**Talamanca-Osa Ecological Forecasting**

*Determining Habitat Suitability to Establish a Jaguar Corridor between the Talamanca Mountains and the Osa Peninsula in Costa Rica*

**VPS Title:** Corridor to Survival: Jaguars in Costa Rica

**Project Team**

***Project Team:***

Hikari Murayama (Project Lead)

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***Advisors & Mentors:***

Dr. Marguerite Madden (University of Georgia)

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**Project Overview**

***Project Synopsis:*** Habitat loss, agricultural expansion, and conflict with humans threaten the jaguar (*Panthera onca*) in Southern Costa Rica. Our team collaborated with the Arizona Center for Nature Conservation and Osa Conservation to design a jaguar corridor to reunite two isolated populations by connecting habitat fragments between the Talamanca Mountains and the Osa Peninsula. This project analyzed changes in vegetation and forecasted land use and land cover using NASA Earth observations to investigate potential corridor areas, prioritize areas for reforestation and wildlife-friendly agriculture, inform local efforts on educating the public about jaguars, and expand policies to preserve their habitats.

***Abstract:***

Costa Rica houses many diverse environments, including La Amistad International Peace Park in the Talamanca Mountains and Corcovado National Park on the Osa Peninsula. Jaguars (*Panthera onca*) can be found throughout these two parks, but urbanization and agricultural development have fragmented habitats, isolating these populations. As a result, this apex predator and keystone species, is endangered throughout the country. NASA DEVELOP partnered with the Arizona Center for Nature Conservation – Phoenix Zoo and Osa Conservation to design a jaguar corridor between these two protected areas to connect isolated populations by linking habitat fragments, facilitating movement. This project used Landsat 5 Thematic Mapper (TM), Landsat 8 Operational Land Imager (OLI) and PlanetScope satellite imagery to assess historical vegetation health and classify current land use and land cover. Forecasting classifications to 2030 identified potential risk areas for agricultural expansion, increased development, preserved habitat fragments, and human-jaguar conflict. This land use trend analysis informed a suitability assessment for the implementation of a jaguar corridor.

**Keywords:**

jaguar, corridor, Costa Rica, Osa Peninsula, land use change, Landsat, Normalized Difference Vegetation Index, Enhanced Vegetation Index

***National Application Area Addressed:*** Ecological Forecasting

***Study Location:*** Southern Puntarenas province of Costa Rica within the Osa, Golfito, Coto Brus, and Corredores districts

***Study Period:*** January 1987 to March 2019, Forecasting to 2030

***Community Concerns:***

* Costa Rica had one of the highest deforestation rates in the world between the 1940s and 1986, with a 21% decrease in overall forest cover.
* Significant habitat loss and landscape fragmentation have negatively impacted endemic and endangered species in the region including jaguar because they require a home range of up to 26 km2 for survival.
* Decreased habitat size and quality drive jaguars closer to human settlements, increasing human-jaguar conflict and jaguar-livestock conflict, which increases the likelihood of retaliatory hunting.
* Habitat loss and fragmentation isolate jaguar populations, resulting in decreased genetic diversity and an increased likelihood of inbreeding. Corcovado National Park’s population is especially affected, with only an estimated 6 to 12 individuals living within the park.
* Because the jaguar is an apex predator, population decline would cause a negative trophic cascade.
* Certain crops, such as pineapple and African oil palm plantations, act as barriers to jaguar movement.
* Agricultural expansion further invades the limited habitats available for jaguars.

