MONITORING RICE PADDY AND FLOOD IN THE LOWER MEKONG BASIN

APPLICATION TO THE GEO-AMAZON EARTH OBSERVATION CLOUD CREDITS PROGRAMME

by

HO CHI MINH CITY SPACE TECHNOLOGY APPLICATION CENTER (STAC), VIETNAM NATIONAL SPACE CENTER (VNSC/VAST)

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APPLICATION FORM

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Implementing Organisation, Collaborators and End-Users

Both rice and flood monitoring projects will be implemented by the HCMC Space Technology Application Center (STAC) of the Vietnam National Space Center (VNSC). The following STAC personnel will be directly involved for these projects

- Dr. Lam Dao Nguyen – Director of STAC/VNSC, will provide overall leadership
- Mr. Pham Bach Viet – Coordinator for the GEO - Amazon EO Cloud Credits Programme
- Dr. Pham Thi Mai Thy – Member
- Mr. Hoang Phi Phung – Member
- Mr. Nguyen Van Anh Vu – Member
- Ms. Nguyen Kim Thanh – Member

Dr. Thuy Le Toan, Center for the Study of the Biosphere from Space (CESBIO), France, Professor Armando Apan and Dr. Thong Huy Nguyen, University of Southern Queensland (USQ), Australia, will collaborate with on these projects. They will provide expertise on application development and image analysis.

The multi-disciplinary nature of end-users (and most of them are also collaborators) will maximize diversity of knowledge and opinions valuable in optimising the success of the projects and their benefits. These organisations include the following:

- Regional Flood Management and Mitigation Center (RFMMC) / Mekong River Commission (MRC) (Dr. Lam Hung Son, Head of RFMMC)
- Center for Informatics and Statistics (CIS) / Ministry of Agriculture and Rural Development (MARD), Vietnam
- Department of Crop Production (DCP), MARD, Vietnam
- Faculty of Agriculture, An Giang University (AGU)
- General Statistical Office, Ministry of Planning and Investment
- MARD Statistical Divisions of Provinces, Districts, Communes
- Local farmers and extension workers in An Giang Province

EXECUTIVE SUMMARY

Earth observations (EO) data and geospatial information are assets and tools that support the goals of international agenda, programs and projects dealing with earth's resources and their conditions. For instance, the attainments of the *United Nations 2030 Agenda for Sustainable Development* will benefit from Earth observations in making decision for target planning, as well as for monitoring progress and reporting of outcomes. In Vietnam, remote sensing and GIS technologies are being used in several application areas, such as agriculture, forestry, water resources, environmental management, land use change, and disaster management.

This proposal aims to establish cloud computing services to host, process and analyse big Earth observation (EO) data and geospatial information for our projects focused on a) monitoring rice paddy (agriculture) and b) flood (disaster and water resources management). AWS cloud credits will allow us to build EO applications on these areas relevant to Vietnam's national and international commitments, such as for the *UN Sustainable Development Goals* (e.g. Goal 2 Zero Hunger, Target 2.c, and Indicator 2.4.1.) and *Sendai Framework for Disaster Risk Reduction* (e.g. on Priority 1 (Understanding disaster risk)).

Both projects cover the Lower Mekong Basin. It is a part of the Mekong River, which is the tenth-largest river in the world. The entire Mekong River basin drains a total land area of 795,000 km^2 and flows approximately 4,909 km through six countries (China, Myanmar, Lao PDR, Thailand, Cambodia, and Vietnam). The Lower Mekong Basin covers 76% (about 604,200 km^2) of the total area of the Mekong River basin and contributes 80-85% of the water that flows into the Mekong River. In Cambodia, 40% of the population depends on the Tonle Sap Great Lake and its flood plains for their livelihoods. Similarly, the Mekong Delta in Vietnam is vital for the people in Vietnam, as large area in the Delta is farmed intensively.

Our application for the *GEO-Amazon Earth Observation Cloud Credits Programme* aims to support two major projects requiring suitable spatial handling, infrastructure, processing methods, and data security for EO Big Data datasets. The first project aims to identify, map and monitor rice paddy areas and cropping system. The data and time period for this study will involve radar imagery (Sentinel-1) from 2014 to present, and optical data (MODIS from 2000). For the second project, the goal of flood monitoring is to identify, map and monitor flood-inundated areas. This study will involve radar data (Sentinel-1) from 2014 to present, and optical data (MODIS) from 2000, focusing on rainy season.

