NASA DEVELOP National Program 2021 Fall Project Proposal

Virginia – Langley

Tonlé Sap Food Security & Agriculture III

Evaluating Changes in Ecosystem Vitality and Freshwater Health in the Tonlé Sap Basin using Remotely Sensed Data

Project Overview

Project Synopsis: Tonlé Sap, located in Cambodia's Lower Mekong Basin, is the largest freshwater lake in Southeast Asia and provides fisheries and freshwater to nearby agricultural communities. Increased pumping and shifts in global climate threaten the ecosystem's water quality and fish habitat. In collaboration with Conservation International (CI), this project seeks to provide end users in Cambodia with a tool for sub-indicator processing. These products will integrate Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, Terra & Aqua MODIS, GRACE, and GPM IMERG. These products will be used to create sub-indicators to measure ecosystem vitality within the Freshwater Health Index (FHI) to understand the implications of water quality changes within the region. End users will use these analyses to guide future resource allocation in the Tonlé Sap Basin.

Community Concern: The Tonlé Sap Lake and river basin is a crucial ecosystem that exemplifies a tightly linked social-ecological system. The lake supplies freshwater and supports crucial fisheries that drive the economy of the region. Pumping water from the Tonlé Sap Lake puts the ecosystem at risk, as this may result in a decrease in lake health and a reduced fish catch. However, to increase agriculture during the dry season (October – April), water pumped from the lake is essential to irrigate crops, particularly rice. Rice and aquaculture feed the region and sustain the economy. In recent years, rice production in the region has increased, and as a result, farmers are more reliant on the lake, rivers, and groundwater stores.

Source of Project Idea: This project originated from Dr. Venkat Lakshmi's conversations with Derek Vollmer, Freshwater Science Program Senior Director at Conservation International, and subsequent conversations with end users and partners in Cambodia.

National Application Areas Addressed: Food Security & Agriculture, Water Resources Study Location: Tonlé Sap Lake and River Basin, Cambodia Study Period: October 2000 – December 2020

Advisors: Dr. Venkataraman Lakshmi (University of Virginia, Department of Engineering Systems and the Environment), Dr. Kenton Ross (NASA Langley Research Center), Dr. Derek Vollmer (Conservation International)

| Partner Organizations: | | | | | | |
|----------------------------|-----------------------------------|--------------|------------------|--|--|--|
| Organization | POC (Name, Position/Title) | Partner Type | Boundary Org? | | | |
| Conservation International | Derek Vollmer, Freshwater Science | End User | Yes | | | |
| | Program Senior Director; Nicholas | | | | | |
| | Souter, Freshwater Research | | | | | |
| | Manager; Srabani Roy, Regional | | | | | |
| | Director – Greater Mekong | | | | | |

Partner Overview

| Ministry of Water Resources | H.E. Sin Viseth, Secretary General; | End User | No |
|-----------------------------|---|----------|----|
| and Meteorology, Tonlé Sap | H.E. Khov Meas, Deputy of secretary | | |
| Authority | general; Mr. Heng Sovannara, | | |
| | Director of Department of | | |
| | Exploitation Control and | | |
| | Conservation; Mr. Srun Siline, officer; | | |
| | Mr. Kvan Pheaktra, officer | | |

End User Overview

End User's Current Decision-Making Process: CI works with multiple different stakeholders including governments, corporations, and indigenous communities to provide cutting-edge science that helps guide policy decisions for conservation and human wellbeing across the world. Cambodia's Ministry of Water Resources and Meteorology (MoWRaM) identifies policy and strategy development for the country's water resources. Its meteorology department uses a variety of remote sensing data sources, including radar, satellite, and drone technology. Given the central importance of Tonlé Sap Lake to Cambodia's water resources and fisheries, the Tonlé Sap Authority (TSA) was created within MoWRaM to coordinate the management, conservation, and development of the river basins that feed into the lake basin. The TSA has some direct experience working with remote sensing but also works through Cambodia's MoWRaM and partner organizations who can provide additional expertise.

End User's Capacity to Use NASA Earth Observations:

- *Conservation International* CI maintains several offices in Cambodia, including in the capital city of Phnom Penh as well as a "floating office" on the lake itself. CI's programs focus on a wide range of environmental conservation and livelihood improvement topics including the application of the Freshwater Health Index within the Tonlé Sap region. CI links technical expertise and products to government agencies and local communities and helps to guide research mainly with *in situ* data and some remote sensing data.
- Ministry of Water Resources and Meteorology, Tonlé Sap Authority– TSA has some familiarity with NASA Earth observations (EO) products, though the capacity rests with a small number of individuals. A goal of this project will be to expose more of the staff to NASA's EO products and the related capabilities of remote sensing to aid their decision making and build more internal capacity.

