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Differentiating climatic and anthropogenic alpine land cover change drivers from 1972 – 2012 in the Cordillera Blanca, Peru

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Abstract

This study combines remote sensing (coarse-scale) and ground-based measurements (fine-scale) to examine patterns of land cover change over the past 40 years in Huascaran National Park (HNP) and adjacent communal areas in the Cordillera Blanca, Peru. We are testing how these measurements can best be used as predictors of vegetation community structure and to differentiate between anthropogenic and climatic drivers of change in this region. In addition, we are assessing how potential shifts in plant community composition affect key ecosystem functions including carbon and nutrient cycling. Satellite imagery including Landsat MSS and TM, along with ASTER and MODIS, are used to characterize differences in vegetation and fire disturbance over time. Vegetation patterns are assessed using NDVI and fire spatial analysis is performed using MODIS thermal anomaly and burned area products. Between 2011-2013, the American Climber Science Program (ACSP) collected data on vegetation type, ground cover classes, and disturbance with an extensive set of ground control points (>300 10-m-radius plots) along the length of the Cordillera Blanca. In order to assess if/how native forest stands have changed over time, we are measuring the structure, composition, and patterns of regeneration in a series of *Polylepis* forest stands throughout HNP. In order to assess how upslope shifts in vegetation, particularly woody species, may alter carbon and nutrient cycling, we are testing temperature effects on decomposition of litter of dominant species. Preliminary results show substantial increases in NDVI between 3000-5000m over the past 40 years. Fires initiate predominantly inside the park rather than in the buffer zone and are anthropogenic in origin. Vegetation cover and *Polylepis* forest regeneration is negatively correlated with grazing intensity and accessibility to grazing animals. This research is on-going in 2013-2014.

INTRODUCTION

The tropical Peruvian Andes provide critical ecosystem services to human populations and harbor high levels of biodiversity, including endemic and threatened species. These high altitude ecosystems are under increasing pressure from human activities including burning, deforestation, and overgrazing. In addition, the region is undergoing extremely rapid changes due to warming temperatures. Glacier cover in the Cordillera Blanca, the largest tropical glacier-covered area in the world, has decreased by >25% in the last 40 years (e.g., Rabatel et al. 2013) and predicted changes in temperature may have significant consequence for native plant communities, ecosystem services, and human livelihoods. Because of the strong interdependence of human and natural systems in the Peruvian Andes, the region is considered to be particularly vulnerable to the impacts of climate change and environmental degradation.

Land-cover change has profound effects on ecosystem structure, function, and associate ecosystem services (Sala et al. 2000). Land cover change is driven by multiple factors including direct human impacts as well as indirect effects through shifts in temperature and precipitation regimes due to climate change. Throughout the Andes, deforestation, changes in fire regimes, conversion of land for agricultural uses, and increased grazing pressure have extensively altered high altitude vegetation cover). Vegetation cover in the Cordillera Blanca ranges from high altitude cloud forest on the Eastern slope to arid grassland (Puna) mixed with shrubs, remnant tree patches, and alpine tundra on the western slope. Although these grasslands evolved with native grazing animals, increased grazing pressure, particularly from cattle, along with traditional burning practices to renew pastures, have lead to significant degradation (Cingolani et al. 2008). High altitude tree lines in the Andes are formed almost exclusively by trees of the genus *Polylepis* (Rosaseae). *Polylepis* forests are considered to be a key ecosystem in the high Andes and are important for biodiversity, water quality, and soil retention, and are a possible carbon (C) sink (Fjeldsa 2002, Hoch and Korner 2005). Although *Polylepis* forests are thought to have historically fluctuated with climatic factors (Gosling et al. 2009), these forests have been extensively cleared, fragmented, and degraded through human activities and are currently considered to be among the most endangered tropical mountain forest ecosystem (UNEP-WCMC 2004, IUCN 2010). Disturbance and degradation can also lead to replacement of forest stands with more disturbance tolerant shrub species.

