River Cross-Section Addition from the Google Earth Engine in Downstream of the Ba River

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Abstract

Riverbed depth is the main and essential data to conduct hydrodynamic modeling research. Typically, riverbed topography data is collected directly from cross-sections arranged along the river at relatively distant intervals. This paper presents the results of applying Google Earth Engine technology and high-resolution Sentinel 2 remote sensing images combined with digital elevation model data and field-measured cross-sections to supplement the cross-sections of the downstream Ba River. The reliability of the cross-sections obtained using this technology has been verified against actual measurements at several locations on the mainstream of the Ba River. The research results indicate that most of the interpolated cross-sections are consistent with the actual measured data.

Keywords: *Google Earth Engine, river cross-section, Ba river basin*

1. Introduction

Collecting riverbed topography data is not an easy and simple task as it requires extensive field measurement time and data processing post-survey. However, traditional measurement methods cannot address the scarcity of riverbed topography data. Recently, remote sensing technology has rapidly developed with big data and cloud computing technology. Google Earth Engine (GEE) is an advanced cloud-based geospatial processing platform that utilizes large-scale open-source big data, including petabyte-scale global geospatial images and data [1]. This tool has the potential for exploiting, processing, and analyzing satellite images and other spatial data for various research purposes [2]. Additionally, this technology can overcome the processing issues that traditional satellite image processing methods are facing [3]. Globally, GEE technology can be applied in many fields such as mapping and monitoring land cover [4], land cover classification [5], agriculture [6], disaster management [7], forestry [8], supplementing river cross-sections [9], and determining river width [10], fluvial geomorphology [11], river discharge retrieval [12]. However, in Vietnam, the application of GEE is still quite new, and currently, there are not many studies utilizing this technology. Most studies focus on disaster management fields such as floods [2], droughts [1], and land use changes [13]. Hoang et al. (2020) applied the GEE platform to create drought monitoring maps for the Dong Nai river basin in the Southeast region. The research results demonstrated that the GEE platform is an effective and rapid tool for drought monitoring [1]. Nhung and Thy (2019) also showed the effective application of the GEE tool to analyze the change in forest area and land surface temperature in the Ba-Da Rang river basin [13].

Additionally, Long et al. conducted the exploitation, processing, and analysis of satellite images on the GEE system to extract flood developments and statistically analyze the flood-affected areas over the years in the Dong Thap province [2]. Forest dynamics monitoring in Lam Dong province was also carried out using a remote sensing method on the GEE platform. The results showed that GEE is an effective tool and brings significant efficiency to forest monitoring. Besides GEE applications in disaster management and land use change monitoring, this technology can be applied to supplement river cross-sections. [14] used this method to densify river cross-sections in downstream of the Ca river. The results are used to evaluate saltwater intrusion developments and establish a saltwater intrusion risk map, taking into account the impact of climate change and sea level rise.

Both domestic and international research results have demonstrated the effectiveness of GEE, allowing users to combine various types of spatial data for different analysis and processing purposes. Therefore, this study combined optical satellite images from Sentinel-2, DEM topographic data, and field survey cross-section data to supplement the cross-sections in downstream of the Ba river area for researching and evaluating water resources. The research results will contribute to perfecting the scientific basis for applying new technology in the planning and management of water resources in the study area.

2. Study area

The Ba River is the largest river in the central coastal region with a basin area of 13,508 km². The geographical coordinates of the basin are approximately 12°55' to 14°38' North latitude and 108°00' to 109°55' East longitude [15]. It borders the Tra Khuc River basin to the north, the Cai Ninh Hoa River and the Serepok River basins to the south, the Kone and Ky Lo River basins to the east, and the Sesan and Serepok River basins to the west. The Ba River originates from the peak of Ngoc Ro Mountain at an elevation of 1,549 meters in the Truong Son range. The total length of the main river is 374 km [16].