<u>Collaborator & Boundary Organization Overview</u> Dissemination by Boundary Organizations:

Conservation International – CI functions as a boundary organization, linking technical expertise and products to government agencies and local communities, and helping to guide research that is responsive to end users' needs. CI's programs focus on a wide range of environmental conservation and livelihood improvement topics, with a special emphasis on working with fisher communities on the Lake, and forest conservation in the Cardamom mountain forests. CI will share the team's results with their contacts at the Asian Development Bank and the World Bank, who are both involved in ongoing resource management projects within the Tonlé Sap lake region.

Project Communication & Transition Overview

In-Term Communication Plan: The team will communicate with partners at CI in Washington, DC via teleconference weekly throughout the term. The team will also meet with the end users and the CI liaisons in Cambodia (TSA) once at the beginning of the term, and once at the end of the term. The Project Lead, alongside Derek Vollmer from CI, will coordinate communication with these groups.

Transition Plan: After the term, the team will conduct a handoff presentation via videoconference with all end users and collaborators to walk through the methods, challenges, and conclusions reached throughout the term and communicate how the handoff package will be organized and delivered.

| Earth Observations: | | | | |
|---------------------|---|---|--|--|
| Platform & Sensor | Parameter | Use | | |
| Landsat 5 TM | Surface reflectance, NDVI, NDWI | Landsat 5 TM imagery will be used to map land use land cove change in the Tonlé Sap Basin from 2000 to 2013. Landsat 5 TM-derived NDWI and NDVI will be used to map agricultural areas in the Tonlé Sap Basin from 2013 to 2020. | | |
| Landsat 7 ETM+ | Surface reflectance | Landsat 7 ETM+ imagery will be used to map land use land cover in the Tonlé Sap Basin from 2000 to 2003. | | |
| Landsat 8 OLI | Surface reflectance, NDVI, NDWI | Landsat 8 OLI surface reflectance will be used to map land use land cover change in the Tonlé Sap Basin from 2013 to 2020. Landsat 8 OLI-derived NDWI and NDVI will be used to map agricultural areas in the Tonlé Sap Basin from 2013 to 2020. | | |
| Terra MODIS | Surface reflectance, Enhanced Vegetation Index (EVI), NDVI, NDWI, Land Surface Temperature (LST) | Terra MODIS EVI, NDVI, NDWI, and LST will be used to map agricultural areas in the Tonlé Sap Basin from 2000 to 2020. Terra MODIS surface reflectance will be used to map agricultural intensity in reference datasets. | | |
| Aqua MODIS | Surface reflectance, EVI, NDVI, NDWI, LST | Aqua MODIS EVI, NDVI, NDWI, and LST will be used to map agricultural areas in the Tonlé Sap Basin from 2002 to 2020. Aqua MODIS surface reflectance will be used to map agricultural intensity in reference datasets. | | |
| GRACE | Integrated water | GRACE data from Goddard Space Flight Center's Global Land Data Assimilation System (GLDAS) will be used to measure changes in groundwater level in groundwater storage map. | | |
| GPM IMERG | Precipitation | GPM IMERG will be used as an input into the Soil & Water Assessment Tool (SWAT) to calculate nutrient flows into Tonlé Sap lake. | | |

Earth Observations Overview

Ancillary Datasets:

• Lake level altimetry timeseries – created by the Tonlé Sap Food & Ag Spring 2021 team, the altimetry time series will be included in the GEE tool and user guide and it will be used as an input for calculating the FHI.

Modeling:

 Soil & Water Assessment Tool (SWAT) (POC: Dr. Venkataraman Lakshmi, University of Virginia) – SWAT will be used to derive the amount of sediment and nutrient (nitrogen and phosphorus) that are mobilised from the land surface to the lake. These outputs of SWAT will be compared to *in situ* sensor data.

