Digital Technologies for Water Salinity Intrusion Early Warning in Big Deltas: A case study for Mekong Delta

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ABSTRACT

Salinity intrusion in the **Vietnamese Mekong Delta (VMD)** threatens **agriculture** and **livelihoods**, worsened by **climate change** and **human activities**. This research integrates **numerical modeling, remote sensing, machine learning,** and **IoT-based monitoring** within a **digital twin platform** for **real-time** and **long-term forecasting**. A **high-quality database** will support **risk assessment** and **decision-making**, enhancing **early warning systems**. The study balances **technical** and **human-centered aspects** to improve **hazard risk communication** and **water resource management**, with potential for **commercialization**.

INTRODUCTION

The **VMD** is a large, fertile region in Vietnam that is vital for **food security, livelihoods,** and **economic stability**. It supports **17 million people** and **produces 50% of Vietnam's rice** (MARD, 2021). However, **salinity intrusion**, driven by **climate change**, **upstream dams**, and the proposed **Funan Techo Canal** (a proposed Cambodian waterway), is threatening **freshwater**, **agriculture**, and **local economies**. Farmers are struggling with **soil degradation, water shortages,** and **declining yields. Existing forecasting methods** are **fragmented**, reducing their effectiveness. This research proposes a **digital twin platform** (a **digital replica** of a physical system), integrating **real-time data, IoT**, and **modeling** to provide **early warnings** and better **decision-making**, helping **government agencies** and **communities** manage **salinity risks** and **protect livelihoods**.

LITERATURE REVIEW

Salinity intrusion in the **Mekong Delta** is the increasing movement of **saltwater into freshwater systems**, driven by **climate change, upstream dams**, and **sea-level rise**, threatening **agriculture**, **water supply**, and **livelihoods** (Smajgl et al., 2015).

Previous studies have applied **numerical modeling, remote sensing,** and **machine learning** to **predict salinity levels** (Nguyen et al., 2021). However, these methods are often **used separately**, limiting their effectiveness in real-world applications. **IoT-based monitoring** has **improved real-time data collection** but **lacks integration** with **predictive models** for proactive decision-making (Vo et al., 2022). ↗

