**Carmel Valley Urban Development**

*Monitoring Land Cover Change to Understand Conservation Outcomes in Coastal California*

**Project Team**

***Project Team:***

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**Project Overview**

***Project Synopsis:***

This project aimed to analyze the effects of the Santa Lucia Conservancy’s (SLC) land management strategy, which allows selective development on the Santa Lucia Preserve (SLP) while maximizing conserved lands, in comparison to the surrounding Carmel Valley region, which has not implemented such measures. By using satellite imagery and ancillary data from the SLC, the team mapped land cover changes in the Carmel Valley in 1991 and 2019. This will inform the SLC about the impact of their land management practices in the context of the greater area over a nearly 30-year study period.

***Abstract:***

Urban expansion in diverse ecosystems has numerous detrimental impacts, including diminished biodiversity, impaired water quality, and reduced carbon storage potential. In the Carmel Valley region of California’s Central Coast, the Santa Lucia Preserve (SLP) implemented a unique land management plan in the 1990s to allow limited development while conserving the majority of the land. Our goal was to test whether our partner’s (Santa Lucia Conservancy) management plan reduced urban spread and forest cover loss compared to surrounding areas from 1991 to 2019. We used Landsat 5’s Thematic Mapper and Landsat 8’s Operational Land Imager (OLI) to classify land cover into eight classes (agriculture, developed [infrastructure], developed [structures], forest, grasslands, rocks/cliffs, shrubs, water) using a random forest classification in R Studio, then modeled land cover change using IDRISI TerrSet Land Change Modeler (LCM). The best models for both years used all variables and a combined developed class (1991 OOB error = 17.4%, 2019 OOB error = 20.1%). The greatest vegetation loss occurred in grasslands; 11% of grasslands on SLP became developed, along with 14% of public and 12% of private. Throughout the study area, developed and forest land cover increased by 2%, while grasslands decreased by 4% and shrubs by 2%. Approximately 3.5% of privately owned forest was developed, while about 1% of public and SLC-owned forests were. Transition between vegetation classes masked losses within each class, and further analysis of the drivers of land cover change is necessary to fully evaluate the efficacy of the SLC conservation model.

***Key Terms:***

Remote sensing, Landsat, land cover change, Google Earth Engine, LandTrendr, random forest, IDRISI TerrSet Land Change Modeler

***National Application Area Addressed:*** Urban Development

***Study Location:*** Santa Lucia Preserve and the surrounding Carmel Valley region, CA

***Study Period:*** 1991 – 2019

***Community Concerns:***

* The Santa Lucia Conservancy employs a unique development and conservation strategy that incorporates conservation easements, protected wildlands, and residential development. Understanding forest cover loss throughout this area will be instrumental in evaluating the effectiveness of the Conservancy's model compared to surrounding areas.
* Evaluating landscape changes over time both within and around the SLP will inform the Conservancy about the efficacy of their land management model and determine whether it could serve as a model for future conservation initiatives.
* The Central Coast of California is greatly impacted by a variety of obstacles to land management, such as wildfire, development, and invasive shrub species, which are approached differently by different land managers. Understanding how forest cover has changed over the years will demonstrate which tactics have been most effective to combatting these issues.

***Project Objectives:***

* Analyze change in vegetation cover in and around Santa Lucia Preserve from 1991 to 2019
* Produce land cover maps of neighboring properties to the Santa Lucia Conservancy
* Compare land cover changes and development rates under various conservation models

**Partner Overview**

***Partner Organization:***

|  |  |  |
| --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** |
| **Santa Lucia Conservancy** | Dr. Brian Woodward, Conservation Ecologist | End User |