Although we have conducted several projects on rice crop in the past, opportunities exist this time to conduct more innovative approaches involving time-series data analysis covering wider temporal extent. These will allow better use of data and information for commodity forecasting and ensuring food security. Similarly, while we have conducted flood-related mapping projects before, this proposed project on flood monitoring utilising the GEO-Amazon Earth Observation Cloud will provide new and improved ways of analysing, summarizing and visualizing floods.

The design principles of the system will focus on providing the ability for various users to make on-demand display, mapping, time-series visualization, and analyses of EO data. Users can customize to choose specific product types, datasets, region of interest, calculations, statistical summaries, and time period. We estimated that the system will involve processing EO data of around 5-6 TB in total volume. The analytical tools to be used in these projects will include land classification, land change, spectral indices, and water extent tools. The information generated from this system will allow users to develop strategies, take actions, and monitor progress of important projects. Our Geo-AWS average monthly bill is estimated to be about $1,603.53, with a total of $57,727.28 over the 3-year period.

PROJECT PLAN

A. INTRODUCTION

The use of Earth observations (EO) data and geospatial information has brought numerous benefits to society in several application areas. Satellite-based EOs are valuable as a measurement or monitoring tool, such as for global biodiversity indicators (O'Connor et al., 2015; Secades et al., 2014), for food security and agriculture (Xu, et al., 2018), and disaster management (Guo, 2010). For instance, the attainments of the United Nations 2030 Agenda for Sustainable Development will benefit from Earth observations in several ways: a) enabling informed decision-making and by allowing monitoring of the expected results; b) improve national statistics for greater accuracy, and directly contribute to calculate the agreed SDG Targets and Indicators; and c) facilitate countries' approaches for working across different development sectors (Anderson et al., 2017).

In Vietnam, remote sensing and GIS technologies found niche applications in several disciplines typical of many developing countries in Asia. The conventional applications of remote sensing in the country include agriculture (Son et al., 2014), forestry (Khoi and Murayama, 2010), water resources (Tam and Batelaan, 2014), environmental management (Seto and Fragkias, 2007), land use/cover change analysis (Lam-Dao, et al., 2011), disaster management (Huong and Nagasawa, 2014), and climatology (Kuo, et al., 2004). Except for agriculture-related application, the above studies are often experimental or exploratory research works.

There are hundreds of satellites observing the Earth repetitively, and thus accumulating large volumes of Earth observation data (EOD). Over a petabyte (1,000 terabytes) of data is being produced daily, offering many potential benefits and uses for various applications. However, such big data imagery poses problems and issues related to spatial handling, infrastructure, processing methods and software, and data security. Many organisations, particularly those from developing counties, found those issues challenging, which can often impede their use. The use of cloud computing for EO Big Data is a positive step towards addressing these issues and problems.

This proposal aims to establish cloud computing services to host, process and analyse big Earth observation (EO) data and geospatial information for our projects focused on monitoring rice paddy (agriculture) and flood (disaster and water resources management). We wish to apply for AWS credits that will allow us to build EO applications on these areas relevant to Vietnam's national and international commitments, such as for the UN Sustainable Development Goals (e.g. *Goal 2 Zero Hunger, Target 2.c,* and *Indicator 2.4.1.*) and Sendai Framework for Disaster Risk Reduction (e.g. on *Priority 1 (Understanding disaster risk*)).

B. RICE CROPPING AND FLOODS IN THE LOWER MEKONG BASIN

1. The Mekong River Basin

The project covers the Lower Mekong Basin. It is a part of the Mekong River (Figure 1), which is the tenth-largest river in the world. The entire Mekong River basin drains a total land area of 795,000 km^2 (Mekong River Commission, 2019). The Mekong River flows approximately 4,909 km through six countries (China, Myanmar, Lao PDR, Thailand, Cambodia, and Vietnam), before emptying into the sea.

