**Peru & Bolivia Climate**

*Estimating soil Organic Carbon using NASA Earth Observations to Inform Irrecoverable Carbon Reserve Management in Peru and Bolivia*

**Project Team**

***Project Team:***

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**Project Overview**

***Project Synopsis:***

The Peru and Bolivia Climate project aimed to monitor soil organic carbon (SOC) stocks in the two countries from 2016 to 2022. Through collaboration with Conservation International, the team utilized Soil Moisture Active Passive (SMAP) Level 4 Carbon data to monitor and analyze changes in soil organic carbon stocks over time. The end products from this project will assist Conservation International in co-managing irrecoverable carbon sites of interest in South America with local communities including Indigenous groups and local governments.

***Abstract:***

Irrecoverable carbon (IC) reserves contain large stores of the element, are at risk of being released due to human activity and consequentially contribute to global warming upon eviction. The Amazon, which covers about 0.5% of Earth's surface, contains the largest and highest-density reserves of IC. Conservation International (CI) works with local communities to establish and expand protected areas to prevent the loss of these reserves. This project's research strived to help CI better understand soil organic carbon (SOC) stocks and supplement their ability to monitor SOC changes in South America through a remote sensing lens. Earth observations utilized included the Soil Moisture Active Passive Level 4 Carbon Net Ecosystem Exchange (SMAP L4C) product and Level-2A true color imagery from Sentinel-2 MultiSpectral Instrument (MSI). SOC distribution maps and trend analyses were generated for Peru and Bolivia between 2016 and 2022. SMAP L4C SOC estimates were then compared to SoilGrids, CI’s current SOC data source. Additionally, a methodology for monitoring SOC utilizing SMAP will allow CI to monitor future changes. The project determined that trends of significantly decreasing SOC generally occurred within the extent of the Andes Mountains while most areas outside had increased. Overall, SOC increased across the entire study period for each plant functional type and average SOC over all plant functional types. SMAP agrees with SoilGrids in the eastern portion of the study area and within the Bolivian Amazon but disagrees along the Andes range and in northeastern Peru.

***Key Terms:***

Soil Moisture Active Passive (SMAP), Sentinel-2 MSI, soil organic carbon, irrecoverable carbon, SMAP Level 4 Carbon (L4C) Product, climate change

***National Application Area(s) Addressed:*** Climate

***Study Location:*** Peru and Bolivia

***Study Period:*** January 2016 to November 2022

***Community Concerns:***

* Over the past decade, at least 4 billion metric tons of irrecoverable carbon have been lost due to human activity. Deforestation in tropical and subtropical regions is responsible for the release of 0.6 gigatons of carbon per year alone. The Management of irrecoverable carbon reserves helps to mitigate global warming effects such as increased precipitation and heat stress that will in turn accelerate losses.
* Indigenous peoples and local communities manage at least a third of Earth’s irrecoverable carbon informed by valuable traditional knowledge, though global land degradation is not well quantified. This project applied a remote sensing lens to assess the feasibility of SMAP L4C in observing Peru and Bolivia’s carbon stocks.
* Conservation International relies on modeled products that do not show changes in soil organic carbon over time; integrating NASA Earth Observations will allow for near real-time monitoring of changes in soil organic carbon and accelerate conservation responses.

***Project Objectives:***

* Create and analyze annual SOC maps showing the changes of SOC over the study period
* Compare the outputs of SMAP SOC estimates to SoilGrids SOC estimates
* Produce a methodology for monitoring SOC utilizing SMAP
* Obtain true color imagery of study area

**Partner Overview**

***Partner Organization:***

|  |  |  |
| --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** |
| **Conservation International** | Monica Noon, Senior GIS Manager;Erika Munshi, Irrecoverable Carbon Project Manager;Patrick Roehrdanz, Director, Climate Change and Biodiversity  | End User |

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

CI is a non-profit organization that works on a variety of environmentally focused projects that protect nature across the globe. Managing irrecoverable carbon sites is a new initiative for the organization that aims to prevent the release of billions of metric tons of carbon into the atmosphere from human activity and prevent biodiversity loss. In South America, CI co-manages carbon reserves with local communities, including indigenous groups and local governments. However, their decision-making is often informed by modeled SOC datasets that do not show changes over time. This makes it difficult for CI to identify, monitor and respond to SOC changes or connect changes in management strategies with SOC stocks.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Aqua MODIS** | Land Cover Classification | Land cover classification was used to generate downscale SMAP L4C. |
| **Terra MODIS** | Land Cover Classification | Land cover classification was used to generate downscale SMAP L4C. |
| **Copernicus Sentinel-2 Multispectral Instrument (MSI)** | Surface Reflectance | True color imagery was collected for visual reference of study area and areas of interest. |
| **Soil Moisture Active Passive Radiometer (SMAP)** | Soil Organic Carbon Concentration | Daily timesteps of soil organic carbon were used in trend analysis. |

***Ancillary Datasets:***

* International Soil Reference and Information Centre (ISRIC) World Soil Information SoilGrids v.2.0 - Modeled SOC estimates currently referenced by CI
* USGS Global Mountain Explorer 2.0 Landform Classifications Model – Mountain landform classification used to calculate areal statistics of significant SOC trends

***Software & Scripting:***

* ArcGIS Pro 2.9.6 – Trend analysis and SMAP vs SoilGrids comparison
* Google Earth Engine (GEE) API – Extract Sentinel-2 true color imagery
* Python 3.10.9 – Shapefile buffering, SMAP downscaling, Mann-Kendall analyses
* R 4.2.2 – SMAP vs SoilGrids visualizations and RMSE calculations

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Maps of Soil Organic Carbon** | SMAP L4C | These maps will identify key regions to focus further management efforts. | N/A |
| **Soil Organic Carbon Change Map** | SMAP L4C | This map will provide a deeper understanding of how soil organic carbon has changed over the study period throughout the locations that CI manages in Peru and Bolivia. | N/A |
| **Comparison Between SMAP derived and SoilGrids Soil Organic Carbon Estimates** | SMAP L4C | This comparison will help CI better understand how SMAP L4C data can be used to monitor soil organic carbon over time in comparison to SOC estimates provided by the SoilGrids model. | N/A |
| **Soil Organic Monitoring Framework** | SMAP L4C, MODIS, Copernicus Sentinel-2 MSI | A detailed overview of the methodology used in this project will provide CI with resources to continue monitoring SOC beyond the DEVELOP term. | N/A |
| **True Color Maps of Irrecoverable Carbon Sites** | Copernicus Sentinel-2 MSI | These images will allow CI to show their stakeholders high resolution maps of their land. | N/A |
| **Downscaled SMAP Data** | SMAP L4C, MODIS | This will allow CI to compare SOC to the other analyses and datasets they utilize on the same scale. | N/A |

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

With these analyses and the overall methodology for tracking SOC changes over time, Conservation International will be able to identify if their smaller areas of interest are within areas of overall increasing or decreasing SOC and what management strategies would be applicable to those regions. The true color imagery will provide C.I. with the ability to connect changes in SOC to their working sites on the ground and allow them to show Indigenous Groups and other stakeholders their lands in high resolution.

**References**

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