Remote Sensing and Ground-based Measurements Across a Remote Rainforest Transect

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INTRODUCTION

The American Climber Science Program (ACSP) is an integrated research effort that combines remote sensing analysis with extensive data-collection from a variety of scientific partners (All 2014). Through a series of PE&RS Highlight Articles, we are periodically sharing ACSP work on diverse environments from tropical rainforests to high mountain glaciers in Central America, the Himalayas, and the Andes. More information can be found about the ACSP at www.climberscience.com and www.mountainscience.org and we invite collaborators in all disciplines.

This article describes the integration of remote sensing (RS) data with diverse ground-based data collected during an ACSP expedition across a remote and almost unexplored region of southern Costa Rica. The objective of the Costa Rica Coast to Coast Environmental Transect (C2C) was to cross from the Pacific to the Atlantic coasts of Central America to collect environmental data of direct interest and utility for local land mangers and conservation organizations. We selected a route that covered a broad range of rainforest life zones and areas considered to be of key value for conservation of biodiversity as well as the provision of critical ecosystem services such as watershed protection and carbon sequestration (Figure 1). Remote sensing was the tool that linked together diverse types of data collected along the route.

Figure 1: Ground data collected across the country of Costa Rice from the Pacific to the Atlantic Ocean. Landsat TM data provides the background for the image.

This type of fieldwork can often entail significant risks – each ACSP expedition has its own risk profile from charging elephants to facing avalanches. The C2C expedition described here traversed a mountainous region characterized by very dense and untracked rainforest which necessitated careful navigation at all times. Travel involved management of a suite of hazards common to field research in tropical rainforests. These hazards ranged from negotiating extremely steep and slippery terrain to avoiding poisonous snakes, insects, and plants, and to preventing infection and diseases. For example, a substantial number of our data collection points were on slopes exceeding 70° and several sections of the transect required crossing large, swift rivers that become impassable during prolonged rainstorms. Lower elevation section of the route (below 1300m) had habitat associated with high densities of venomous snakes (Figure 2) including the Fer-de-lance (*Bothrops asper*), a pit viper responsible for the greatest percentage of snakebite incidents in Costa Rice (Sasa-Marin et al. 2009).

Figure 2: ~~The author holding~~ part of an over ten foot long snakeskin that was encountered on our route.

Tropical forests are among the most important biomes on Earth. They house extraordinary levels of biodiversity, play a key role in the terrestrial carbon and hydrological cycles, and provide a range of critical ecosystem services.

Disease concerns included risks of Dengue and Leishmaniasis as well a myriad of nuisances such as ticks, chiggers, and botflies. Sources of water at higher elevations were scarce and/or difficult to access, and were often separated by more than one day's travel. Because rescue responses at more remote points of the transect would have required multiple days to over a week under best-case scenarios, careful planning of the expedition was required.

Study area

Tropical forests are among the most important biomes on Earth. They house extraordinary levels of biodiversity, play a key role in the terrestrial carbon and hydrological cycles, and provide a range of critical ecosystem services. They are also threatened by extensive land conversion and forest degradation leading to increased CO_2 emissions and loss of biodiversity (Laurence and Useche 2009, van der Werf et al. 2009). Recent studies also suggest that the tropics are likely to experience the earliest emergence of historically unprecedented climates within the next few decades (Mora et al. 2013). Because many tropical species are not adapted to large variations in temperature, they are vulnerable to even small changes (Deutsch et al. 2010). Baseline information on the condition of intact tropical forests and the modified forest types that have replaced them in human-managed landscapes is important in order to monitor future changes and to provide land managers with information. However, this baseline information is lacking throughout many regions, and particularly in more remote locations that are of high importance to conservation of biodiversity.

The C2C transect focused on collecting baseline ecological data across Costa Rica with a special focus on two areas of key interest to conservation including an agricultural landscape in Coto Brus county near the Las Cruces Biological Station and the Cordillera de Talamanca, in the La Amistad International Park (PILA). The landscape in Coto Brus county is typical of much of Central America in that it consists of a highly fragmented mosaic of agricultural land uses and remnant forest (Cole et al. 2010) (Figure 3). Such multi-use landscapes

Figure 3: A typical mixed mosaic of tropical agricultural lands. Coto Brus county, Costa Rica near the Las Cruces Biological Station

Remote Sensing Challenges in Mountainous Regions

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Remote sensing technology is advancing at a dizzying pace as ever more accurate sensors and analysis techniques emerge. However, while this cornucopia provides us with seemingly unlimited tools, there is still the need for ground reference data and other ancillary data so that the radiative transfer state variables translate into biophysical variables of interest. The American Climber Science Program (ACSP) is on the cutting edge of this process as we explore some of the harshest areas on Earth – from Central American mountain rain forest to the summit of Mt. Everest - and gather data that is integrated through remote sensing to create holistic understandings of these environmental systems. The ACSP is an integrated research program designed to facilitate field data collection opportunities for scientists in regions that are difficult to access. Scientists and climbers come together for expeditions to collect in situ data for scientific projects and to share their enthusiasm for the mountains. Research expeditions are also designed to provide opportunities for non-scientists to learn about scientific practices as well as to instruct future scientists on safety in mountain regions.