As global temperatures rise, climatic conditions suitable to species will be displaced towards higher elevations and latitudes (Loarie et al. 2009). Plant species are predicted to experience range shifts and contractions as they move their distributions to stay within their thermal niches (e.g., Chen et al. 2011). Although such changes have been documented in temperate areas, very few studies have focused on the tropics despite increasing recognition of rapid climate change effects, particularly in tropical mountains (Feely et al. 2013). Changes in vegetation cover and composition have direct consequences for biodiversity and key ecosystem services and biogeochemical processes such as carbon storage and nutrient cycling. The decomposition of dead organic material is a fundamental biogeochemical process through its role in the global C cycle and in the recycling of nutrients to soil and plant communities. Changes in the rates of decomposition can have major effects on ecosystem functions. Understanding patterns of land cover change and their consequences for ecosystem process and services is important for long-term planning in critical regions, particularly in the context of climate change. Although an increasing number of studies are examining direct impacts of disturbance on high altitude vegetation types, there is little current information on interactions between disturbance and climate change, on longer-term shifts (40+ years) in vegetation cover, or effects on key ecosystem functions.

This study combines remote sensing (coarse-scale) data with ground-based measurements (fine-scale) to examine patterns of land cover change over the past 40 years in Huascaran National Park (HNP) and adjacent communal areas in the Cordillera Blanca, Peru. We aim to (1) assess changes in vegetation cover over time (1972-2012); (2) differentiate between anthropogenic and climate factors affecting vegetation cover in the Cordillera Blanca; (3) evaluate factors influencing *Polylepis* forest structure; and (4) test how shifts in temperature affect decomposition of organic material.

METHODS

STUDY AREA. The Cordillera Blanca is the highest tropical mountain range in the world, with over 33 peaks higher than 6000 meters and hundreds of 5000+ meter peaks, and it is protected within the Huascaran National Park. The National Park was created in 1975 and UNESCO declared this region important enough to be designated the Huascarán Biosphere Reserve in 1977 and a World Heritage Site in 1985. The Cordillera Blanca is critical for biodiversity and as a source of water for the entire region (Silverio and Jaquet 2003).

SATELLITE AND GROUND VERIFICATION METHODS. Landsat imagery from 1972 to 2012 is classified at five year intervals to delineate grass, shrub, and forest boundaries in Huascaran National Park. Global NASA SRTM-derived Digital Elevation Models (DEMs) are used to characterize elevation/slope/aspect variations in the ecozone boundary shifts. NOAA's Moderate Resolution Imaging Spectroradiometer (MODIS) will be used to analyze fire frequency and severity. Normalized Difference Vegetation Index (NDVI) and are used to measure vegetation productivity and compared to climate variables such as an ENSO index. Net Primary Productivity (NPP) is calculated to examine the overall impact of vegetative transitions on potential provision of ecosystem services.

Satellite data is verified using a series of ground-based measurements. Between 2011 and 2013, volunteers with the America Climber Science Program measured an extensive series of ground control points (>300 10-m-radius plots) in 8 major valleys and accessible slopes along the length of the mountain range. Specific parameters recorded at each ground location include: UTM coordinates, altitude, aspect, slope, geomorphology (e.g., debris slide, alluvium, talus cone, colluvial terrace), ground cover categories (ecotype, grass, moss needle leaf litter), vegetation classes, and an assessment of human impacts – grazing, trekking, campsites, trash). In the absence of measurable disturbances, climate changes should be responsible for most vegetation variability. Areas of high human-induced impacts such as fire or grazing are compared to more remote areas with fewer disturbances to evaluate climate versus anthropogenic drivers for change.

VEGETATION MEASUREMENTS. In order to assess if/how native forest stands have changed over time, we are measuring the structure, composition, and patterns of regeneration in a series of 20 *Polylepis* forest stands throughout HNP. Forests have been selected across a gradient of disturbance and accessibility in major valleys across the Cordillera Blanca. We are sampling vegetation in 10-m-radius plot established at the approximate center of each forest stand. All woody stems > 5cm diameter are identified to species level and diameter at breast height (dbh, ca 1.3 m) and height measured. All understory plant species present in the plot are noted and identified. Forest floor cover (exposed soil, bryophytes, rock, coarse woody debris) is characterized along a 10-m transect. In smaller 5×5 m plots established in both the forest stand center and at the forest edge, we identify and count all woody sapling and seedlings (>10 cm height and <5 cm dbh).