The Lower Mekong Basin comprises the Northern Highlands, Khorat Plateau, Tonle Sap Basin and Mekong Delta. It covers 76% (about 604,200 km2) of the total area of the Mekong River basin and contributes 80-85% of the water that flows into the Mekong River. The Tonle Sap Basin is a large alluvial plain surrounded by hills. It covers the Tonle Sap Lake, located in the Cambodian floodplain and is the largest body of fresh water in Southeast Asia. In Cambodia, 40% of the population depends on the Tonle Sap Great Lake and its flood plains for their livelihoods. Similarly, the Mekong Delta in Vietnam (approximately 40,500 km^2) is vital for the people in Vietnam, as large area in the Delta is farmed intensively.

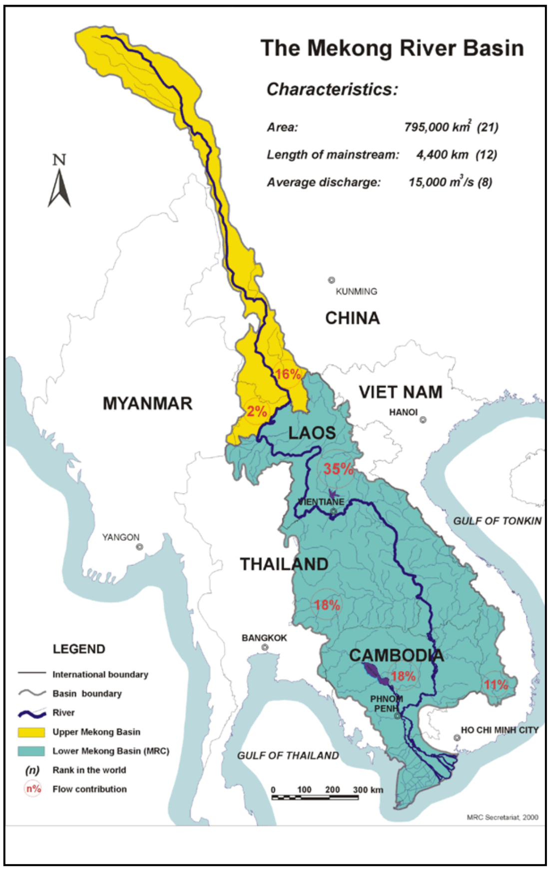


Figure 1. The Mekong River Basin (Source: Mekong River Commission Secretariat, 2000)

2. Rice Cropping in the Lower Mekong Basin

The Mekong Delta in Vietnam is intensively cultivated for agricultural production. It was estimated that over 64 % of the delta (2.6 million ha) is used for agriculture, with rice (Figure 2) as the dominant crop, comprising about three-quarters of the total cultivated land (GSO, 2015). Official statistics indicate that while the Delta only covers 12% of the total land area of Vietnam, it contributes 52% to the national food production and over 80% to the Vietnamese rice export (GSO, 2015). In Cambodia, rice is the staple food and main commodity. Wet rice is the main crop and is grown on the flood plains of the Tonle Sap, Mekong, and Bassac Rivers. Based from data reported by the Agriculture Ministry, Cambodia exported more than 635,000 tonnes of rice in 2017 and recorded a 17.3% growth from the previous year (CNA, 2018).

Figure 2. Rice farming in the Mekong River Basin (Source: Mekong River Commission, 2019)

With more than 20% of the population considered to live below the poverty line, and 15% undernourished, agriculture provides food security and livelihoods for approximately 60% of the Mekong River Basin's population (Mekong River Commission, 2019).

3. Floods in the Lower Mekong Basin

Due to low topography, the Mekong Delta is subjected to flooding caused by high river discharge, tidal backwater effects, and storm surges (Triet et al., 2018). Floods in this region are annual events, mainly triggered by the Asian monsoons, as well as by tropical cyclones. While some floods can bring certain benefits to people, extreme floods can result in widespread damages to life and property (Figure 3). For example, the 2000 flood resulted in over 450 fatalities and economic losses of USD 250 million (MRC, 2012).

a)

b)

Figure 3. Floods in the Mekong Delta: a) An Giang Province and b) Long An Province (Source: *Viet Nam News*, 2013, 2017)

C. METHODS

1. Rice paddy monitoring

Our application for the GEO-Amazon Earth Observation Cloud Credits Programme aims to support our project on "*Applied research on the multi-temporal, multi-resolution optical and radar remote sensing data for rice planted area monitoring and rice yield production estimation in the Mekong Delta and Red River Delta (VNRice)*". It is a State level research project, funded by the Vietnam Government.