The ACSP's central tenet is integrated research and our expeditions are formed of scientists and students from diverse disciplines. Each participant leads their individual project and also assists in data gathering for all of the expedition studies. We gather a variety of ground data: from spectroradiometer readings to glacier particulate composition and quantity to interviews of local yak herders on grazing patterns. This information is then integrated and regionalized using remote sensing data to help inform local resource management and conservation efforts in coordination with various stakeholders. At the end of the day, we seek out research projects with maximum societal benefit and scientific innovation.

Over the next year, we will be periodically sharing ACSP work from Central America, Africa, the Himalayas, and the Andes as *PE&RS* Highlight articles. More information can be found about the ACSP at www.climberscience.com or www.mountainscience.org and we invite collaborators in all disciplines.

Our first example will be from the ACSP Cordillera Blanca expeditions in Peru. In association with the American Alpine Club, the Peruvian Ministry of the Environment, Huascaran National Park, and several Peruvian Universities, the ACSP has conducted research expeditions where, among other things, we have sampled anthropogenic pollutants deposited on glaciers. These pollutants can lead to increased glacier melt rates and the article which follows discusses the issues involved in using remote sensing techniques to detect these pollutants.

play a critical role in conserving biodiversity outside the protected areas such as national parks (Daily et al. 2001). The PILA, our second area of focus, is 401,000 ha region protecting the largest remaining contiguous tropical forest in Central America. The PILA includes the highest and wildest non-volcanic peaks on the isthmus, the Cordillera de Talamanca, which run across the spine of southern Costa Rica and northern Panama. The range rise from near sea level to over 3,800m and provides habitat for an extraordinary wealth of flora and fauna including many endangered and endemic species. It has been suggested that the PILA contains some of the highest species diversity of any protected areas of equivalent size on the planet (UNESCO 1990). The park has been designated as a Biosphere Reserve and a UNESCO World Heritage Site. Despite its importance for conservation, it remains one of the least explored and unstudied regions in Central America.

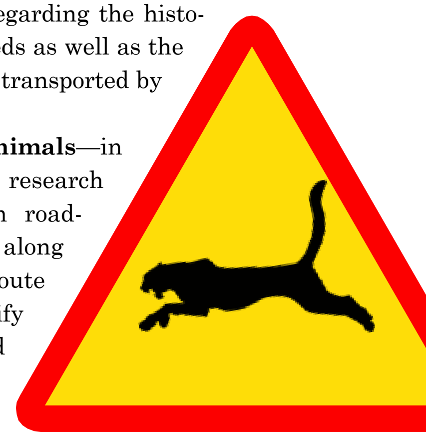
Data Collection

In collaboration with PILA administration and conservation organizations in Coto Brus county, we selected five types of environmental data to collect along our route. These included:

1. **Vegetation parameters**—we took measurements of vegetation and ground cover at over 100 ground control points spaced at ~500m intervals across the transect.
2. **Soil Carbon and Nitrogen**—we collected soil samples at each of 60 ground control points on the Atlantic slope of the PILA (Figure 4) to be analyzed at the Center for Stable Isotope Biogeochemistry, University of California at Berkeley.
3. **Acoustic data**—Song Meter SM2+ recording equipment was used to record acoustic data at set times of day and night. The recordings are used to determine the species, mainly birds and frogs, which are present at different locations as well as in the interiors and edges of remnant forests.
4. **Black carbon in water**—we filtered water samples at different points along the watersheds in the PILA to examine the types of sediments being transported downstream. Significant levels of black carbon (soot or charcoal) leaching from the soil can be an indication of past wild fires. These data can provide useful information regarding the history of disturbance in watersheds as well as the mineralogy of other particles transported by the water.

Figure 4: ~~The author collecting soils~~ during the transect.

5. **Road kill of native animals**—in collaboration with PILA research staff, we collected data on road-related mortality of wildlife along the lowland sections of our route near the coasts to help quantify incidence and locations of road kills in order to facilitate wildlife management and biodiversity protection.



All of these data are being related to environmental variables derived from RS data. This allows us to generate information on vegetation structure across elevation gradients and give us information on factors driving patterns of soil nutrients at broad scales (Figure 5). The acoustic data will be related to RS data of forest structure and forest cover in the surrounding landscape to examine how these factors affect presence and absence, and acoustic behavior of bird and frog species. The black carbon in water data will similarly be related to other visible data on fire disturbances in the area upstream of collection points and help inform the history of fire in the region. Finally, the road kill data will be included in a database by PILA staff with the objective of using RS tools to identify key hazard areas for wildlife on roadways near the park.