The Ba River basin (Figure 1) can be divided into various topographical types: the middle and upper reaches are pri-

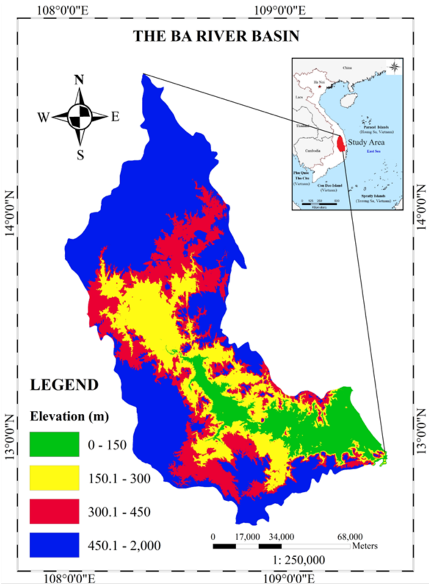


Fig. 1. Research process
Rys. 1. Obszar badawczy

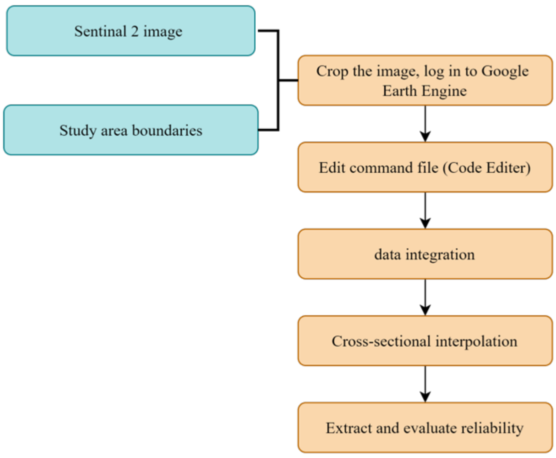


Fig. 2. Flow chart illustrating methodology of the study
Rys. 2. Schemat blokowy prezentujący metodykę analiz

marily mountainous and highlands; the lower reaches feature low hills, valleys, and coastal alluvial plains [17]. The flow in the Ba River basin not only varies greatly across different areas but also changes significantly over time, as evidenced by the fluctuations in seasonal flow and the monthly distribution of flow in various parts of the basin. In the Ba River, the minimum flow (or dry season flow) typically occurs in March or April for rivers and streams in the middle and upper regions, and in April or July for those in the downstream area [18].

3. Data and research methodology

3.1. Data

This study uses a Sentinel-2 remote sensing image with a resolution of 10x10 meters (with a cloud cover rate below 30%) and a Digital Elevation Model (DEM) created from topographic maps of the study area. Sentinel-2 images have a high revisit frequency (one scene per month), a clear processing procedure, and many automated steps. The Sentinel-2 data used in this study were obtained from GEE (ee.ImageCollection('COPERNICUS/S2_SR')) at processing level 2A, which includes atmospheric correction and geometric correction (converted to Bottom-of-Atmosphere Reflectance (RefBOA)). In addition to images and DEM, the study uses actual measured cross-section data to densify river cross-sections from the images. Currently, the actual measured cross-section data at the lower Ba River averages 1.2 to 1.5 km per cross-section.

3.2. Research methodology

Figure 2 shows the process of supplementing river cross-sections using GEE technology. GEE is a cloud computing platform that allows users to run geospatial analyses on Google's infrastructure. GEE operates through an online interface of a JavaScript application (API) called the Code Editor [19].

On this interface (Figure 3), the users can write and run scripts to share and reimplement the analysis process as well as cleaning and wrangling geospatial data. Code Editor helps users perform all features of Earth Engine. This interface is much more flexible than Explorer's and is even capable of conducting highly complex analysis procedures per user's request.