This project aims to identify, map and monitor rice paddy and its area and cropping system. The subject area covers the Lower Mekong Basin, covering part of Cambodia and Vietnam. For Vietnam, it plans to include the entire Mekong Delta.

The data and time period for this study will involve the following:

- Radar data (Sentinel-1) – from 2014 to present
- Optical data (MODIS from 2000) – only rice area and cropping system

While we have conducted several projects on rice crop monitoring (please see Section 5 and Figure 4 below), opportunities this time exist to conduct more innovative approaches involving time-series data analysis covering wider temporal extent. These will allow better use of data and information for commodity forecasting and ensuring food security.

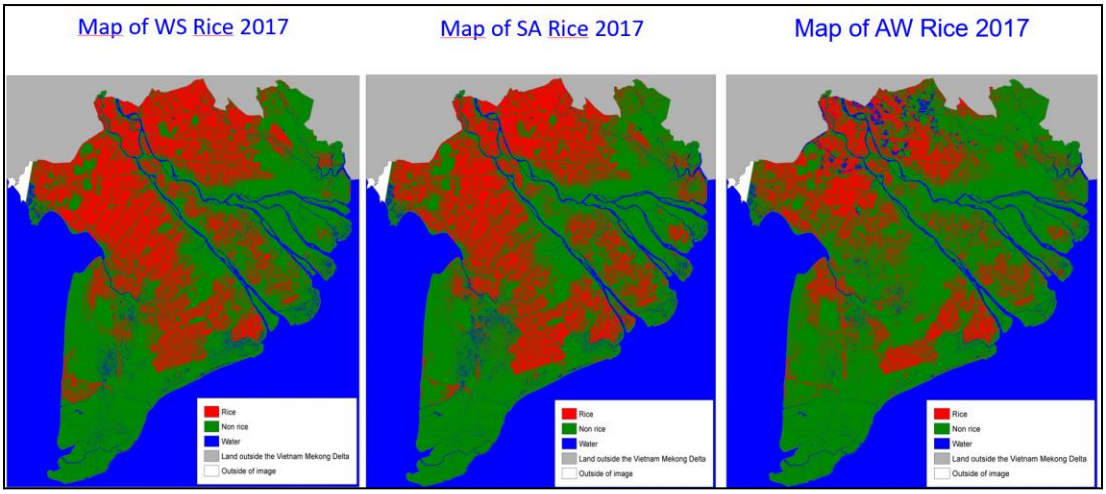


Figure 4. Multi-temporal maps showing rice planted area in the Vietnam's Mekong Delta (WS: Winter Spring; SA: Summer Autumn; AW: Autumn Winter)

This current project supports the attainment of the UN 2030 Agenda for Sustainable Development, particularly *Goal 2 Zero Hunger, Target 2.c,* and *Indicator 2.4.1.* The information generated from this system will allow users (policy makers, local communities, private business, scientists, etc.) to develop strategies and plans, monitor progress, and take actions. The benefits of EO data in several aspects of UN 2030 Agenda for Sustainable Development are well documented in various documents (e.g. GEO, 2017), and these are also applicable to this current project focused on rice crop mapping.

2. Flood monitoring

The goal of this project is to identify, map and monitor inundated areas by flood (e.g. Figure 5), focusing on rainy season (July to December). Similar with the above project, the target area for flood monitoring covers the Lower Mekong Basin, covering part of Cambodia and Vietnam.

The data and time (period) for this study will involve the following:

- Radar data (Sentinel-1) – from 2014 to present
- Optical data (MODIS) – from 2000 to present