The PILA includes the highest and wildest non-volcanic peaks on the isthmus, the Cordillera de Talamanca, which run across the spine of southern Costa Rica and northern Panama.

Analysis Methods

Our remote sensing analysis of the Cordillera de Talamanca takes advantage of the historical period of record for Landsat and so we utilize both Multispectral Scanner (MSS) and Thematic Mapper (TM) for examining land cover trajectories from the early 1970's to today. Fortunately Landsat 8 allows continuity in these measurements (Figure 5). Landsat imagery is classified using the ground reference data collected. Additionally, various vegetation indices such as EVI (Enhanced Vegetation Index) and NDVI (Normalized Difference Vegetation Index) are used in our spatial statistical analyses along with derived products such as NPP.

Topographic data is another critical component in our research and elevation values are used to derive slope and aspect

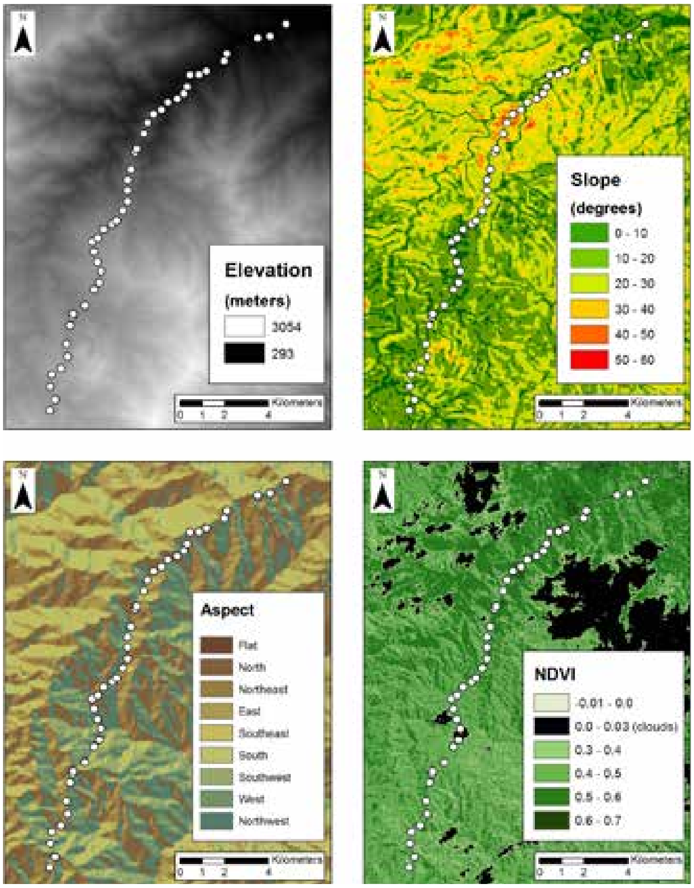


Figure 5: Elevation, slope, aspect, and NDVI maps for the study region in PILA. These were derived from the NASA SRTM DEM and from Landsat 8 imagery. Finding cloud-free imagery for this study area proved impossible and clouds have been masked out in the NDVI image.

information. We use elevation data from Global Digital Elevation Models (GDEMs) created from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) images – a passive sensor on the Terra satellite where stereoscopic correlation techniques were used to create a DEM – and the Shuttle Radar Topography Mission (SRTM) – a year 2000 space shuttle mission that utilized radar to create a near global DEM. We have forthcoming research that indicates the best application for each DEM and so we utilize the strengths of whichever is more useful for a given application (Figure 5). This data is ground verified by using a Suunto engineering compass and inclinometer.

Ground reference data was collected using a random stratified collection system - beginning at a random point each morning, data was collected at set distances from previous locations. Additionally, opportunistic points were taken whenever distinct land features were encountered (Figure 6). Specific parameters recorded at each ground location included: UTM coordinates and altitude from a handheld GPS, aspect and slope using the Suunto, dominant and common species, canopy closures, vegetative parameters, vegetation classes, soils, and an assessment of any human impacts – grazing, trekking, campsite remnants, trash, etc. Data was accessed for a 10-meter radius and photos were taken in the eight standard directions and of the ground and canopy for later reference.

Figure 6: The research team walking through a creek to escape the thick vegetation for a time.

Project Outcomes

This project resulted in several products of direct relevance to land managers in the study area. Additionally, secondary products such a video and forest sound recordings are available for use in local schools and by other stakeholders interested in protecting the area. Finally, the baseline data we collected on forest structure can be used to inform more detailed future RS studies such as an overflight with LiDAR equipment. While the C2C expedition was incredibly successful, there are still broad swaths of the PILA in both Costa Rica and Panama that are poorly documented. We anticipate working with the PILA and other local conservation organizations in future expeditions to address their areas of concern and further the development of scientific knowledge in the area.

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