***Project Objectives:***

* Produce January 1987 through March 2019 Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) time series maps to evaluate trends in vegetation health
* Conduct a current (March 2018 to March 2019) land use and land cover classification to evaluate habitat loss, fragmentation and the suitability of implementing a jaguar corridor
* Forecast land use and land cover classifications to 2030 to identify areas of potential human-jaguar conflict and habitat loss
* Provide guidance on how to use land use and land cover forecasts to determine the location of a potential jaguar corridor

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Phoenix Zoo, Arizona Center for Nature Conservation** | Dr. Jan Schipper, Field Conservation Research Director; Annie Johnson, Field Conservation Research Assistant; Chelsey Tellez, Field Conservation Research Assistant; Andrew Martinez, Field Conservation Research Assistant | End User | Yes |
| **Osa Conservation** | Hilary Brumberg, Healthy Rivers Program Coordinator | End User | No |

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

The Arizona Center for Nature Conservation – Phoenix Zoo and Osa Conservation are collaborating with other organizations, such as the National University of Costa Rica (UNA) and ProCAT, to establish a jaguar monitoring program in Costa Rica by installing a network of camera traps. The organizations use images from these camera traps in conjunction with ground survey data to monitor jaguar population density and distribution. Information from these studies inform programs such as the Payments for Ecosystem Services (PES), which prevents jaguar home range diminution by compensating landowners for adopting eco- and wildlife-friendly farming practices. Although this helps restore vital habitats, the identification of high-risk areas, proper fund allocation, and increased law enforcement are needed to enhance program effectiveness. Scientists at the Arizona Center for Nature Conservation have used some basic remote sensing techniques such as manual interpretation of Landsat imagery to connect forest fragments as a potential jaguar corridor. They do not have the required software, hardware or expertise to perform more advanced imaging analyses and geospatial modeling for assessing trends in land use and land cover changes. Osa Conservation has worked with NASA DEVELOP during three previous terms and use the maps and data tools provided by those projects to assess impacts of restoration efforts on watershed and coral reef health.

***Project Benefit to End User:***

The Arizona Center for Nature Conservation will share these results with a variety of partners across Costa Rica, including local non-governmental organizations such as Las Alturas del Bosque Verde, Finca Bellavista, and ProCAT. Both partner organizations will use corridor models and updated land use and land cover classifications in their collaborative efforts to establish a jaguar corridor connecting La Amistad and Corcovado National Parks. This will reduce human-jaguar conflict, especially in upland agriculture areas, and increase the possibilities of genetic exchange between jaguar populations. Osa Conservation will use these classifications to further analyze the effectiveness of Forest Law 7575 of 1996 on riparian deforestation and reforestation to delineate priority watersheds. The forest law designated riparian corridors, which are a core habitat for jaguars, as protected land in Costa Rica. These delineations will aid in targeting educational programs, policy enforcement and monitoring initiatives for watershed restoration and jaguar conservation.

**Earth Observations & End Products Overview**

***Earth Observations:***

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| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 5 TM** | Surface Reflectance, Enhanced Vegetation Index (EVI), Normalized Difference Vegetation Index (NDVI), Normalized Difference Built Index (NDBI), Normalized Difference Moisture Index (NDMI) and Normalized Difference Water Index (NDWI), Tasseled Cap Brightness (TCB), Tasseled Cap Greenness (TCG), Tasseled Cap Wetness(TCW), Gray-Level Co-occurrence Matrix (GLCM) | 1987 to 1999 Landsat 5 TM imagery was used to evaluate changes in vegetation by creating a suite of spectral indices. |
| **Landsat 8 OLI** | Surface Reflectance, EVI, NDVI, NDBI, NDMI, NDWI, TCB, TCG, TCW, GLCM | Landsat 8 OLI data were used to classify land use and land cover and assess vegetation health based on surface reflectance from 1999 through 2019. |
| **PlanetScope** | Surface Reflectance, EVI, NDVI, NDBI, NDMI, NDWI, TCB, TCG, TCW, GLCM | PlanetScope data provided high temporal (daily) and spatial resolution (3 m) imagery to verify classifications in targeted areas of agriculture and development. |