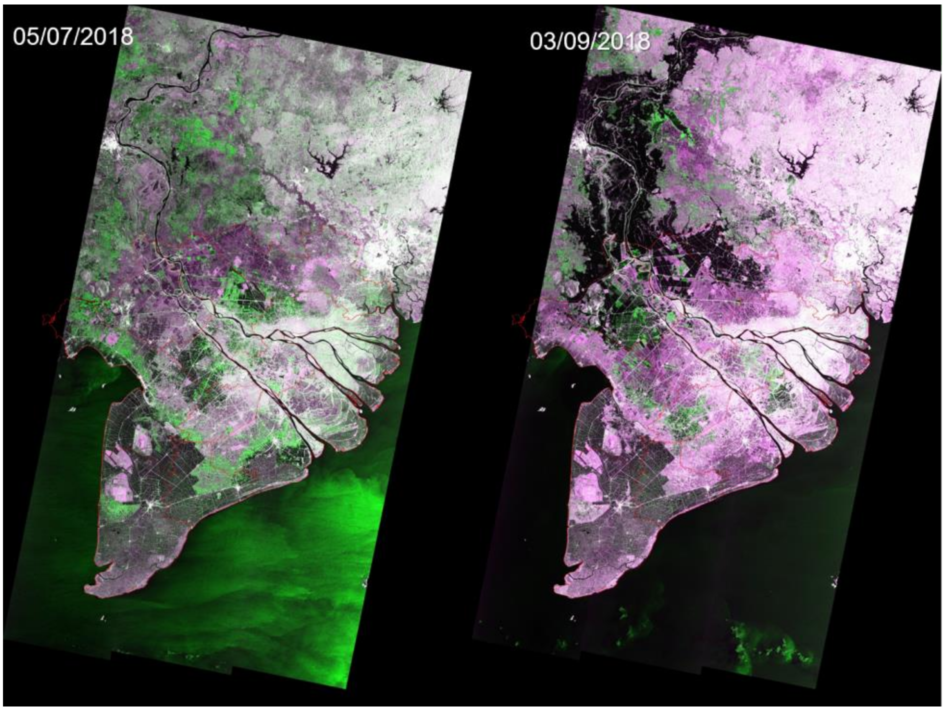


Figure 5. Sentinel-1 images showing changes in flooded area in the Lower Mekong Basin

In the past, we have conducted flood-related mapping projects (e.g. WISDOM). However, the new project on flood monitoring utilising the GEO-Amazon Earth Observation Cloud will provide new and improved ways of analysing, summarizing and visualizing floods. This capability will support better decision-making for disaster management and other areas of application. Our current project directly addresses *Priority 1 (Understanding disaster risk)* of the Sendai Framework for Disaster Risk Reduction. It aims at improving disaster management by providing flood information needed in developing mitigation and adaptation strategies.

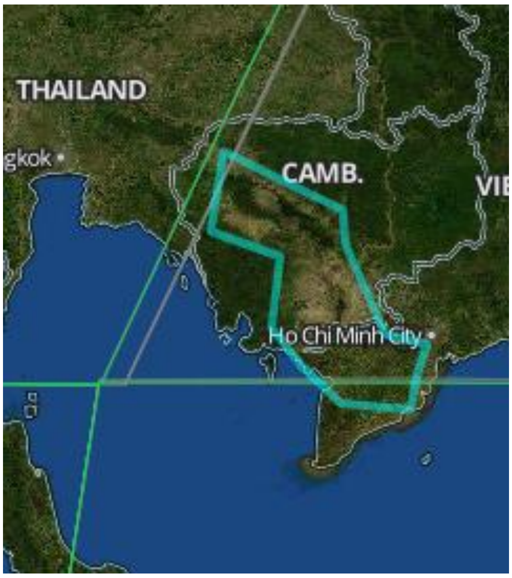
3. Applications and Data

The development and design principles of the system will focus on providing the ability for various users to make on-demand display, mapping, time-series visualization, and analyses of EO data. Users can customize to choose specific product types, datasets, region of interest, calculations, statistical summaries, and time period.

We estimated that the system will involve processing EO data of around 5-6 TB in total volume. This will involve the following:

a) For data: total of approximately 2.8 TB
   - Sentinel-1A: dual polarization, high resolution (2014-2019) – 1,459 granules, ~ 1.2 TB

- MODIS daily reflectance, 250 m ~ 1.6 TB (from 2000-2019)
  Including:
  - MODIS-Terra, daily reflectance, 250 m – 13,800 granules, ~ 835 GB
  - MODIS-Aqua, daily reflectance, 250 m – 12,200, ~ 740 GB



Both Sentinel-1A and MODIS are available in https://search.earthdata.nasa.gov

b) For processing, approximately 2-3 TB

The analytical tools to be used in these projects on rice and floods will include the following:

- **Land classification** – use of algorithms like neural networks, K-means, random forests, decision trees, etc. Tools in *MLHub Earth* will be explored.
- **Land change** – analysis of changes in rice and flood area, e.g. using thresholding, etc.
- **Spectral Indices** – calculating NDVI, NDWI, SAVI, EVI, Fractional cover,

etc.

