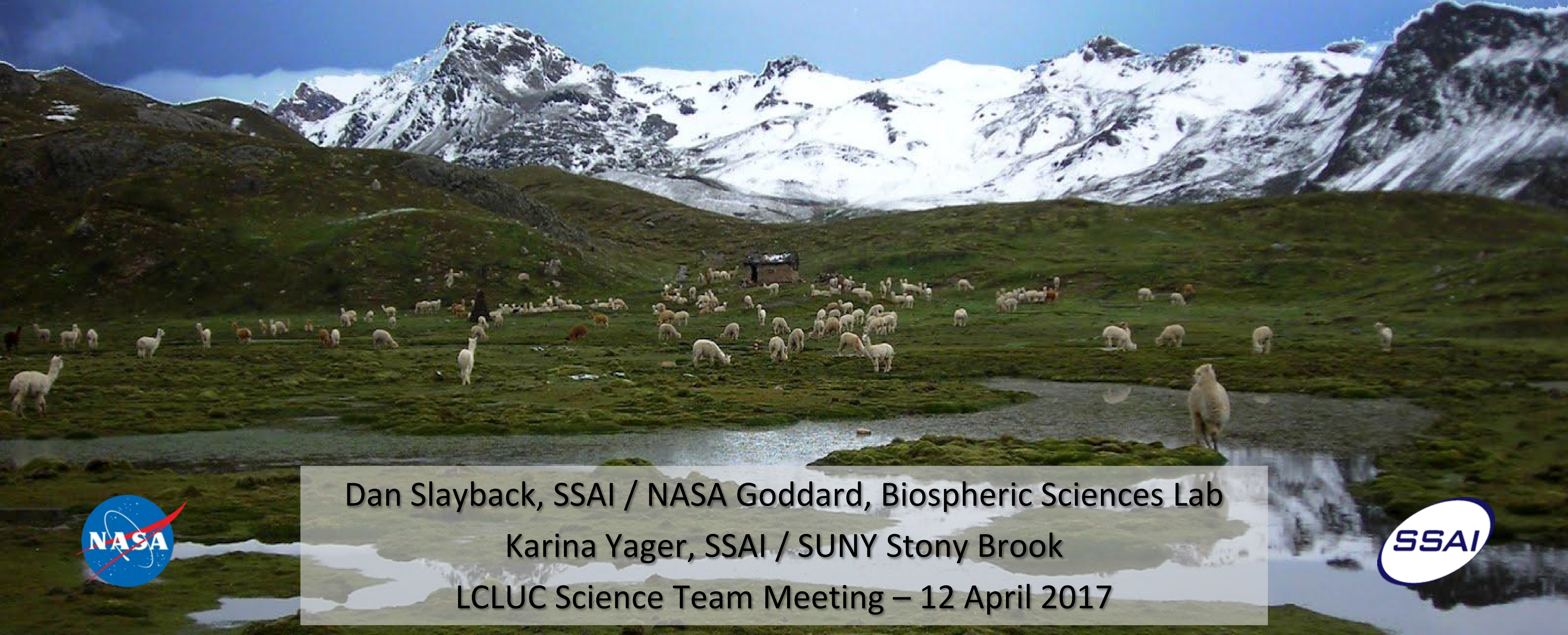
# Climatic and socioeconomic drivers of land-cover and land-use change in tropical Andean alpine wetlands

