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Chiang Rai, Thailand, 11-13 December 2024

GIS IDEAS

CONFERENCE CHAIRS : Venkatesh RAGHAVAN & Phaisarn JEEFOO

EDITORS : Natraj VADDADI, Sittichai CHOOSUMRONG & Chaiwiwat VANSAROCHANA

Osaka Metropolitan University

Association of GeoInformatics Laboratories for EarthSciences

Technical Document 1

GIS-IDEAS 2024

DECEMBER 11 to 13TH 2024

UNIVERSITY OF PHAYAO (UP)

CHIANG RAI, THAILAND

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GeoInformatics for Spatial - Infrastructure Development in Earth & Allied Sciences

The International Conference on GeoInformatics for Spatial-Infrastructure Development in Earth & Allied Sciences (GIS-IDEAS) provides a platform for sharing of knowledge and valuable experiences and help promote collaborations and scientific exchanges between not only between students, researchers and practitioners Japan, Vietnam and Thailand but also our other colleagues involved in developing and promoting GeoInformatics technologies. The conduct of GIS-IDEAS Conferences is based on the spirit of mutual cooperation and openness.

GIS-IDEAS is planned around a central theme which is decided in consultation with the host institution. Apart from Technical Sessions on GeoInformatics technologies and applications, Special sessions on different topics related to Geo-informatics are also held during the conference.

GIS-IDEAS is organized in collaboration with premier institutes located in Asia. GIS-IDEAS which was founded in 2002 to develop and promote Geoinformatics applications and foster cooperation in application of Information and Communication Technologies to problems and issues related to our natural and social environment. To achieve these aims, the conference aims to;

- support capacity building through organization of symposia, workshops and fieldwork.
- share information resources and know-how in Geoinformatics
- promote research collaborations and joint research in Geoinformatics
- promote exchange of information and academic publications
- develop a human resource network to support development and growth of Geoinformatics

Previous GIS-IDEAS Conferences were organized in collaboration with premier institutions like Can Tho University (VN), Danang University of Education (VN), Japan Geotechnical Consultant Association (JP), Japan Society of Geoinformatics (JP), Hanoi University of Mining and Geology (VN), Hanoi University of Natural Resources & Environment (VN), Ho Chi Minh City University of Technology (VN), Kyoto University (JP), Naresuan University Thailand, Osaka City University (JP), Osaka Metropolitan University (JP), Vietnam National University (VN) and others.

From the Conference Chairs

Our best wishes to the GIS-IDEAS Community for a Happy New Year! We are very happy to bring out this volume of the GIS-IDEAS 2024 Conference Proceedings, that was held from December 11–13 in the vibrant city of Chiang Rai, Thailand. As we look back at this exciting event, we feel immense satisfaction to continue the proud tradition of fostering global collaboration and innovation in geoinformatics that began with the establishment of the Japan-Vietnam Geoinformatics Consortium (JVGC) in 2001.

The GIS-IDEAS 2024 conference provided a unique platform to exchange ideas, share knowledge, and explore the latest advancements in spatial sciences, urban planning, and environmental sustainability. The beautiful and culturally rich Chiang Rai offered a excellent venue to discuss how Geoinformatics can address some of the most pressing global challenges. With a program that included inspiring keynote speeches, dynamic technical sessions, and hands-on workshops, GIS-IDEAS 2024 promises to deliver insights and solutions that will resonate well beyond the event.

We extend our heartfelt thanks to all the contributors whose research enriches the proceedings of this conference. Our deepest appreciation to our wonderful host the University of Phayao and to various conference committees, faculty, staff, and students who work tirelessly to ensure the event's success. Special acknowledgment is due to our sponsors and supporters, whose generous contributions enable us to create a collaborative and vibrant platform to showcase innovations and current trends in Geoinformatics research and application. We also express out thanks to the editors and manuscript reviewers and commend their hard work to bringing out the proceedings in a timely manner.

Together, we hope to kindle innovative ideas, foster meaningful collaborations, and deepen the connections that unite the Geoinformatics community worldwide. Your participation and support are integral to the success of GIS-IDEAS 2024, and we look forward to the insights, discoveries, and partnerships that this conference will inspire.

Thank you Chiang Rai!, and See you at GIS-IDEAS 2026!! Warm regards,

Phaisarn JEEFOO & Venkatesh RAGHAVAN

Chairs, GIS-IDEAS 2025 Dt: January 2025

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DR PAKORN PETCHPRAYOON

Dr. Pakorn Petchprayoon is the Director of the Geo-Informatics Product Innovation Office at the Geo-Informatics and Space Technology Development Agency (GISTDA). His research focuses on understanding the physical processes of energy exchange between the land and water surfaces and the atmosphere by integrating satellite data with direct field measurements. Dr. Petchprayoon has dedicated 23 years to GISTDA, contributing in various research and leadership roles. He has authored and co-authored several publications and was a lecturer on GEOG 4093 Remote Sensing of the Environment at the University of Colorado, Boulder, USA. Dr. Petchprayoon holds a B.S. from Burapha University, M.S. from Mahidol University, and M.A. and Ph.D. from the University of Colorado-Boulder, USA.