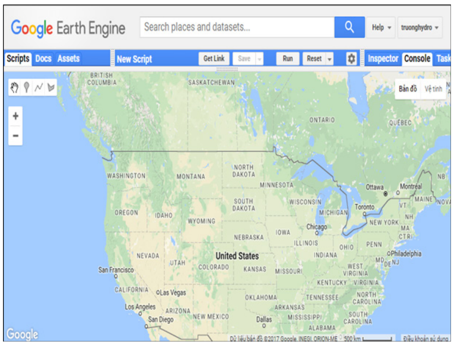


Fig. 3. Register domain to analyze remote sensing image data on Google Earth Engine
Rys. 3. Rejestracja do domeny analizy danych z obrazów teledetekcji w Google Earth Engine

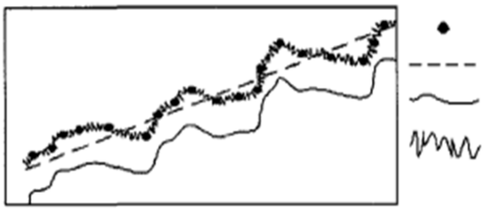


Fig. 4. Main components of Kriging Interpolation [20]
Rys. 4. Główne składniki interpolacji metodą krigingu [20]

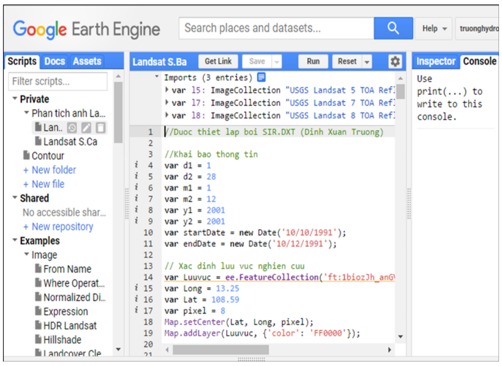


Fig. 5. Code editor in Google Earth Engine
Rys. 5. Edytor kodu w Google Earth Engine

In the Scripts library, there are many sample script files to showcase the capabilities and code that can be used in analyses. Users can review these samples to understand what Earth Engine can perform and then save them in their personal repository. The Docs tab contains a list of guide notes that help identify the types of objects and functions in GEE. Users will use the Inspector (similar to the Identify tool in ArcMap) to view information about map layers at specific locations on the map. The Console will display messages when running scripts and print information about data, products, and intermediate results. The Console will also log any detection messages (such as information or error messages when running scripts). The Tasks tab is used to manage the export of data and the final results of the analysis, which are saved in Google Drive via a Gmail account [19].

The study uses the Kriging interpolation method, which is based on the assumption that spatially varying variables can be represented by a sum of three main components. These are (a) the structural component, which has a constant mean or trend, (b) the random component, which is spatially correlated, and (c) random noise, which is independent of spatial correlation [20].

Figure 4 shows the main components of Kriging interpolation. In this interpolation method, assuming that X is a location in space, the value of a variable Z at that location can be expressed as follows [20]:

$$Z(x) = m(x) + e'(x) + e'' \quad (1)$$

In which: m(x) is a function describing the structured component of Z at X, e'(x) is the spatially correlated component, and e'' is the spatially independent Gaussian noise with a mean value of p = 0 and variance δ^2 [20].

4. Results and Discussion

After signing in to register the domain to analyze remote sensing image data from GEE, the next step is to enter the command file editing window (Code Editor). On the web page of the GEE platform, the JavaScript programming language is used to perform direct execution (Figure 5).

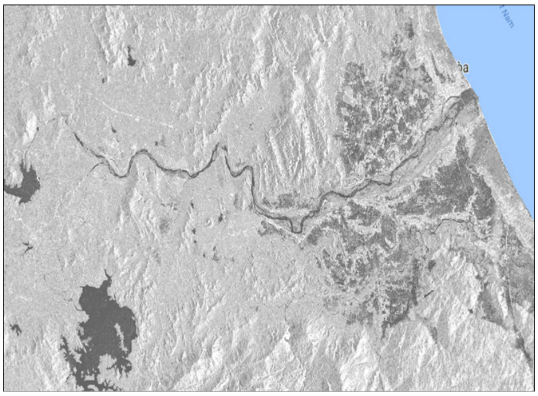


Fig. 6. Incorporation of DEM and Sentinel remote sensing image

Rys. 6. Włączenie DEM i obrazu teledetekcyjnego Sentiel

Fig. 7. Interpolation, supplement cross-section data for downstream of the Ba river area

