**Tonlé Sap Food Security & Agriculture II**

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

**Project Team**

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***Partner POC:*** Derek Vollmer, dvollmer@conservation.org

**Project Overview**

***Project Synopsis:***

The Tonlé Sap Basin in central Cambodia is a regionally important water source for irrigation, fisheries, and hydropower that has become increasingly stressed in recent years. Building on a previous team’s work, we used remotely-sensed data to measure groundwater storage and model nutrient flows in the basin, which were used as inputs in a Freshwater Health Index. Partnering with Conservation International, the Cambodian Ministry of Water Resources and Meteorology, and the Tonlé Sap Authority, implementation of the Freshwater Health Index will provide information on the status of the basin to guide future resource allocation.

***Abstract:***

The Tonlé Sap Lake and river basin in central Cambodia provide critical ecosystem services to the region, including fisheries, agricultural irrigation, hydropower, and biodiverse habitats. Deforestation, increased pumping for farming, and effects of climate change such as droughts and forest fires threaten the health of the lake and food security in the region. This project built upon the previous term through a partnership with Conservation International (CI), the Cambodian Ministry of Water Resources and Meteorology, and the Tonlé Sap Authority to assess ecosystem vitality and implement CI’s Freshwater Health Index (FHI) tool, in an effort to prioritize resource expenditure and highlight areas of concern. Due to the COVID-19 pandemic and related travel restrictions, partners had not been able to readily collect in situ data for the past year, which make up the majority of FHI inputs. To help fill this data gap, we developed a methodology for using Gravity Recovery and Climate Experiment (GRACE) satellite data to calculate groundwater storage depletion, and a Python Application Programming Interface for processing and formatting remotely-sensed data for the Soil and Water Assessment Tool (SWAT) model. We then used SWAT to model nutrient flows and of phosphorous, nitrogen and suspended sediments amounts in the basin from October 2000 to December 2020. These outputs served as inputs for the FHI and provided policy makers with robust monitoring information to aid decision-making in the area and safeguard the lake’s vital fisheries and biodiversity.

***Key Terms:***

SWAT, hydrologic modeling, GRACE, Freshwater Health Index, dams, lake level change, MODIS

***National Application Areas Addressed:*** Food Security & Agriculture, Water Resources

***Study Location:*** Tonlé Sap Lake and River Basin, Cambodia

***Study Period:*** October 2000 – December 2020

***Community Concerns:***

* The Tonlé Sap Basin is home to 4.5 million people, many of whom rely directly on the Tonlé Sap Lake for critical ecosystem services, most notably fisheries that drive the economy of the region and provide up to 80% of the protein consumed by millions of people in the surrounding province of Cambodia and beyond.
* Increased pumping for agriculture during the dry season (October - April) may result in a decrease in lake health and a reduced fish catch.
* Deforestation of flooded forests reduces habitat for fish nurseries. It also leads to lower carbon absorption in the area, which contributes to regional climate feedback loops like increasing temperature and increasing seasonal variability.
* Development of hydropower upstream and downstream of the basin also decreases water availability and quality, which threatens fisheries and the sustainability of irrigated agriculture in the area.
* 53% of Cambodian households drink from groundwater sources in the dry season. If trends continue in Cambodia, use of groundwater for industry and agricultural irrigation will increase. Monitoring groundwater levels will be critical for the continued availability of safe drinking water for Cambodians.

***Project Objectives:***

* Calculate groundwater storage and depletion in the basin
* Model nutrient flows in the basin with remotely sensed and *in situ* data to analyze water quality
* Develop a Google Earth Engine tool to integrate remotely sensed data into future freshwater analyses, specifically related to the Freshwater Health Index

***Previous Term:***

Spring 2021 (LaRC) – Tonlé Sap Food Security & Agriculture I

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Ministry of Water Resources and Meteorology (Cambodia)** | H.E. Sin Viseth, Secretary General; H.E. Khov Meas, Deputy of Secretary General; Mr. Heng Sovannara, Director of Department of Exploitation Control and Conservation; Mr. Srun Siline, Officer; Mr. Kvan Pheaktra, officer | End User | No |
| **Conservation International** | Derek Vollmer, Freshwater Science Program Senior Director; Nicholas Souter, Freshwater Research Manager; Srabani Roy, Regional Director – Greater Mekong | Collaborator | Yes |