DR SUSUMU NONOGAKI

Dr. Susumu Nonogaki is a Geo-informaticist and Chief Senior Researcher at the Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology (AIST). He earned his Ph.D. in Geosciences from Osaka City University in 2009 and specializes in 3D modeling and analysis of shallow subsurface geological structures in urban areas of Japan. His expertise encompasses GIS analysis, spatial interpolation, machine learning, geo-visualization, and web mapping. From 2005 to 2012, he lectured on GIS techniques for sustainable natural resource management and agricultural productivity in JICA training programs. Since 2010, he has been a member of the Scientific Committee for GIS-IDEAS. His work supports urban development and planning, contributing to safer, more sustainable cities through improved understanding of urban geological conditions.

PROF. SONG XIANFENG

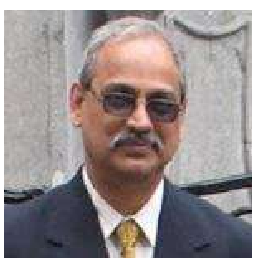
Prof. Song Xianfeng is a distinguished expert in Geographic Information Sciences (GIS) and Remote Sensing Hydrology, focusing on geospatial data mining using vehicle GNSS trajectories, cellular network signalling, and DVR data. He holds an MS in Remote Sensing Geology (1995) from China University of Mining & Technology, along with a PhD in GIS from the Chinese Academy of Sciences (1998). He is presently serving as a Professor at the University of Chinese Academy of Sciences since 2011, following roles as Associate Professor and Assistant Professor there and at Kyoto University. His industry experience includes managing IT for the Chinese Investment Corporation for Sciences and Technology.

The Keynote speakers

DR TRAN VAN ANH

Dr. Tran Van Anh is a lecturer at Hanoi University of Mining and Geology (HUMG). She obtained her Master's degree in Surveying and Mapping Engineering from HUMG, Vietnam, in 2001 and her PhD degree in GeoInformatics from Osaka City University (Japan) in 2007. Her field of study is remote sensing and GIS. She has working interests in Radar Interferometry (InSAR) for land deformation detections and optical images for air pollution (PM10) determination. Besides that, she also works on geospatial data research and builds predicting models. She has had more than 50 works published in prestigious domestic and international journals.

DR NATRAJ VADDADI



Dr. Natraj Vaddadi, an Executive Member of the Governing Council at the Centre for Education & Research in Geosciences, is a geologist specializing in Urban Groundwater Recharge through Rainwater Harvesting. He holds a Master's degree in Geology from the University of Pune and a Ph.D. in Natural Resources and Environment from Naresuan University, Thailand. With over three decades of teaching experience, he serves as a Visiting Professor in Petroleum Technology at Nowrosjee Wadia College and teaches postgraduate courses in Drilling Engineering and Production Operations at the University of Pune.

Dr. Vaddadi has conducted numerous workshops on Open-Source GIS in India, Thailand, and Vietnam and is the author of the internationally acclaimed book *An Introduction to Oil Well Drilling*. As a founding member of the Centre for Education & Research in Geosciences, he advocates for geoscience education, promoting its integration into environmental conservation and sustainability initiatives.

GIS-IDEAS 2024 – CONTENTS

PROCESSING AND ANALYZING MULTI-SOURCE, MULTI-RESOLUTION GEOSPATIAL DATA ON CLOUD PLATFORMS FOR SOME ENVIRONMENTAL AND DISASTER APPLICATIONS

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ABSTRACT

Recently, our earth has been facing increasingly severe conditions due to various climate change phenomena. Natural disasters such as storms, floods, and landslides have become more frequent. Monitoring changes or deformations in the land surface has thus become more crucial. While processing data over large areas often provides a comprehensive view for assessing the extent of changes and damage caused by natural and human factors, it requires handling vast amounts of data. Fortunately, cloud computing platforms have become more powerful and are now supporting numerous studies in earth science and environmental monitoring. This article provides an overview of how two cloud computing platforms, Google Earth Engine (GEE) and Google Colab (GC), are utilized to process large datasets for monitoring and forecasting land surface changes in various regions of Vietnam. Four examples of applications using GEE and Google Colab include: analyzing open-pit coal mine changes using Sentinel-1 and Sentinel-2 satellite images on the GEE platform; predicting landslides using Support Vector Machine (SVM), Random Forest (RF), and Gradient Boosting (GB) machine learning models on the GEE platform; monitoring landslides from Sentinel-1 Radar image series using PyGMTSAR on Colab, and last is forecasting land subsidence using a subsidence value series from 2015 to 2023 showcasing the capabilities of these platforms.

1. INTRODUCTION

In recent years, the use of satellite image processing for applications related to natural resources, the environment, and natural disasters has become increasingly widespread. Combining satellite imagery with geospatial data has enhanced the accuracy of land cover interpretation and the monitoring of surface changes. Machine learning models and artificial intelligence, when integrated with multi-source data, have been instrumental in forecasting natural disasters such as floods, landslides, and subsidence, thereby helping to mitigate risks to human life.

Given the large volume of imagery and geospatial data, the diversity of sources and formats, and their growing accessibility, these datasets can be classified as "big data" (Laney 2001, Diebold 2012). Cloud computing platforms, which function as virtual supercomputers, provide access to vast processing and computational resources for various data types. In addition, cloud computing allows flexible data storage, enabling more efficient post-processing.