Software & Scripting:

- Esri ArcGIS Pro Map production and raster analysis
- QGIS Map production and SWAT analysis
- Google Earth Engine Data collection and groundwater analysis
- Python Data processing and raster analysis

Decision Support Tool & End Product Overview

| End Products: | End Products: | | | | |
|--|--|---|---------------------------------|--|--|
| End Product | Partner Use | Datasets & Analyses | Soffware Release Category | | |
| GEE Tool User Guide | The User Guide will provide partners with a step-by-step process for acquiring satellite data for FHI sub-indicator creation using the GEE Tool created by the team. | The sub-indicator tool will incorporate the previous two term's land use land cover maps (created using Landsat 5, 7 & 8 and Terra & Aqua MODIS), lake level time series, groundwater storage map (created using GRACE), and water quality index (created using GPM IMERG). | N/A | | |
| Google Earth Engine tool for FHI sub-indicator creation | The sub-indicator tool will allow partners to leverage remotely sensed data when running the FHI. This tool will focus on the pre-processing steps for FHI ecosystem vitality sub-indicators. | The sub-indicator tool will incorporate the previous two term's land use land cover maps (created using Landsat 5, 7 & 8 and Terra & Aqua MODIS), lake level time series, groundwater storage map (created using GRACE), and water quality index (created using GPM IMERG). This term will ensure a clean transition and full synthesis of materials within the code. | III | | |

End User Benefit: The FHI tool is mainly an *in situ* driven methodology that incorporates some remote sensing. Given the current restrictions on travel, partners have not been able to readily collect *in situ* data for the past year. This project will serve to help fill the data gaps using remote sensing and therefore provide information to policy makers on agricultural development in the basin that safeguards the lake's fisheries and biodiversity. This work will complement partners' previous connections to NASA SERVIR, which has heavily invested in the Lower Mekong River Basin.

Project Timeline & Previous Related Work

Project Timeline: 3 Terms: 2021 Spring, 2021 Summer, and 2021 Fall

Multi-Term Objectives:

- Term 1: 2021 Spring (LaRC) Tonlé Sap Food Security & Agriculture
 - o This term, the team created a water level time series of Tonlé Sap lake, and used it to calculate deviation from natural flow within the FHI. The team also compiled land use and land cover change maps from various sources to calculate land cover naturalness and bank modification within the FHI. These parameters were created using Landsat and other optical satellite data as well as Jason, TOPEX-Poseidon, and other altimeter data. The team met with CI on a weekly basis, and met with the TSA at the end of the term to share their results and receive feedback on their work.
- Term 2: 2021 Summer (LaRC) Tonlé Sap Food Security & Agriculture II
 - o The team will build on prior work by continuing to integrate and refine inputs into the FHI to calculate ecosystem vitality as a major indicator. The work will focus on calculating groundwater storage depletion and water quality to complement the past term's calculations of deviation from natural flow, channel modification, and land cover naturalness. The team will continue to meet with CI on a weekly basis, and will meet twice with TSA. The team will also deliver the created datasets and outputs from spring and summer terms at the end of the summer term.
- Term 3 (Proposed Term): 2021 Fall (LaRC) Tonlé Sap Food Security & Agriculture III
 - o This term the team will compile the work done by previous terms, and combine it into a GEE script that will be submitted through Software Release to be handed to partners. This term will focus on the synthesis of results, and forecasting future resource distribution in the basin. The team will meet with CI on a weekly basis, and met with the TSA at the end of the term to share their final results.

Previous Terms:

- 2021 Summer (LaRC) Tonlé Sap Food Security & Agriculture II: Evaluating the effects of Increased Dry Season Agriculture and Water Quantity Pumped from the Tonlé Sap and Surrounding Rivers in the Lower Mekong River Basin
- 2021 Spring (LaRC) Tonlé Sap Food Security & Agriculture: Evaluating the effects of Increased Dry Season Agriculture and Water Quantity Pumped from the Tonlé Sap and Surrounding Rivers in the Lower Mekong River Basin

Related DEVELOP Work:

- 2020 Spring (LaRC) Toa Baja Disasters: Mapping Tropical Storm Susceptibility in Puerto Rico's 'Underwater City' Using NASA Earth Observations to Assist the Municipality's Intervention Efforts
- 2018 Summer (LaRC) Colombia Ecological Forecasting: Validating the Effectiveness of the NASA Open Data Cube on Augmenting Deforestation Analysis in Colombia

Notes

The Freshwater Health Index requires data from multiple sources outlined here: <u>https://www.freshwaterhealthindex.org/data-requirements</u>