***Decision-Making Practices & Policies:***

The Ministry of Water Resources and Meteorology (MoWRaM) and the Tonlé Sap Authority (TSA) are currently striving to balance the overfishing, hydrological development, agriculture, and pollution of a growing population and the health of the Tonlé Sap Lake ecosystem. Policy makers use *in situ* data to help make management decisions, but with the COVID-19 pandemic, gathering *in situ* data has been more difficult and time consuming. Since 2008, Conservation International (CI) has been working with the MoWRaM to provide technological expertise to help with decision-making.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **GRACE** | Groundwater and precipitation | GRACE was used to measure changes in groundwater storage in the study area. |
| **GPM IMERG** | Precipitation | GPM IMERG was used to measure daily precipitation in the study area and served as an input to the SWAT model. |
| **AQUA AIRS** | Air temperature | AQUA-AIRS was used to measure daily maximum and minimum air temperature in the study area and served as an input to the SWAT model. |
| **ERA5 SRTM** | Digital Elevation Model (DEM) | ERA5-SRTM provided a DEM to the SWAT model which was used to derive stream networks. |

***Ancillary Datasets:***

* NASA DEVELOP Spring 2021 Tonlé Sap Food Security & Agriculture I Land Use/Land Cover maps – Input dataset for SWAT model
* Food and Agriculture Organization (FAO) of the United Nations Digital Soil Map of the World – Soil raster used as input dataset for SWAT model

***Modeling:***

* Freshwater Health Index (FHI) (POC: Dr. Derek Vollmer, Conservation International) – Used to guide the creation of the framework for sub-indicator processing
* Soil and Water Assessment Tool (SWAT) (POC: Dr. Venkataraman Lakshmi, University of Virginia) – Analysis of nutrient flows in the study area

***Software & Scripting:***

* QGIS 3.18 – Map production, general GIS analysis, and SWAT analysis
* QSWAT 3\_64 v 1.1 - Model product, QGIS extension for water quality analysis
* SWAT Calibration Uncertainty Program (CUP) – Calibration of the SWAT model for more accurate results
* Google Earth Engine API – Data acquisition and pre-processing for SWAT model and GRACE methodology
* Python API – Automating data processing, analysis, and exportation for end users and project team members
* ArcGIS Pro 2.6.2 – Visualize soil raster and create layout for Presentation

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **GRACE Groundwater Methodology** | GRACE | This methodology will be useful for stakeholders to perform analysis on groundwater storage in the Tonlé Sap Basin, which will also be used in the FHI to measure ecosystem vitality. | N/A |
| **SWAT Output for Tonlé Sap Basin** | GPM IMERG, ERA5 SRTM, AQUA AIRS | These outputs provide water quality measurements that will be used in the FHI to assess ecosystem vitality in the Tonlé Sap Basin. | N/A |
| **Python API Tool for SWAT** | N/A | Stakeholders will use this tool to leverage remotely sensed data when running the SWAT model, which provides water quality measurements to the FHI. | N/A |

***Product Benefit to End User:***

Our work will build on the information collection and analysis required to implement the FHI tool in the Tonlé Sap Basin. Due to the COVID-19 pandemic and related travel restrictions, partners have not been able to readily collect *in situ* for the past year, which make up the majority of FHI inputs. This project will help fill data gaps using remote sensing, specifically by calculating groundwater storage depletion and several water quality metrics for the basin. Our contributions to research on the health of the basin will provide policy makers with robust information to aid decision-making in the area and safeguard the lake’s vital fisheries and biodiversity.

***Project Continuation Plan:***

In the third term of this project, the team will continue to analyze FHI sub-indicators in the Tonlé Sap Basin. Groundwater analysis will be completed using the methodology developed in Term II. The team will also use *in situ* data to validate the SWAT model and results produced in Term II. Lastly, the team will compile work by the two previous teams and combine it into a software package and set of tools that will allow partners to leverage this previous work and additional remotely sensed data when using the FHI.

**References**

Arias, M. E., Cochrane, T. A., Kummu, M., Lauri, H., Holtgrieve, G. W., Koponen, J., & Piman, T. (2014). Impacts of hydropower and climate change on drivers of ecological productivity of Southeast Asia’s most important wetland. *Ecological Modelling*, *272*, 252–263. <https://doi.org/10.1016/j.ecolmodel.2013.10.015>

Lohani, S., Dilts, T., Weisberg, P., Null, S., & Hogan, Z. (2020). Rapidly Accelerating Deforestation in Cambodia’s Mekong River Basin: A Comparative Analysis of Spatial Patterns and Drivers. *Water, 12*(8), 2191. [https://doi.org/10.3390/w12082191](https://doi.org/10.3390/w1208219)

Sophally, S. (2014). Groundwater Resources in Cambodia (p. 18). Ministry of Rural Development. https://portal.mrcmekong.org/assets/v1/documents/Groundwate-Cambodia\_Sphally.pdf