Several current cloud computing platforms are relevant to natural resources and environmental applications. Amazon Web Services (AWS) offers access to the largest suite of machine learning and artificial intelligence (AI) services. AWS hosts various satellite imagery datasets, including Sentinel-1, Sentinel-2, Landsat 8, and the National Oceanic and Atmospheric Administration's (NOAA) High-Resolution Rapid Refresh (HRRR) Model. Google Cloud Platform (GCP), introduced by Google in 2008, is a public cloud-based service designed for developing and hosting web applications in Google-managed data centers on a pay-as-you-go basis. GCP offers services such as data storage, analytics, machine learning tools, and enterprise mapping services (Krishnan and Gonzalez 2015).

In 2010, Microsoft launched Azure, a cloud computing platform for building, testing, deploying, and managing applications and services via Microsoft-managed data centers (Wilder 2012). Azure provides machine learning services and hosts satellite data products such as Landsat, Sentinel-2 for North America (from 2013 to present), and MODIS imagery (from 2000 onwards).

More recently, Google Earth Engine (GEE) has emerged as a prominent platform for big data processing in geospatial applications. GEE is a cloud-based platform that enables parallel processing of geospatial data at a global scale using Google's cloud infrastructure (Gorelick, Hancher et al. 2017). GEE is a free platform hosting petabyte-scale archives of over 40 years of remote sensing data, including Landsat, MODIS, Sentinel 2, 3, and 5-P, as well as meteorological datasets like NOAA AVHRR and radar satellite data from ALOS PalSAR 1, 2, and Sentinel-1 (Gorelick et al., 2017). GEE also includes geospatial datasets related to climate, weather, and geophysics, and offers ready-to-use products such as monthly and daily rainfall data from satellite and ground-based rain gauges, and the Normalized Difference Vegetation Index (NDVI) (Kumar and Mutanga 2018).

GEE's notable strength lies in its ability to process large-scale satellite data without requiring users to download data locally, thanks to Google's powerful server infrastructure. This infrastructure allows users to access millions of optical and radar satellite images, as well as environmental data from various sources. GEE provides robust tools for processing and analyzing satellite data, including image operations, time series analysis, and the generation of environmental maps and indices. Additionally, GEE offers a code editor via a web-based Integrated Development Environment (IDE), enabling users to write, develop, and execute complex scripts using JavaScript APIs (Kumar and Mutanga, 2018).

However, while GEE is a powerful tool for processing and analyzing satellite data, it has limitations when it comes to applying advanced data analysis methods, such as artificial intelligence (AI), machine learning, and deep learning. GEE primarily focuses on image data processing and offers direct support for only a limited range of machine learning algorithms, which may restrict users from conducting more detailed analyses. This is where Google Colab becomes essential.

Google Colab is an online notebook environment that strongly supports Python and data analysis libraries such as TensorFlow, PyTorch, and scikit-learn. It allows users to perform advanced data analysis and build machine learning or deep learning models without worrying about hardware limitations.

The combination of GEE and Colab creates a more efficient data analysis workflow. Users can leverage GEE to retrieve and process large-scale satellite data and then export the data to Colab to apply AI and machine learning algorithms to uncover deeper patterns and insights. For instance, after generating environmental indicators from satellite data in GEE, users can use Colab to develop and train machine learning models to analyze environmental changes or predict future trends.

In this paper, we aim to explore the capabilities of GEE in analyzing multi-source satellite data over time and integrate it with machine learning algorithms to predict surface changes such as the expansion of open-pit mining Thai Nguyen and landslide prediction in a mountainous region of Vietnam. Additionally, we will show a landslide monitoring study using a multi-temporal Sentinel-1 complex image series for the 2019-2020 period, as well as a land subsidence forecast for a small area in the Mekong Delta of Vietnam.

2. METHODOLOGY

2.1 Google Earth Engine (GEE) Applications

As presented in the introduction, GEE is a cloud computing platform with large data sources related to satellite image data and geospatial data. Below is a summary of some of the functions of GEE (Tamiminia, Salehi et al. 2020)

Table 1. Some algorithms and features available in the Google Earth Engine Code Editor.

Order	Package	Capabilities	Order	Package	Capabilities
1	Machine learning	- Supervised Classification - Unsupervised Classification - Regression	4	Geometry Feature Feature Collection	-Filtering - Mapping - Reducing -Vector to raster Interpolation
2	Image	- Image Visualization - RGB composites - Color plates - Masking - Mosaicking - Clipping - Rendering categorical maps - Thumbnail	5	Image Collection	- Histograms - Image Regions charts - Time-series in Image Regions - Charts by image classes - Iterating over an image collection ……………..

		images - relational, conditional) - Edge detection - Texture - Spatial Transformation - Object-based Methods - ……..			
3	Charts	Time-series charts	6	Specialized algorithms	- Landsat algorithms - Sentinel-1 algorithms - Resampling and Reducing Resolution

As discussed, the remote sensing data processing capabilities of GEE have encouraged researchers to leverage this technology for various environmental applications (Table 1). GEE's ability to store geospatial datasets, along with its features for coding, sharing, processing, and visualizing data, has made it a standout competitor among existing cloud platforms. Although several studies have explored geospatial big data analytics, they have primarily focused on its characteristics, existing tools, and applications (Chi, Plaza et al. 2016); (Tamiminia, Salehi et al. 2020). In the fields of remote sensing and spatial data analytics, a Google Scholar search returns approximately 356,000 results that related to the GEE, underscoring the effectiveness of GEE's tools and functionality in meeting the demands of image and geospatial data analysis and processing. Figure 1 below shows the GEE interface.

