The Development of Machine Learning and Remote Sensing-based Water Management Platform

機械学習とリモートセンシングに基づく水管理プラットフォームの開発

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1. Introduction

River deltas in Asian countries serve as vital agricultural regions, particularly for rice cultivation due to their flat terrain, rich soil, and ample water supply. However, they face significant water-related risks such as flooding and saltwater intrusion. To address these challenges, agricultural agencies have implemented physical control structures and management protocols. Yet, these methods often grow complex over time. With increasing urbanization and extreme weather events, disaster risk management in deltas has become imperative. This emphasizes the need for real-time monitoring and an accessible system, ensuring accessibility for all stakeholders. This research aims to develop a smart water management system for deltas, which could be utilized to potentially minimize water-related damages and ensure sustainable agricultural production through an integrated platform.

2. Materials and Methods

2.1 Study sites

The study was conducted in three watersheds: Kameda Watershed in Niigata Prefecture, Japan; Xuan Thuy Watershed in Nam Dinh Province, Vietnam; and Cimacan Watershed in Subang Regency, Indonesia.

2.2 Methodology

Our methodology encompasses the integration of (1) remote sensing techniques, including the calculation of NDVI to determine the heading stage and the utilization of quadratic equations to approximate temporal changes (Kriegler *et al*, 1969), are employed for prioritizing rice yield prediction; (2) development of physical models to generate diverse input data for training machine learning models (Yoshikawa *et al*, 2011); (3) implementation of a machine learning (long short-term memory (LSTM)) model to enable rapid real-time forecasting of water levels (Hochreiter and Schmidhuber, 1997).

This integration was encapsulated into a visualization application accessible on both PC and handheld devices. Leveraging Streamlit in conjunction with Github, we have developed a web-based application platform to facilitate this process.

3. Results

A water management platform was developed

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under the domain “marswm-asia.streamlit.app”.

This web-based application hosted an LSTM-based inland flood prediction model driven solely by rainfall data. Key inputs included the trained LSTM model, rainfall data, calibration data (water level derived from numerical simulations), and cell areas. Comparative analyses between the numerical simulation-based and LSTM-based predictions of water depth (m) and volume (m^3) were provided, showcasing the platform's capability to deliver accurate results in under 5 seconds with R^2 and NSE reaching to 0.99 (Fig.1).

The web application also showcased predictions of inland flood models for the case study locations. Users were able to select different rainfall and water depth scenarios to be depicted. Additionally, a sliding bar allowed users to specify the time step they preferred for viewing flood inundation maps (m) and hydrographs (depicting flood inundation volume (m^3) and the rainfall (mm)) (Fig.2).

Rice yield predictions were also generated for each paddy field area within the three study case locations, presenting results in kilograms per 10 acres (kg/10a). Within the same mapping system, each cell for all study areas also showed numerical simulation-based flood inundation depths for different rainfall events (100, 200, and 300 mm) (Fig.3).

5. Conclusions

In conclusion, the developed water management platform, integrating remote sensing techniques, physical models, and machine learning for inland flood analysis, was made, and offered a potential solution for real-time monitoring and accessible system to mitigate water-related risks in Asian river deltas.

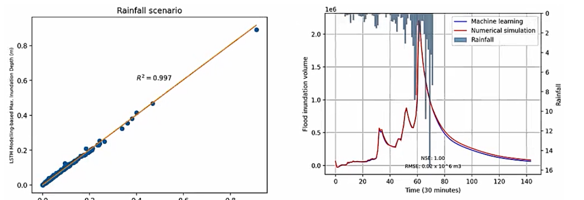

Fig.1 Sample results of water depth and volume from LSTM-based prediction via web-based platform.

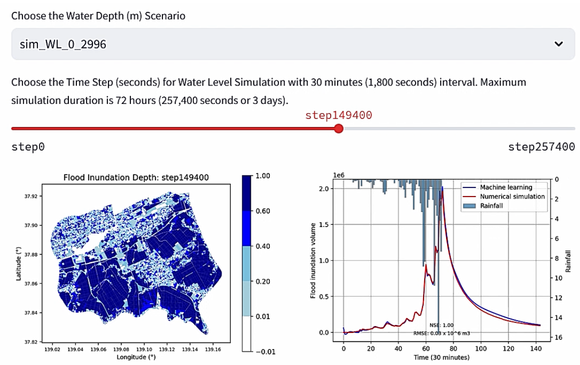

Fig.2 Sample results of flood inundation depth and hydrograph from LSTM-based prediction.

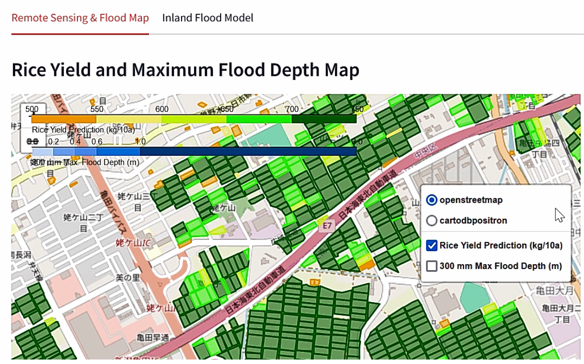

Fig.3 Sample results of rice yield predictions (kg/10a).

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