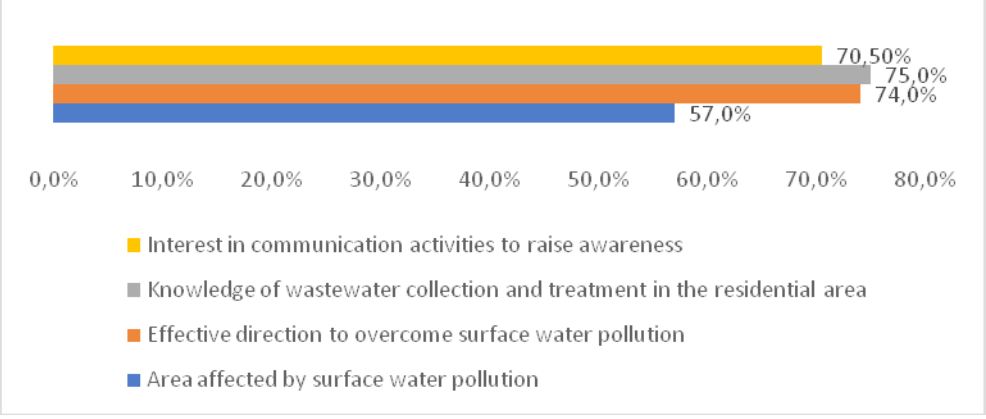


Figure 8. Preferred communication channels for receiving information

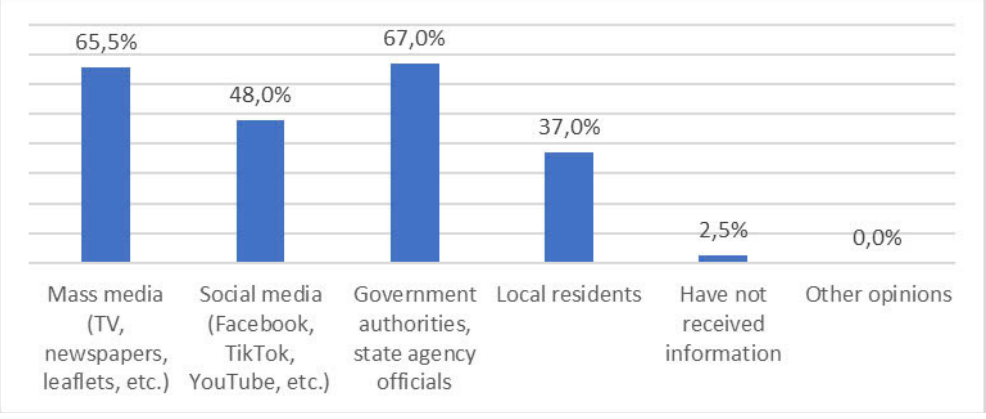
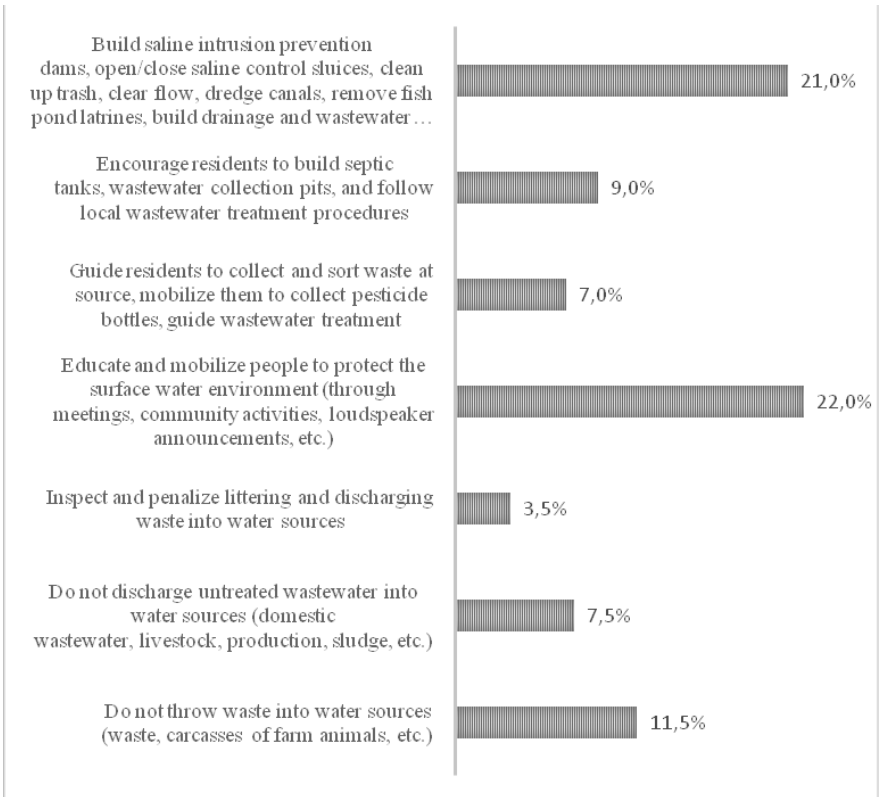


Figure 9. Measures to protect surface water resources in Ben Tre



Residents are highly willing to participate in efforts to protect water sources in their local areas, especially in Ben Tre, where a dense network of rivers exists. As people rely on water sources for daily living and production, they are proactive in safeguarding these resources. The primary purpose of water use is to meet essential needs, as shown in the figure below.