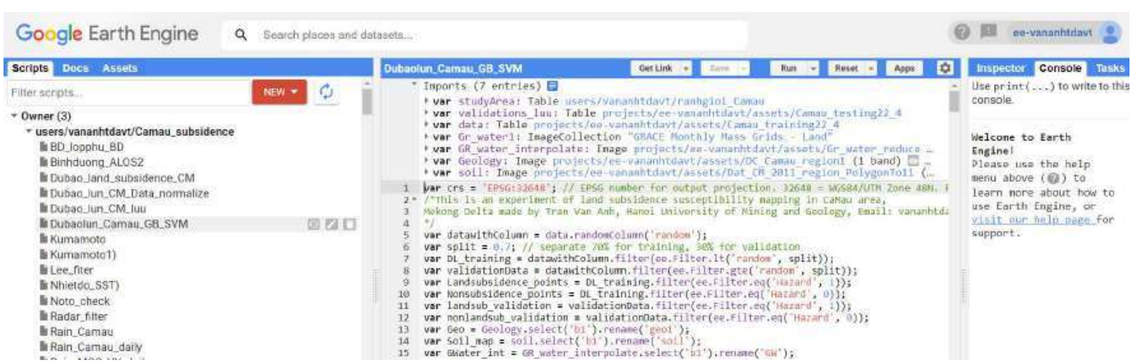

Figure 1. Google Earth Engine Platform

2.2 Applications of the Google Colab Platform

The Google Colab cloud platform is a web-based service that provides users with a coding environment equipped with powerful computing resources, tools, and functions, enabling complex analyses on large datasets. These resources, including storage and highperformance servers, are hosted by the provider and accessed by users through a web browser. With the exponential growth in data and increasingly complex analytical methods used by researchers and businesses, cloud platforms are becoming more advantageous. The availability of GPUs and TPUs, accessible from a user's personal computer, allows for advanced analysis to be performed without the need for expensive hardware. Additionally, many cloud services offer analytics-ready data or access to datasets via APIs, making it faster and easier to collect and utilize diverse data types.

Unlike GEE, Google Colab supports running machine learning and deep learning algorithms from various libraries and can integrate with other platforms like Kaggle, Jupyter, or GEE for advanced Earth observation and geospatial data analysis. Google Colab uses Python, a widely popular language for geospatial data analysis. Figure 2 below shows the Google Colab interface.

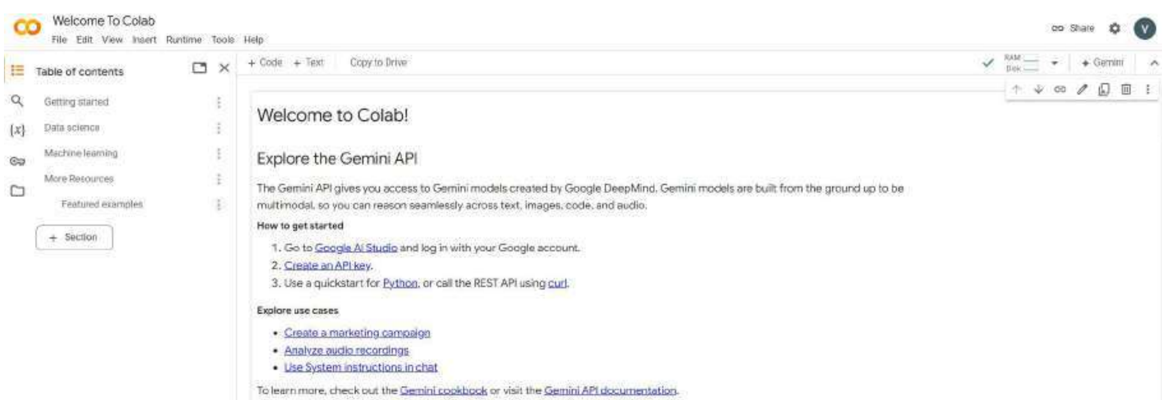

Figure 2. Google Colab Platform

3. UTILIZING CLOUD COMPUTING PLATFORMS FOR ENVIRONMENTAL AND RESOURCE DATA ANALYSIS AND PROCESSING

3.1 Application of Google Earth Engine (GEE) to determine the expansion of open-pit coal mines through the use of optical satellite imagery, radar data

The study focuses on the Minh Tien coal mine, located in the communes of Minh Tien and Na Mao in Thai Nguyen province, Vietnam. Licensed in 2014 with an approved extraction capacity of 8,500 tons per year, the mine began open-pit operations in 2018, significantly increasing its output beyond the licensed limit. As the mining areas have expanded, waste material from the mine has been deposited near agricultural lands, posing environmental risks and threatening the livelihoods of local residents. This study monitors the mine's expansion using satellite data available on Google Earth Engine, including both radar Sentinel-1 images and Sentinel-2 optical images. Figure 3 is Flowchart of data processing.