Rys. 7. Interpolacja, uzupełnianie danych dla przekrojów w dole rzeki Ba

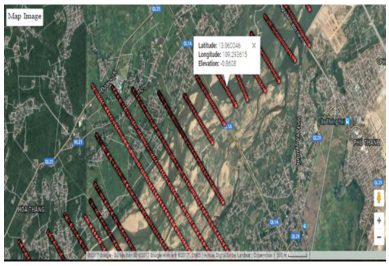
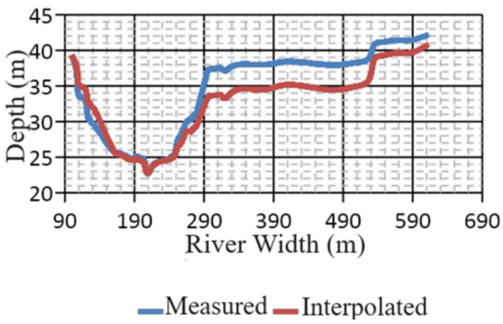


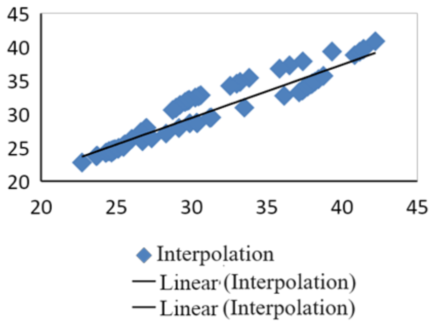
Fig. 8. Depth data of the cross-sections in downstream of the Ba river area

Rys. 8. Dane o głębokości w przekrojach w dole rzeki Ba



a) Actual measured cross-section and interpolation

a) Zmierzone i interpolowane przekroje

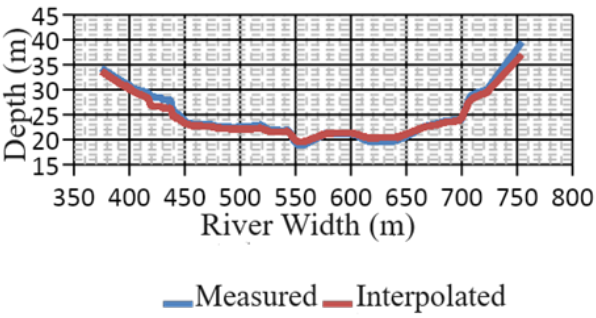


b) Evaluation of realiability of interpolation

b) Ocena wiarygodności interpolacji

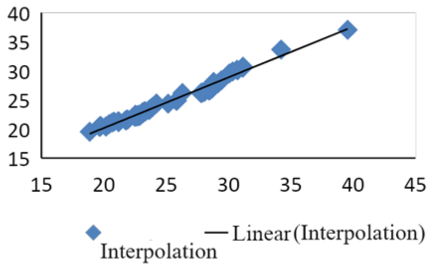
Fig. 9. Cross section of the Ba river in Cung Son

Rys. 9. Przekroje dla rzeki Ba w Cung Son



a) Actual measured cross-section and interpolation

a) Zmierzone i interpolowane przekroje

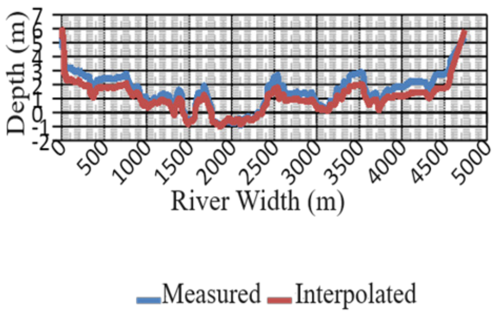


b) Evaluation of realiability of interpolation

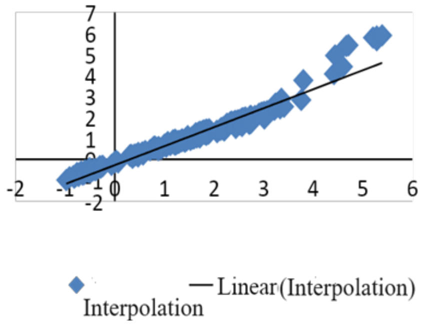
b) Ocena wiarygodności interpolacji

Fig. 9. Cross section of the Ba river in Cung Son

Rys. 9. Przekroje dla rzeki Ba w Cung Son



a) Actual measured cross-section and interpolation
a) Zmierzone i interpolowane przekroje



b) Evaluation of realiability of interpolation
b) Ocena wiarygodności interpolacji