- **Water Extent** – e.g. percent time that every pixel has observed water, using the analysis procedures done in Tanzania by *Open Data Cube*

Custom scripts, e.g. from the Sentinel Hub and other sources, will be used or modified as needed.

4. Validation

In order to validate rice extent and inundation from flood, field checking and observed data will be used as the follows.

- Rice: field checking results from the project of VNrice, which is mentioned above, and as conducted by STAC/VNSC, will be partially used. These data will be taken in advance to validate outcomes of image analysis for this project. It would help to increase the classification accuracy. These data are valid in the Red river delta, the Mekong delta, and in the central areas.
- Inundation extent: Data of hydrological gauge stations will be obtained from the Mekong River Commission (MRC). There are gauges from China, Laos, Thailand, Cambodia and Vietnam. Within this project, data will be collected only in Cambodia and Vietnam. These data include historical data and near real-time data, which consist of rainfall, water level with warning of flooding. These data are available at the URL of http://portal.mrcmekong.org/index (Hydrological Data Service). Near real-time data will be obtained during flood season of 2019 and 2020, while historical data will be done in phase 2.

5. Organization: HCMC Space Technology Application Center (STAC)

STAC is a government agency whose functions are focused on research, development and applications of satellite technology, mainly in the Southern region of Vietnam, in accordance with law. Its main tasks include the following:

- Receive, store, process, and deliver satellite imagery to serve socio-economic development, disaster prevention and national security and defence;
- Implement national duties in research, development and application of satellite technology;
- Establish and deploy international cooperation projects in space technology area, especially in satellite technology;
- Train, cooperate and transfer satellite technology. Linking to universities for higher educating on space and satellite technology; and
- Provide scientific and technological services in the field of satellite technology and its applications.

One of the important tasks ahead of the Center is to take over, manage, and implement the component of Vietnam Space Center project in Ho Chi Minh City. This project, supported by Japan's ODA, performs the following specific tasks:

- Develop highly qualified human resources in the field of satellite technology and applications;
- Receive, store, and process satellite data to serve the deployment of space technology application.

Researchers in the Center have participated in graduate and post graduate training at various universities in Vietnam and abroad. International cooperations are on-going with several organisations, such as with JAXA and RESTEC (Japan) in Asia-RiCE (Asian Rice Crop Estimation & Monitoring), CESBIO/CNES (France) and UMD (USA) in GEOGLAM.

In the past, several projects that utilized satellite imagery and field data were completed by STAC/VNSC. These include the following:

- WISDOM: Water related information system for the Mekong Delta, Vietnam
- RICEMAN: Rice & Mangrove monitoring in Southern Vietnam
- Planet Action: Impacts of climate change and human activities on the environment in the Mekong Delta, Vietnam
- Utilization of SAR data for rice crop monitoring
- Estimation of mangrove forest biomass
- Change detection of Mekong river bank and coastline

Despite our Centre is relatively young (established in 2014), and with only over a dozen staff (many of which are employed on casual basis), the above shows the mandate and very good track record of STAC/VNSC in implementing research projects involving EO data and geospatial information.

D. OUTCOMES

The implementation of these projects under the GEO - Amazon EO Cloud Credits Programme will bring the following outcomes:

1. **Map products and statistical data** – improvements in quality/accuracy of maps, better access to outputs, within the fastest possible delivery time to users. These products (i.e. rice cropping area, cropping system, flood-inundated areas) will be made fully and freely open and accessible to the wider GEO community.

2. **Decisions and actions** – better map products and geospatial information will have flow-on effects on the quality of decisions and actions about rice cropping in the region.

3. **Enhanced capability in cloud computing and processing of Big EO Data** – with exposure and experience in working with AWS environment, we foresee that staff at our Center, as well as users or clients outside the Center, will enhance the technical expertise and knowledge in cloud computing.

4. **Publications** – we plan to publish journal papers about the results of our studies.