The processing for multi temporal Sentinel-1 images in both ascending and descending directions and Sentinel-2 to calculate the Normalized Difference Vegetation Index (NDVI) series to control the different trends from 2016 to 2021. NDVI is then employed to mask the areas with vegetation that witness no abrupt changes in the land cover. This NDVI also acts as the basis for collecting samples for Random Forest classification of the Sentinel-2 images. The results from Sentinel-1 and Sentinel-2 combined with MASK from NDVI have determined the expansion area of the Minh Tien coal mine. The results are compared with those published on the website of Thai Nguyen Portal and have a significant similarity (Van Anh, Hanh et al. 2022).

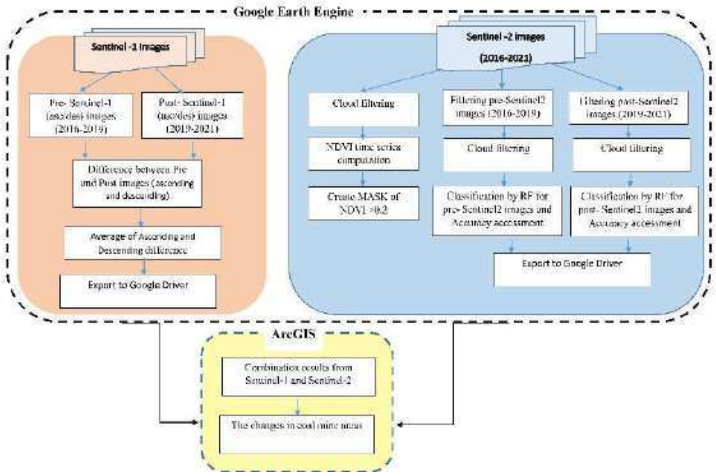

Figure 3. Flowchart of data processing

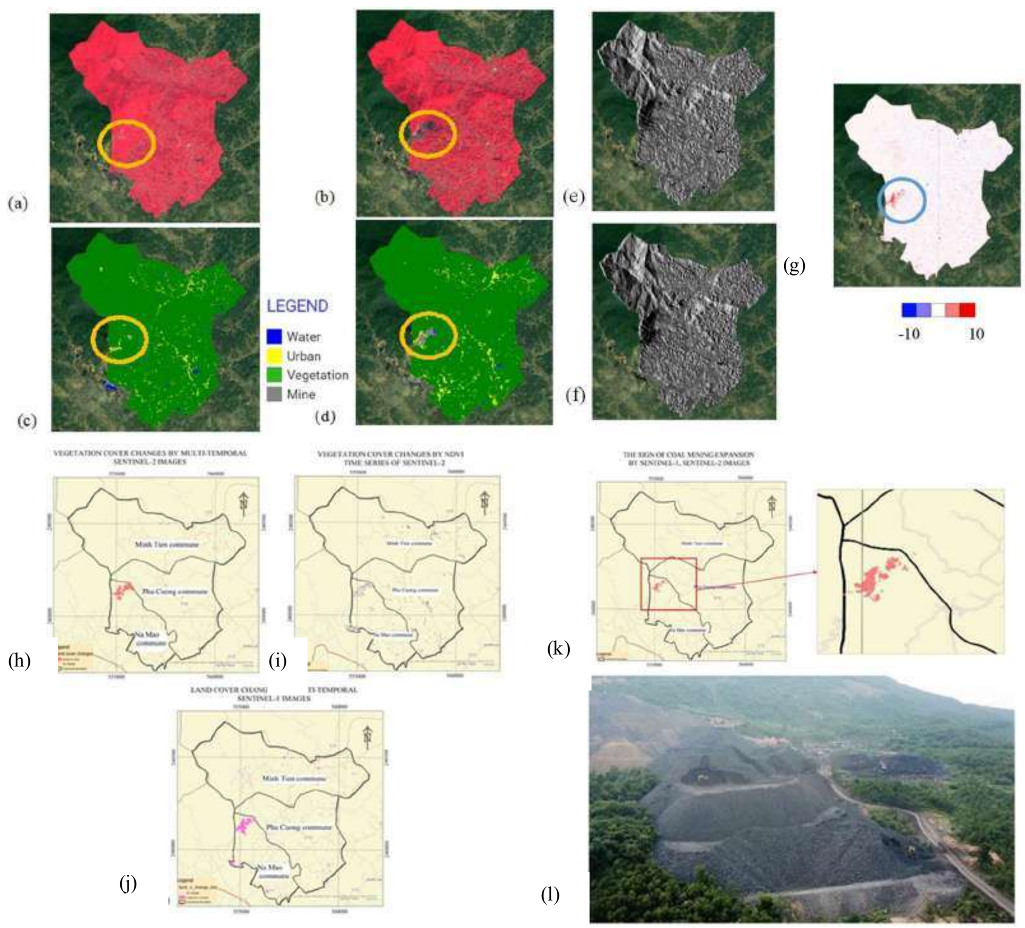

Figure 4. (a) Sentinel-2 image (2016-2019) median filter, (b) Sentinel-2 images (2019-2021) median filter, (c) RF classification image (2016-2019), (d) RF classification image