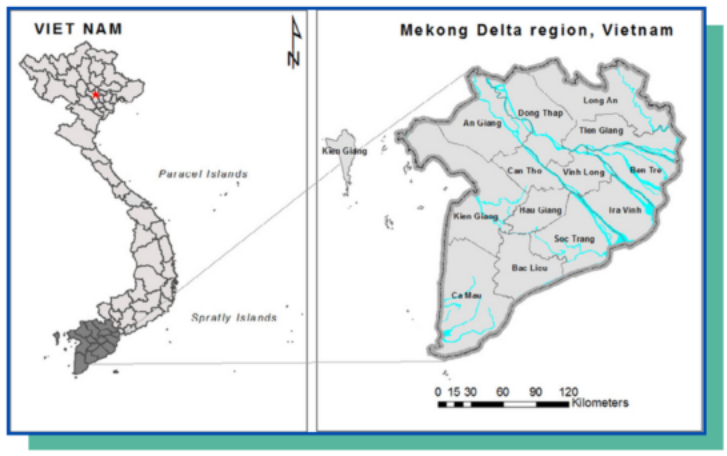

Fig. 1. Mekong Delta region, Vietnam

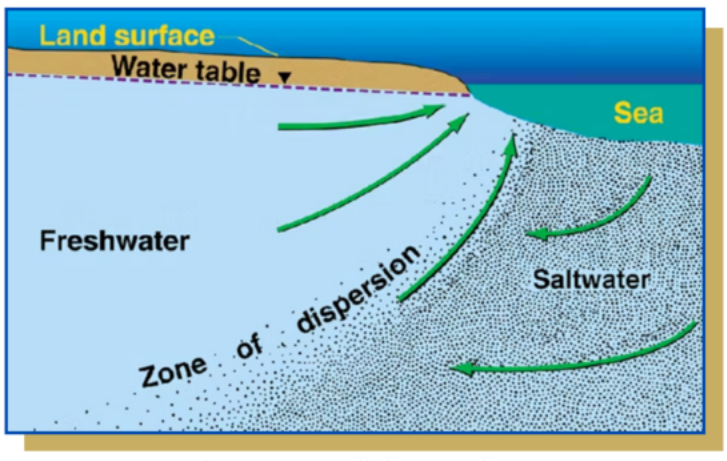

Fig. 2. Water Salinity Intrusion

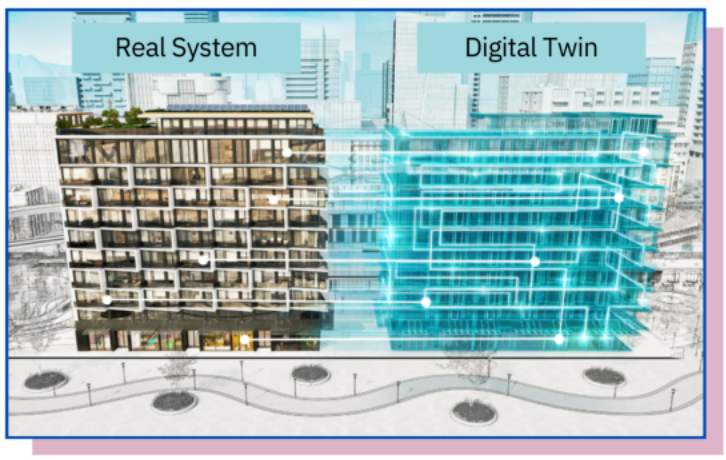

Fig. 3. Example: Digital Twin Technology

Fig. 4. Mekong Delta - Before and After Salinity Intrusion

A **digital twin platform** has shown promise in **early warning systems** and **water resource management** (Tao et al., 2019). **Integrating numerical models, remote sensing, IoT data,** and **machine learning** within a **single decision-support system** could **enhance risk assessment** and **mitigation strategies** for salinity intrusion (Sharma et al., 2020).
Current approaches are fragmented, leading to inefficiencies in hazard risk communication and policy implementation. This research proposes a **comprehensive digital twin-based early warning system,** integrating various technologies to improve forecasting accuracy and **support decision-makers** in mitigating salinity risks in the VMD.

RESEARCH QUESTIONS

1. How can we **integrate various data sources** (e.g., IoT, remote sensing, hydrometeorological data) into a **unified database** for **accurate salinity forecasting** in the Mekong Delta?
2. What are the **most effective machine learning** and **numerical modeling techniques** for **predicting salinity intrusion** at **different timescales** (real-time, short-term, long-term)?
3. How can the **digital twin platform** be **designed** to support decision-makers **in real-time** while also **providing long-term predictions** to stakeholders for proactive salinity management?

RESEARCH METHODOLOGY

- **Modeling & Forecasting:**

Use hydrodynamic models (e.g., Delft3D) and machine learning for salinity prediction.

- **Stakeholder Analysis:**

Conduct interviews/surveys with farmers & policymakers to assess human impact.

- **Validation**:

Compare model predictions with real-world data & expert feedback.

EXPECTED RESULTS

- A **validated salinity forecasting model** using numerical simulations and machine learning for **accurate short-** and **long-term predictions**.
- A **digital twin platform** providing **real-time alerts** to support **proactive early warning system** and **water management**.
- A **data-driven tool** for government agencies to implement **effective salinity mitigation strategies**.
- **Clear, accessible insights** for farmers and policymakers to **reduce agricultural losses** and have **stronger risk communication.**
- Supports **farmers' adaptation strategies**, **prevents income loss**, and **enhances regional water security**.

CONCLUSIONS

This research will provide an **integrated system** for **accurate salinity forecasting**, **real-time alerts,** and **improved decision-making** to manage salinity intrusion in the Mekong Delta. By **empowering local farmers** and **government agencies** with **accessible tools** and **clear communication**, the study aims to **protect livelihoods, reduce agricultural losses,** and **enhance long-term environmental resilience.**

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