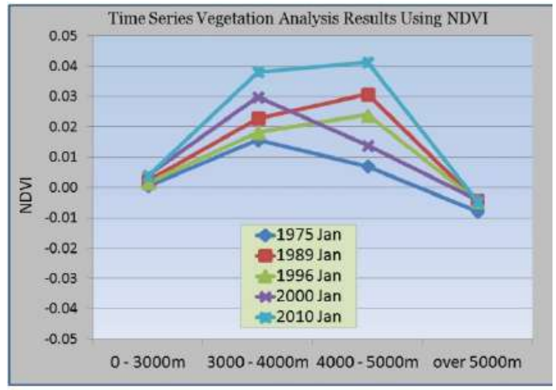

Figure 1. Shows NDVI from selected years between 1975 and 2010 in the Cordillera Blanca between 3000 m to mountain summits (over 6000 m).

Litter Decomposition. Leaf litter from 6 dominant tree, shrub, and grass species were hand-collected in July 2013. The species were collected from lower elevation (3500-3800) and higher elevations (4500-4800) ranges and represent a variety of leaf functional types. Litter decomposition is being evaluated using a litterbag technique. Ten combinations of litter are placed in 400 total litterbags (fine mesh bottom with 3cm mesh on top to allow arthropod access) and deployed in ten replicate depots at two elevations (3800m and 4400m). Soil moisture and nutrient content is measured at each depot and annual surface and soil temperature (5cm depth) is recorded using Hobo data loggers at each elevation point. Litter mass loss and litter nutrient content will be measured after one year.

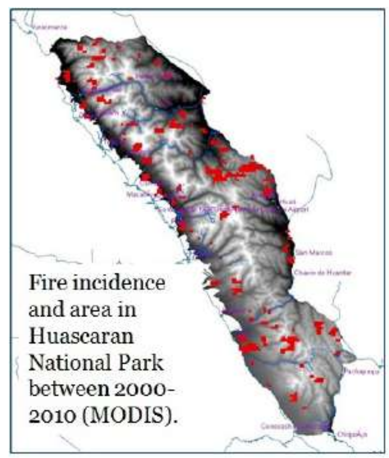

Figure 2. Fires in HNP.

Preliminary Results and Conclusions

The results from the processed satellite images (selected years: 1975, 1989, 1996, 2000, 2010) show significant increases in NDVI for the protected area within HNP (Figure 1). NDVI increased in both the 3000-4000 m range and in the 4000-5000m range. Changes in unprotected areas (elevations below 3000 m) and glacier covered and recent de-glaciated areas (above 5000 m) did not show changes in vegetation productivity during this time interval. This suggests that land management (i.e. protection) within the park has had positive effects on vegetation productivity.

Analysis of MODIS fire products shows that there have been extensive burns within HNP between 2002 and 2010 (Figure 2). Timing of fire events is correlated to fuel load which is correlated with patterns of precipitation (ENSO cycles). Importantly for HNP management, we show that most fires are anthropogenic and originate within the park and move into the communal areas only occasionally. This is in contradiction to National Park policy and is having a direct effect on biogeographic patterns.

Preliminary analysis of forest stand measurements show that seedling density is negatively correlated to grazing intensity and evidence of cow-access to forest patches. Less disturbed forest stands had similar tree seedling densities at centers and edges whereas stands that showed signs of cow disturbance had lower overall seedling densities and few to no seedlings along edges. This research will be ongoing in 2013-2014.

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The American Climber Science Program (ACSP) is a citizen-science program designed to facilitate research opportunities for scientists in regions which are difficult to access. Scientists and climbers come together for expeditions to collect 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.

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