Remote Sensing-Based Topographic and Bathymetric Modelling ("the Latest DTM"): Modification of Drainage Canal Bed Elevation for Inland Flood Model

リモートセンシングによる地形・河床標高モデルの生成：内水氾濫解析モデルで用いる排水路床標高の修正

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1. Introduction

Spatial technology, including Remote Sensing (RS) and Geographic Information System (GIS) are able to provide Digital Elevation Models (DEMs) which consist of both topographic (overland terrain) and bathymetric (underwater terrain) data. However, many countries still lack the necessary data, particularly in low-lying areas. A self-constructed Digital Terrain Model (DTM) can be established to visualize the topography. To obtain a detailed latest DTM, one potential solution is to use various input data and to update the DTM with vertical deformation as a parameter (Suhadha & Julzarika, 2022). The reliability of the result can be assessed in Japan, since high-resolution data are available in the country. Finally, this study also presents a modification of the self-constructed DTM for the detection of drainage canal bed elevations in flood-related studies.

2. Materials and Methods

2.1 Study sites

The study locations were in Niigata Prefecture, Japan, specifically in Kameda, Niitsu, Shirone, and Nishikanbara. In addition, the study also included two (2) other areas, namely Inbanuma in Chiba Prefecture, Japan, for the evaluation of the DTM construction, and Okayama in Okayama Prefecture, Japan, for the modification of the drainage canal bottom elevation.

2.2 Methodology

This study aimed to construct a self-constructed DTM ("the Latest DTM") by using topographic and bathymetric data from different sources, and to evaluate its accuracy. Statistical analysis was used to compare the constructed DTM with available high-resolution data in Japan. Modifications were made to the drainage canal bed elevations using a new approach based on the evaluation results, and the modified DTM was re-evaluated using statistical measures to verify the effectiveness of the proposed approach, including the use of inland flood modeling (Yoshikawa et al, 2011).

4. Results

Self-established topography and bathymetry (the Latest DTM) were established. The analysis from topography showed that all R^2 results obtained from all approaches show a significant correlation (exceeding 0.9). However, the study findings suggest that for the bathymetry, there were no significant correlations (R^2 values were less than 0.25),

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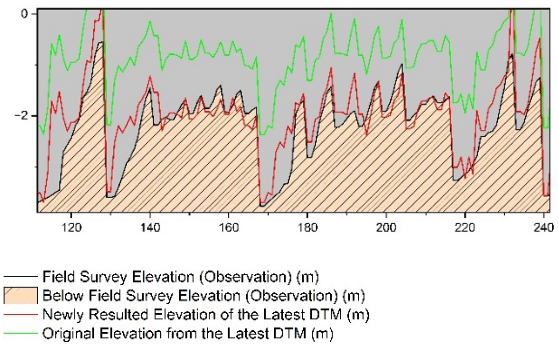

Fig.1 Comparison between field survey elevations, the Latest DTM's original elevations, and the newly resulted elevations at Kameda.

except for narrow water bodies (with R^2 ranging from 0.68 to 0.77). Hence, a new development of an elevation model (drainage canal bed) was established. For this study, field survey data of the bottom height of drainage canals were obtained, which served as the observed bases for the development. A universal modified formula was finally resulted:

$$f^{-1}(x) = \frac{y - 0.9572}{0.8986}$$

The above formula was then applied to an extracted elevation from the Latest DTM. Afterwards, the RMSE was used to compare the original and newly developed elevations against the field survey heights. In results, the newly developed technique is considered preferable to use with differences of RMSEs ranging from 0.03 m to 0.62 m. A sample comparison result in Kameda is given below:

Finally, the developed terrain model was validated to the inland flood inundation model. The validation results of the flood inundation maximum water depth in Kameda, Shirone, Nishikanbara, and Niitsu were presented and showed that the R2 for three locations was satisfactory ($0.50 \leq R^2 \leq 0.70$), whereas Kameda's R^2 was good ($0.70 \leq R^2 \leq 0.80$), and the NSE was within the range of satisfactory for three areas ($0.50 \leq NSE \leq 0.60$). A sample of the result for Nishikanbara is given below.

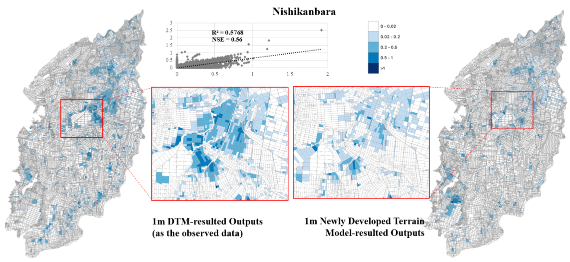

Fig.2 Validation results of the flood inundation maximum water depth based on the newly developed terrain model-derived height models at Nishikanbara.

Despite the unsatisfactory of Niitsu's NSE validation result ($NSE \leq 0.50$), the use of a self-constructed DTM can still be highly beneficial for developing countries with limited access to detailed DTM data, enhancing the resilience of communities in flood-prone regions, especially in lowland areas and in developing countries where detailed DTM data are not available.

5. Conclusions

The study developed a self-established DTM, assessed accuracies for topography and bathymetry, developed an approach to modify the elevation of drainage canal beds based on an established universal regression equation that was satisfactory compared to field measurement elevations and flood inundation results. This approach can be particularly useful for areas with no reliable and precise elevation data, especially at lowland areas.

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References

Suhadha, A. G., & Julzarika, A. (2022). Dynamic Displacement using DInSAR of Sentinel-1 in Sunda Strait. Trends in Sciences, 19(13), 4623. https://doi.org/10.48048/tis.2022.4623.

Yoshikawa, N., Miyazu, S., Yasuda, H. and Misawa, S. 2011. Development of Inundation analysis Model for Low-Lying Agriculture Reservoir. Journal of Japan Society of Civil Engineering Vol. 67, No.4, I_991 – I_996.