Fig. 11. Cross section of the Ba river in Phu Lam
Rys. 11. Przekroje dla rzeki Ba w Phu Lam

After opening the command window to perform the analysis of remote sensing image data from GEE, the integration of terrain data DEM, Sentinel 2 remote sensing image with a resolution of 10 x 10 meters, and real-life river cross-section data was performed (Figure 6). Nowadays, Sentinel images can alleviate the effects of clouds, allowing for analysis across more time layers. During the driest periods, the water level in the Ba River remains only in the main channels with the lowest water level. Therefore, the riverbanks and edges of the main channels are without water. Using Sentinel images helps determine the elevation of these areas.

The terrain data below the water surface during the driest period is determined by interpolating from the data of actual measured cross-sections. Using GEE technology and the Kriging interpolation method, the cross-sections in the research area will be supplemented. Figures 7 and 8 illustrate the densified cross-sections and the depth data of the cross-sections in downstream of the Ba River area.

To evaluate the reliability of the interpolated cross-section results, the study extracts a number of experimental cross-sections to compare the interpolation results with the actually measured cross-sections at several locations along the mainstream of the Ba River, including Cung Son, Son Hoa, and Phu Lam. At these cross-section locations, the correlation relationship in depth between the measured and interpolated cross-sections is shown in Figures 9, 10, and 11. The results indicate a high correlation coefficient between the measured and interpolated cross-sections at the same location ($R \geq 0.9$), demonstrating the trustworthiness of the supplemented cross-sections for downstream of the Ba River.

5. Conclusions

The study has established a process for processing, calculating, and supplementing river cross-sections using Sentinel 2 satellite imagery, DEM terrain data, and actual measured river cross-section data on the GEE platform for the downstream of the Ba River. The results are compared with the data of the measured cross-sections at several locations such as Cung Son, Son Hoa, and Phu Lam, showing that the research method has high reliability, and the GEE platform is an efficient and effective tool for supplementing river cross-sections. Therefore, it can help reduce time, effort, and costs in measuring river cross-sections, contributing to improving the quality of research on flow regimes in rivers as well as issues related to erosion, channel morphodynamics, and river management.

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Conflicts of Interest

The authors declare no conflict of interest.

Ethical statement

The authors state that the research was conducted according to ethical standards.

Funding body

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Pomiar przekrojów w dolnym odcinku rzeki Ba z uzupełnieniem Google Earth Engine

Głównymi i niezbędnymi danymi do prowadzenia badań modelowania hydrodynamicznego jest głębokość koryta rzeki. Zazwyczaj dane o topografii koryta zbierane są bezpośrednio z przekrojów rozmieszczonych wzdłuż rzeki w stosunkowo odległych odstępach. W artykule przedstawiono wyniki zastosowania technologii Google Earth Engine i wysokiej rozdzielczości obrazów teledetekcyjnych Sentinel 2 w połączeniu z danymi cyfrowego modelu wysokości i przekrojami pomierzonymi w terenie w celu uzupełnienia przekrojów poprzecznych dolnego biegu rzeki Ba. Wiarygodność przekrojów uzyskanych tą technologią została zweryfikowana w oparciu o rzeczywiste pomiary w kilku miejscach głównego nurtu rzeki Ba. Wyniki badań wskazują, że większość interpolowanych przekrojów jest zgodna z rzeczywistymi danymi pomiarowymi.

Słowa kluczowe: *Google Earth Engine, przekroje rzeki, dorzecze rzeki Ba*