(2019-2021), (e) Sentinel-1 image before 2019, (f) Sentinel-1 image after 2019, (g) subtraction between the two times of Sentinel-1 images, (h) Land cover changes by Sentinel-2, (i) NDVI MASK, and (j) land cover changes by Sentinel-1 images. (k) Result of expansion of coal mine area from 2016 to 2021, (l) a photo at the location of the Minh Tien coal mine taken in September 2021

3.2 Building a landslide susceptibility map using SVM, RF and GB on GEE platform

Our study focuses on some of the capabilities of GEE in landslide prediction modeling. We tested three algorithms for the Van Yen area, Yen Bai, Vietnam. The study employed data from 13 factors influencing landslides, along with field survey data and PSI-InSAR analysis of Sentinel-1 imagery, to develop landslide susceptibility maps using Support Vector Machine (SVM), Random Forest (RF), and Gradient Boosting (GB) machine learning models. (Tran, Khuc et al. 2024)

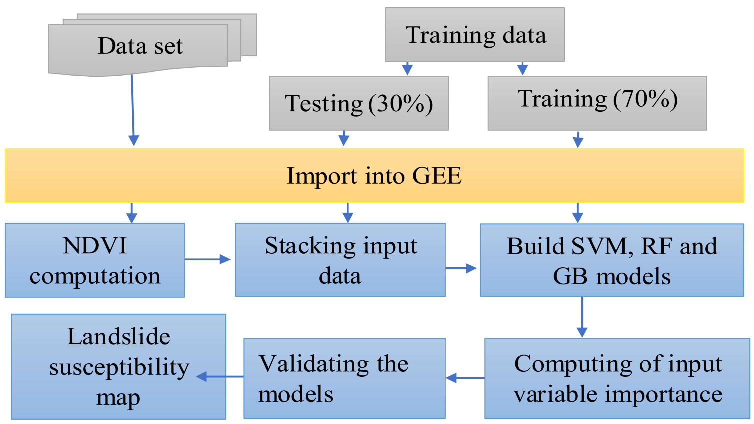

Figure 5. Flowchart of model building for landslide prediction

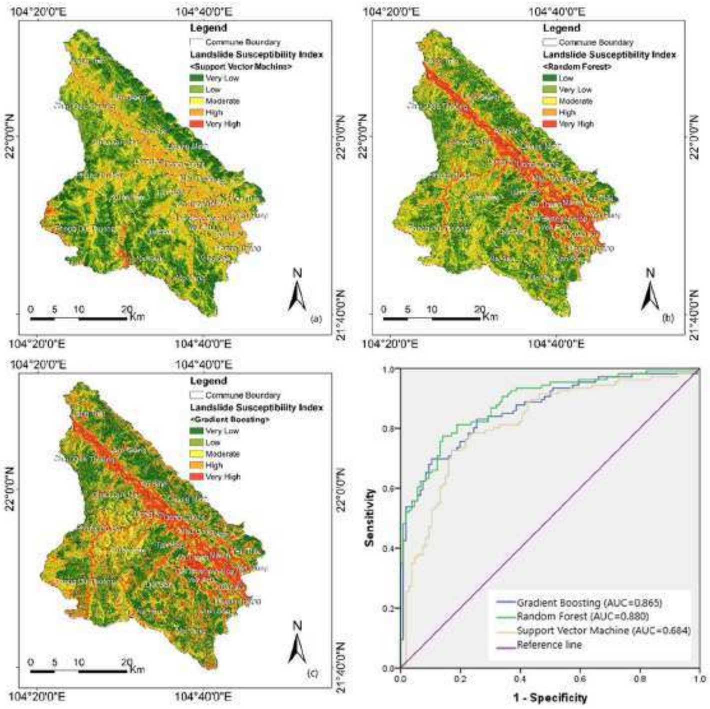

Figure 6. Landslide susceptibility map predicted by models: (a) SVM, (b) RF, (c) GB

The findings revealed that areas with high landslide susceptibility were concentrated along major transportation routes in the districts of Chau Que Ha, Phong Du Ha, and Phong Du Thuong. The results showed that the combination of models improved the accuracy of landslide susceptibility maps, with the Random Forest model outperforming Gradient Boosting and Support Vector Machine, achieving AUC values of 0.880, 0.865, and 0.684, respectively. Additionally, the Google Earth Engine (GEE) cloud platform proved highly effective by integrating vast cloud-based datasets and applying efficient machine learning algorithms to build predictive models.

3.3 Landslide monitoring on Colab GMTSAR platform based on Sentnel-1 Radar image series in the period 2019-2020

As mentioned above, GEE has the ability to obtain and process satellite image data and geospatial database sources quite well, however, for complex Radar images, GEE is not capable. PyGMTSAR was developed by Dr. Eric Fielding and his team at the Jet Propulsion Laboratory (JPL), part of the California Institute of Technology (Caltech), as part of their initiative to create accessible and efficient tools for processing and analyzing SAR data within the scientific community. PyGMTSAR is an open-source, Python-based software package designed for studying Earth's surface deformation through synthetic aperture radar (SAR) data. It integrates with GMT5SAR, another SAR data processing toolkit, and provides various features and utilities for SAR analysis. A new use case for PyGMTSAR, focusing on SBAS analysis by Alexey Pechnikov (Pechnikov 2024), is now available on Google Colab

In this study, we processed data for 18 Sentinel-1 images of Van Yen area, Yen Bai province, Vietnam to monitor landslides during the period from 2019-2020. The processing procedure is as shown in figure 6.