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

The partner currently utilizes field-collected data to inform management and conservation decisions on the Santa Lucia Preserve. Many species and habitat types present on the Preserve are threatened or endangered and protected under the Endangered Species Act, and the SLC uses high resolution land cover maps to manage land on the Preserve. While the Conservancy uses spatial data such as land cover maps to guide decision-making, they do not currently have the capacity to use NASA Earth observations.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor**  | **Parameters**  | **Use**  |
| **Landsat 5 TM** | Tasseled cap brightness, greenness, and wetness (TCB, TCG, TCW), normalized difference vegetation index (NDVI), normalized difference moisture index (NDMI) | Landsat data and derived spectral indices were inputs for the random forest land cover classification model.  |
| **Landsat 8 OLI** | TCB, TCG, TCW, NDVI, NDMI | Landsat data and derived spectral indices were inputs for the random forest land cover classification model. |
| **Shuttle Radar Topography Mission (SRTM)** | Digital elevation model (DEM), slope, aspect, landform, surface relief ratio, roughness | The SRTM DEM for the study area was used to generate topographic parameters to input into the land cover classification models. |

***Ancillary Datasets:***

* Santa Lucia Preserve Habitat Maps – Shapefiles of habitat types within Santa Lucia Preserve created from aerial imagery and field surveys from 1991 and 2019. Used as reference for generating training points.
* LANDFIRE Existing Vegetation Types (EVT) – Reference dataset used to generate training points outside of the SLP boundaries.
* National Agricultural Imagery Program (NAIP) – High-resolution aerial imagery used to classify land cover.
* California Department of Forestry and Fire Protection California Land Ownership database – Used to identify areas with different land ownership in the study area for comparative land cover change analyses.
* USDA Gridded National Soil Survey Geographic Database (gNATSGO) – High-resolution soil data from the study area used as a model input parameter.
* U.S. Census Bureau Tiger Roads database – All roads in the study area were used to generate Euclidean distance from road as a model input.

***Modeling:***

* Random Forest (POC: Anthony Vorster, Colorado State University) – Classify land cover into eight habitat classes.
* IDRISI TerrSet Land Change Modeler (POC: Keith Weber, Idaho State University) – Evaluate and map changes in land cover in the study area.
* LandTrendr (POC: Anthony Vorster, Colorado State University) – Evaluate areas of high disturbance within the Santa Lucia Preserve compared to the surrounding areas throughout the study period.

***Software & Scripting:***

* ArcGIS Pro 3.0.2 – Prepared geospatial data for use in random forest models, generated training points, and prepared classified rasters for IDRISI TerrSet Land Change Modeler, analyzed land cover and change maps
* Google Earth Engine – Downloaded Landsat data for analysis, calculated spectral indices and ran random forest models using NAIP imagery
* IDRISI TerrSet 2020 19.00– Modeled land cover change between 1991 and 2019
* R 4.1.2/RStudio – Prepared raster data for analysis and ran random forest models to classify land cover types

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Carmel Valley and Santa Lucia Land Cover Change Time Series, 1991 - 2019** | Landsat 5 TMLandsat 8 OLI | This time series will allow the Santa Lucia Conservancy to evaluate the effectiveness of their conservation approach by comparing forest loss on the preserve with neighboring areas managed in different ways. | N/A |
| **Carmel Valley Land Cover Maps, 1991 and 2019** | Landsat 5 TMLandsat 8 OLI | These maps will allow the Conservancy to understand habitat distribution on the preserve and how management tactics may have contributed to changes in habitat. | N/A |

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

This project will benefit the Santa Lucia Conservancy by allowing them to evaluate the effects of their conservation tactics over the last 30 years in the context of the greater Carmel Valley ecosystem. Time series of land cover changes will allow the SLC to interpret the success of their initiatives, and subsequently contribute to the direction of the Conservancy’s future resource management, including practices such as fuels reduction and invasive species thinning. In addition to overall measures of land cover change, the partner will be able to use the results to identify areas of greatest change and explore potential drivers of vegetation loss. Furthermore, the ability to understand land cover change in similar neighboring properties to the Preserve will provide a valuable comparison to the surrounding area. The findings will help inform the SLC about the efficacy of their land management model and its use in future conservation efforts.

**References**

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Kennedy, R., Yang, Z., Gorelick, N., Braaten, J., Cavalcante, L., Cohen, W., & Healey, S. (2018). Implementation of the LandTrendr algorithm on Google Earth Engine. *Remote Sensing, 10*(5), Article 691. <https://doi.org/10.3390/rs10050691>

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