E. CLOUD CREDIT REQUIREMENTS AND BUDGET

Our proposed use of GEO - Amazon EO Cloud Credits will be for 3 years (31 May 2019 to 30 April 2022).

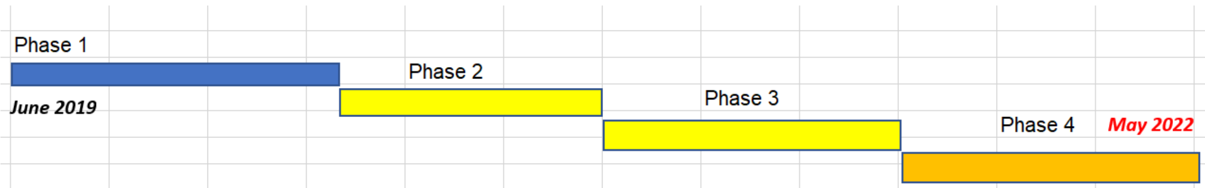
Estimate of monthly bill is $1,603.53, with a total of **$57,727.28** over the 3-year period.

Link in details:

https://calculator.s3.amazonaws.com/index.html#r=SIN&s=EC2&key=calc-2FD80F88-D1A8-41A8-9FC6-4D08D5D69C4D

F. IMPLEMATATION PLAN

1. Timelines



2. Phases

Phase 1: prepare the system and sample satellite images (10 months)

Goals	Outcomes	Duration (months)	Be responsible
1. Set up the system in AWS (Linux)	AWS with Linux OS	3 – 4	Nguyen Van Anh VU & Nguyen Kim THANH
2. Install software packages for image processing and analysis	Required software packages installed	2	Hoang Phi PHUNG, Nguyen Van Anh VU, Nguyen Huy THONG
3. Transfer a part of images into the system	SAR images of Mekong delta were acquired in 1	2	Nguyen Kim THANH & Nguyen Van Anh VU

4. Test analysis of SAR images	or 2 years 1 main scene is analysed in draft (catch to know the operation of the system as image analysis)	2	Hoang Phi PHUNG & Nguyen Van Anh VU

Notes: This phase would take time because we are new to both Linux and cloud computing services

Phase 2: Loading data into AWS and testing the system (8 months)

Goals	Outcomes	Duration (months)	Be responsible
1. Transfer all available SAR images of Vietnam	All SAR images of Vietnam in AWS	2	Nguyen Van Anh VU & Nguyen Kim THANH
2. Transfer all MODIS images of the lower Mekong river	All MODIS images in the AWS	2	Hoang Phi PHUNG & Nguyen Van Anh VU
3. Test analysis of MODIS images	1 main scene with granule of 2-3 years is processed	2	Nguyen Kim THANH & Nguyen Van Anh VU
4. Identify algorithm for classification of rice	Appropriate algorithm for rice classification	2	Lam Dao NGUYEN, THUY Le Toan, Hoang Phi PHUNG & Nguyen Van Anh VU

Phase 3: Image processing, analysis, classification (9 months)

Goals	Outcomes	Duration (months)	Be responsible
1. Identify algorithm for classification of inundation from flood	Appropriate algorithm for inundation identification	3	Nguyen Van Anh VU, Nguyen Kim THANH, Pham Bach VIET, Armando APAN
2. Processing and analysis of SAR imagery	Rice and flood extent for SAR	3	Hoang Phi PHUNG & Nguyen Van Anh VU
3. Processing and analysis of MODIS imagery	Rice and flood extent for MODIS	3	Nguyen Kim THANH & Nguyen Van Anh VU

Phase 4: Validation and assessment (9 months)

Goals	Outcomes	Duration (months)	Be responsible
1. Processing and analysis of combined imagery	Rice and inundated areas	3	Hoang Phi PHUNG & Nguyen Van Anh VU
2. Validate for rice and inundated areas	Validated data	2	Lam Dao NGUYEN, Hoang Phi

3. Validate and adjust algorithm for both 4. Assessment of accuracy 5. Finalise	Algorithm Accuracy Final report	2 2	PHUNG, Nguyen Van Anh VU, Lam Hung SON Hoang Phi PHUNG, Pham Bach VIET Hoang Phi PHUNG, Lam Dao NGUYEN, Pham Bach VIET, THUY Le Toan, Armando APAN

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