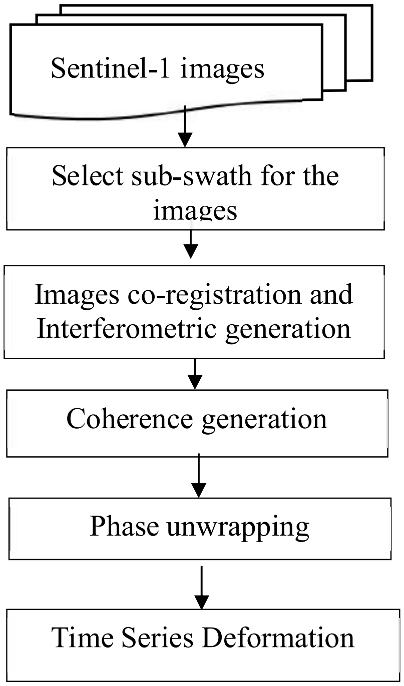

Figure 7. Flowchart of landslide monitoring on PyGMTSAR on Google Colab

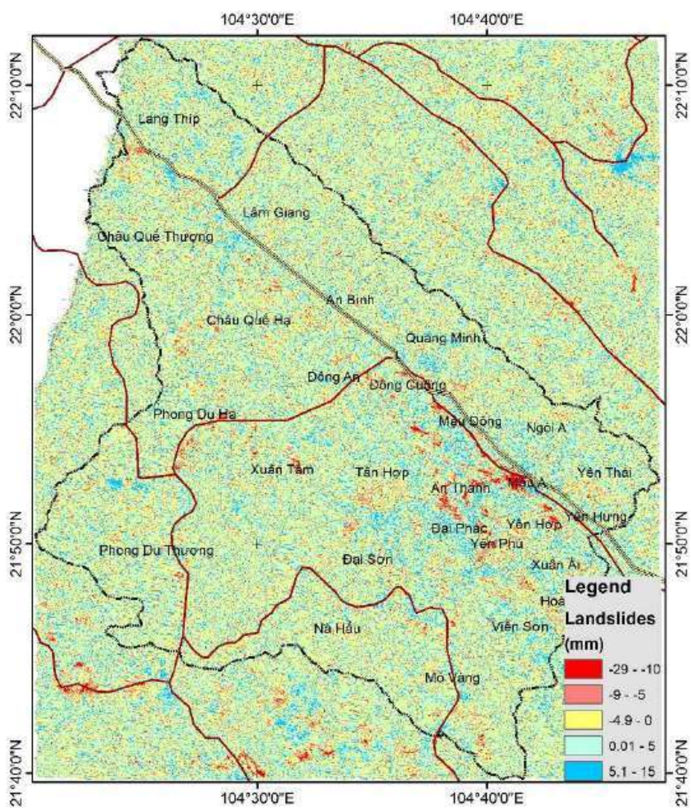

Figure 8. Landslide monitoring in Van Yen, Yen Bai, Vietnam by PyGMTSAR on Google Colab

3.4 Land Subsidence Forecasting on Google Colab Using Data Series Processed from Sentinel-1 Radar Images

As discussed above, GEE offers significant benefits by allowing us to access and process available data without the need to download it to our personal computers. However, specialized processing tools, such as machine learning and deep learning, are somewhat limited in GEE. In contrast, Google Colab, with its support for Python programming, is a valuable tool that integrates with various open-source libraries, making it effective for generating forecast maps. In this application, we highlight the use of the XGBoost machine learning algorithm for forecasting land subsidence based on results from multi-temporal radar image processing of the area around Ca Mau city from 2015 to 2023. Unlike our previous studies that used the Boosting Model to predict subsidence susceptibility, this study focused on estimating the subsidence values one year after the end of the subsidence data series (Tran, Brovelli et al. 2024), (Tran, Khuc et al. 2023). The figure 9 illustrates a subsidence forecast flowchart generated on Google Colab.

To forecast subsidence, we utilized the subsidence value series generated by the PSInSAR method for the period from 2015 to 2023. This time series included 92 subsidence data columns used as input data. A total of 5,290 PS points were selected to build the subsidence forecast model for this area. The set of points was divided, with 70% used for training the model and 30% used for accuracy evaluation. Figure 10 shows the results of land subsidence prediction interpolated by the Kriging algorithm.