Figure 10. Community-level surface water protection practices

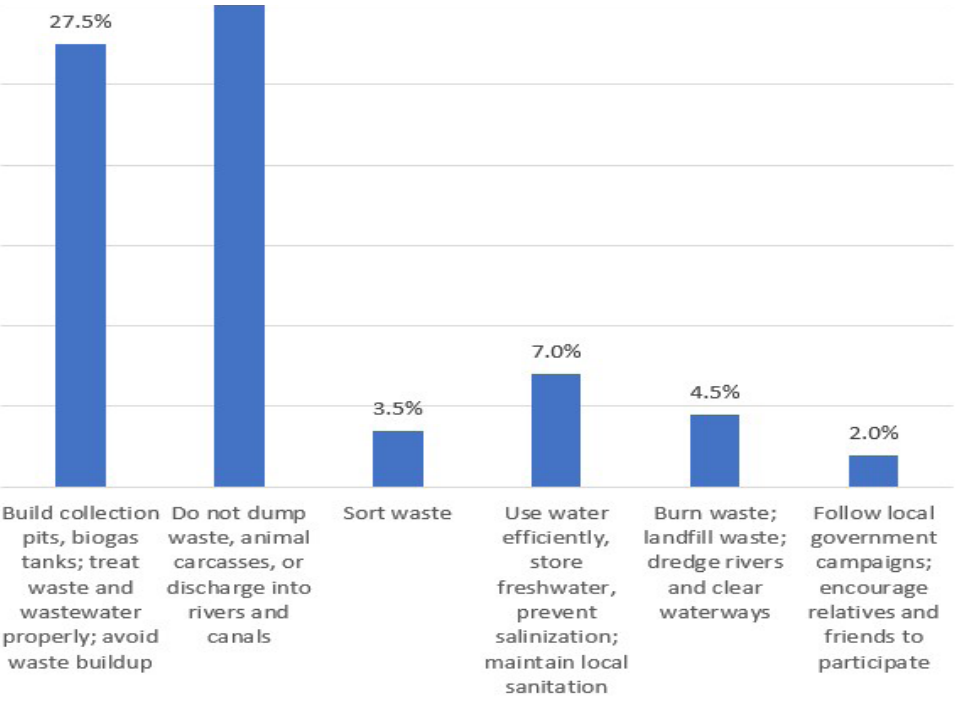
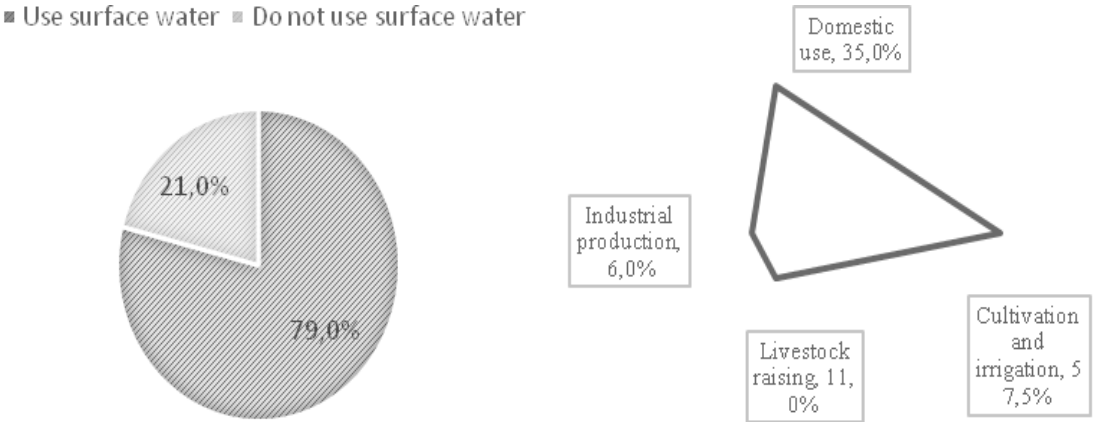


Figure 11. Purpose of surface water use by residents in Ben Tre province



5. CONCLUSION

This study provides a comprehensive overview of the current status of surface water resources in Ben Tre province, highlighting critical challenges to water security. These include prolonged and deep saltwater intrusion, increasing surface water pollution, freshwater shortages during the dry season, impacts of climate change, population growth pressure, and contamination from agricultural pesticides. In addition, sociological surveys reveal that local communities are increasingly aware of water-related issues and are willing to participate in protection efforts when properly supported. The SWOT analysis indicates that while Ben Tre has hydrological potential and policy backing, limitations persist in terms of resource capacity and water governance.

Due to constraints in time and resources, the study mainly focuses on identifying current conditions and key risks without quantitatively assessing the extent to which each factor impacts water security. Some data relies on secondary sources and qualitative community surveys, which may lack temporal updates or fail to capture the full diversity of community awareness and practices across different regions.

This research opens several pathways for further exploration, including quantitative assessment of climate change impacts on water balance, modeling water allocation across sectors, examining the effects of microplastics and emerging pollutants, and piloting community-based water governance models - especially under increasing urbanization and the rise of high-tech agriculture.

Based on the findings, the study recommends integrated water resource management by ecological zones and the inclusion of climate change considerations in long-term planning. Investments in adaptive hydraulic infrastructure and the enhancement of monitoring and early warning systems for saltwater intrusion are essential. Simultaneously, communication and capacity-building for local communities should be strengthened to foster grassroots engagement in water conservation. Policy makers should establish effective cross-sectoral coordination mechanisms and promote multi-stakeholder water governance models with the support of information technology for monitoring and decision-making. Lastly, it is critical to formulate and enforce policies that encourage water saving, wastewater treatment, and pollution control in agricultural production to ensure long-term water security amid increasingly complex climate dynamics.

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