***Ancillary Datasets:***

* Advanced Land Observing Satellite Digital Surface Model (ALOS DSM) – Topographic information to model corridor paths and classify land cover
* 2008 and 2014 Digital Atlas of Costa Rica – Administrative boundaries, protected lands, roads, rivers, watersheds, population, and habitat fragments
* 2018 Spring and Summer (GA) Osa Peninsula Water Resources I and II, land use and land cover datasets (1987, 1997 and 2017) – Assess land use and land cover trends to forecast changes to 2019 in the Osa Peninsula
* Stanford Woods Institute for the Environment Iniciativa Osa y Golfito (INOGO) Land use land cover classification – Files for reference of classification analysis
* Gesellschaft für Internationale Zusammenarbeit (GIZ) GeoEye imagery – 2012 forest cover classification map of Costa Rica to assess the accuracy of land use and land cover data
* Sistema Nacional de Areas de Conservacion (SINAC) Corcovado National Park and Piedras Blancas National Park in Costa Rica – Shapefiles used to delineate study area
* IUCN World Heritage Programme Réserves de la cordillère de Talamanca–La Amistad / Parc national La Amistad – Shapefile to delineate study area
* World Wildlife Fund (WWF) HydroSHEDS (BAS) – 2006 drainage basins (watershed boundaries) to delineate study area

***Modeling:***

* TerrSet Land Change Modeler, Clark Labs (POC: Sergio Bernardes, University of Georgia) – Forecast land use and land cover to 2030
* CIRCUITSCAPE Version 4.0 (POC: Steve Padgett-Vasquez, University of Georgia) – Used to forecast land use and land cover to map a potential jaguar corridor using circuit theory
* Linkage Mapper Version 2.0.0 (POC: Steve Padgett-Vasquez, University of Georgia) – Used to forecast land use and land cover to map a potential jaguar corridor using least cost path

***Software & Scripting:***

* Esri ArcGIS 10.6 – Image classification, modeling and map creation
* Google Earth Engine API – Image processing, including image enhancement, gap filling, mosaicing, computing vegetation indices and classification

***End Products:***

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| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **NDVI and EVI Time Series (1987**–**2019) Analysis Maps** | Landsat 5 TM  Landsat 8 OLI | The partners can use historical trends in vegetation to understand the changing landscape for jaguar habitat suitability. | I |
| **NDVI and EVI Change Maps** | Landsat 5 TM  Landsat 8 OLI | The partners can use this to gain insight into the overall vegetation change trend over the past three decades. | I |
| **Current (2018**–**2019) Land Use and Land Cover Classification Map** | Landsat 8 OLI  PlanetScope | Classification maps allow the partner to determine high and low risk areas for jaguar movement. | I |
| **Forecasted Land Use and Land Cover Classification Map** | Landsat 8 OLI  PlanetScope | These forecasted classification maps can be used by the partner to assess sections of land that are at high risk of further habitat fragmentation and loss. | N/A |
| **Tutorial for Forecasting and Jaguar Corridor Designation** | N/A | The tutorial enabled the partners to use forecasted land use and land change information to determine possible boundaries for a jaguar corridor. | N/A |

**Project Handoff Package**

*Transition Plan:* A virtual handoff via Google Hangouts was conducted by the Talamanca-Osa Ecological Forecasting team for both the Arizona Center for Nature Conservation – Phoenix Zoo and Osa Conservation. The DEVELOP team described final analyses, deliverables produced during the term, as well as the analyses to be conducted for the second iteration of the project. Preliminary forecasting results were also presented and further refinement during term II was discussed. All materials were sent to the partners through Google Drive.

*Project Continuation Plan:* Initial work on forecasting land use and land classification to 2030 will be further refined and expanded to the entire study area. These results will be utilized in the CIRCUITSCAPE and Linkage Mapper models to assess jaguar habitat suitability for a proposed jaguar corridor.

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**Handoff Package:**

* Project Summary
* Technical Paper
* Presentation
* Poster
* Website Image
* Study Area Shapefile
* Project Video
* Technical Image
* NDVI and EVI Time Series (1987–2019) Analysis Maps
* NDVI and EVI Change Maps
* Current (2018–2019) Land Use and Land Cover Classification Map
* Forecasted Land Use and Land Cover Classification Map
* Tutorial for Forecasting and Jaguar Corridor Designation

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