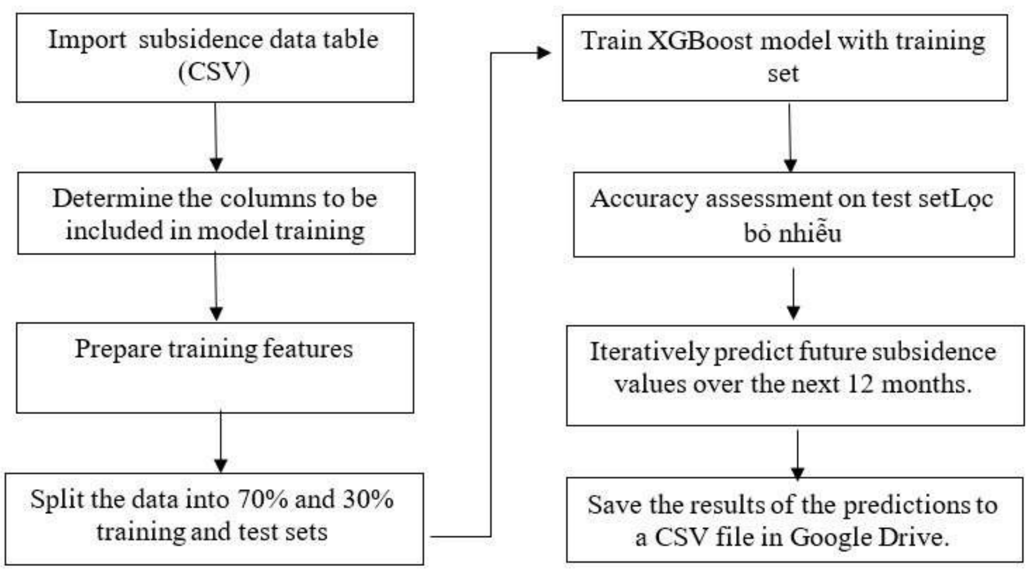

Figure 9. Subsidence forecasting diagram made on Google Colab

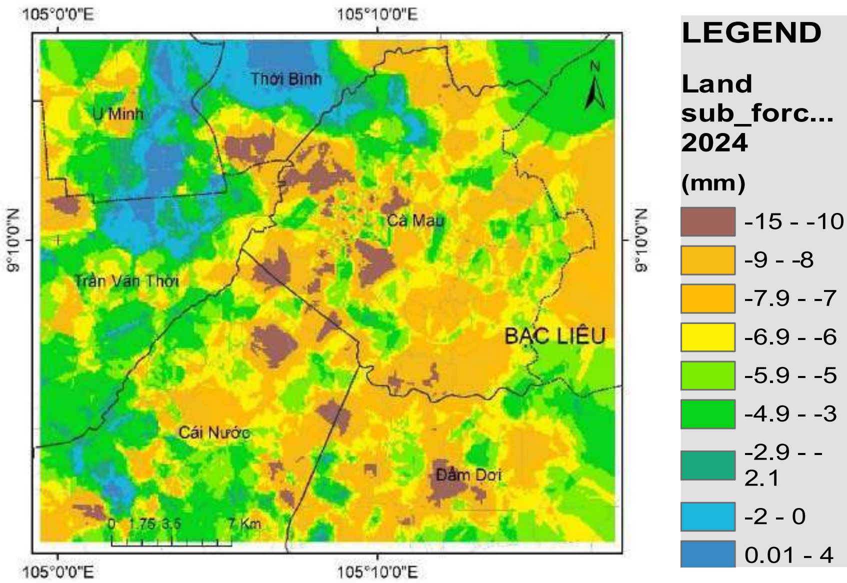

Figure 10. Subsidence forecasting map for 2024 using XGBoost algorithm

The settlement forecast was calculated for the 12 months leading up to the end of the data series, from May 2022 to May 2023. The purpose was to use this 12-month period to assess accuracy before proceeding with the forecast for the following 12 months. A total of 4,232 points were included in the forecast. . Statistical metrics such as RMSE, MAE, and R^2 were employed to assess the accuracy. The RMSE, MAE, and R^2 of 12 months under assessment is presented in the table below.

Table 2. Evaluation error for 12 columns of test data

Month	RMSE (mm)	MAE (mm)	R^2
1	4.13	2.25	0.992
2	3.76	2.34	0.992
3	3.94	2.36	0.991
4	4.44	2.76	0.991
5	4.63	2.87	0.989
6	4.49	2.74	0.989
7	4.70	2.87	0.990
8	4.46	2.72	0.991
9	4.53	2.82	0.989
10	5.33	3.31	0.986
11	5.44	3.45	0.985
12	3.31	1.64	0.994
Average	4.43	2.6775	0.989

The forecasted subsidence over the 12-months was compared with the final time point in the data series from May 2023. The results indicated that the most significant subsidence occurred around Ca Mau city, with additional points around Cai Nuoc district, Tran Van Thoi, and a few in U Minh district. Over one year, the highest recorded subsidence was -14 mm, primarily concentrated in Ca Mau city and the Cai Nuoc area.

4. CONCLUSION

In this study, four applications using the GEE and Google Colab platforms were highlighted: (1) monitoring coal mine expansion in Thai Nguyen, Vietnam, (2) creating a landslide susceptibility map with machine learning on the GEE platform in Van Yen district, Yen Bai province, Vietnam, using SVM, RF, and GB algorithms, (3) monitoring landslides from Sentinel-1 radar image series using PyGMTSAR on Colab, and (4) forecasting land subsidence using a subsidence value series from 2015 to 2023. These applications demonstrate the strengths of both GEE and Google Colab. By utilizing them, users can leverage GEE's capabilities in processing large-scale datasets and Colab's advanced data analysis tools. This combination not only streamlines workflows but also unlocks new possibilities for research and applications across various fields

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