Current progress: July 2015 – present

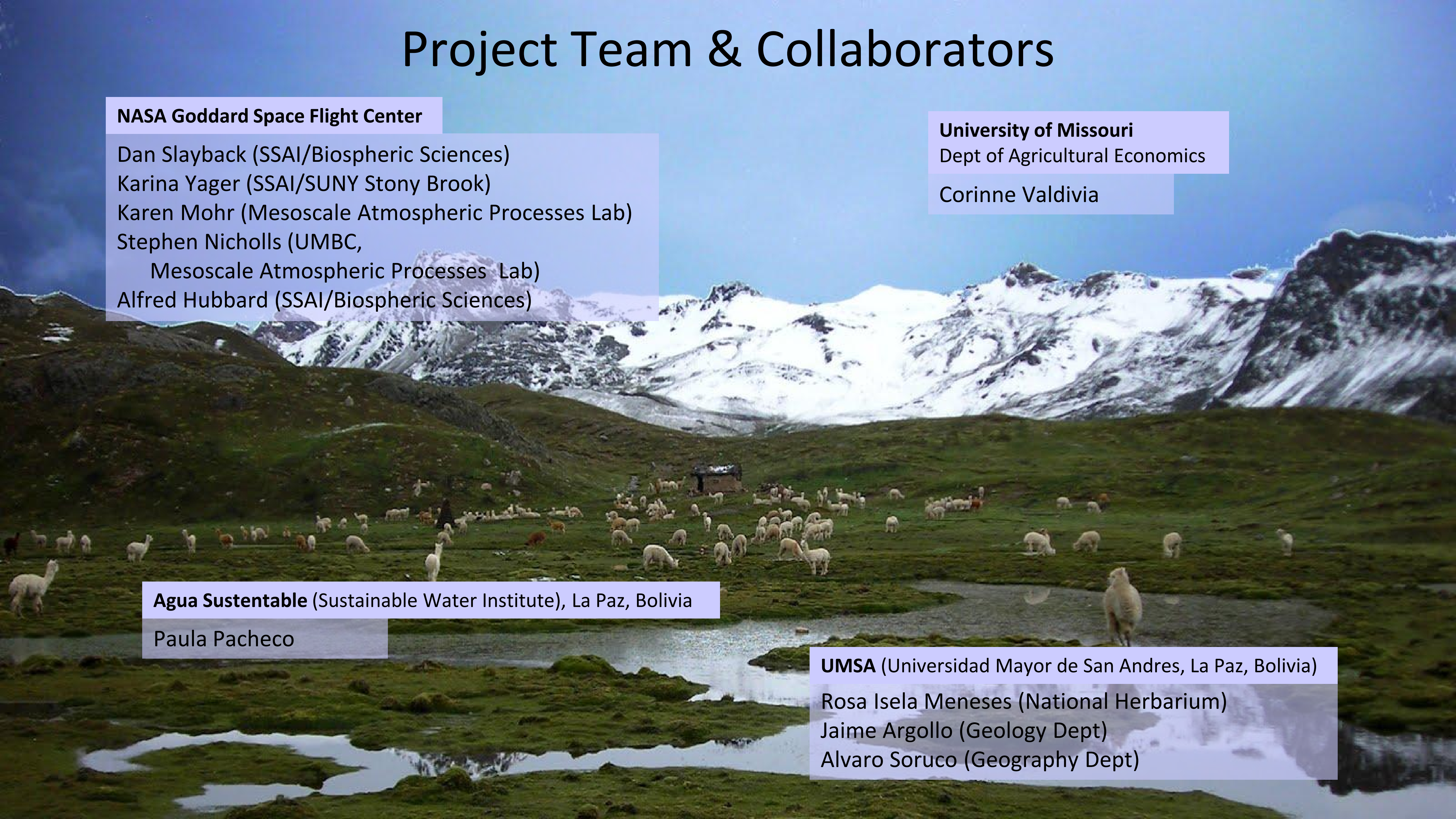


Dan Slayback, SSAI / NASA Goddard, Biospheric Sciences Lab

Karina Yager, SSAI / SUNY Stony Brook

LCLUC Science Team Meeting – 12 April 2017

# Project Team & Collaborators



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# *Bofedales:* alpine peatlands

- Dominated by vascular plants (compact cushion plants Juncaceae family, e.g. *Distichia muscoides* and *Oxychloe andina*)
- Highly palatable and nutritious forage year-round for llama and alpaca


*Distichia* *Oxychloe* moss

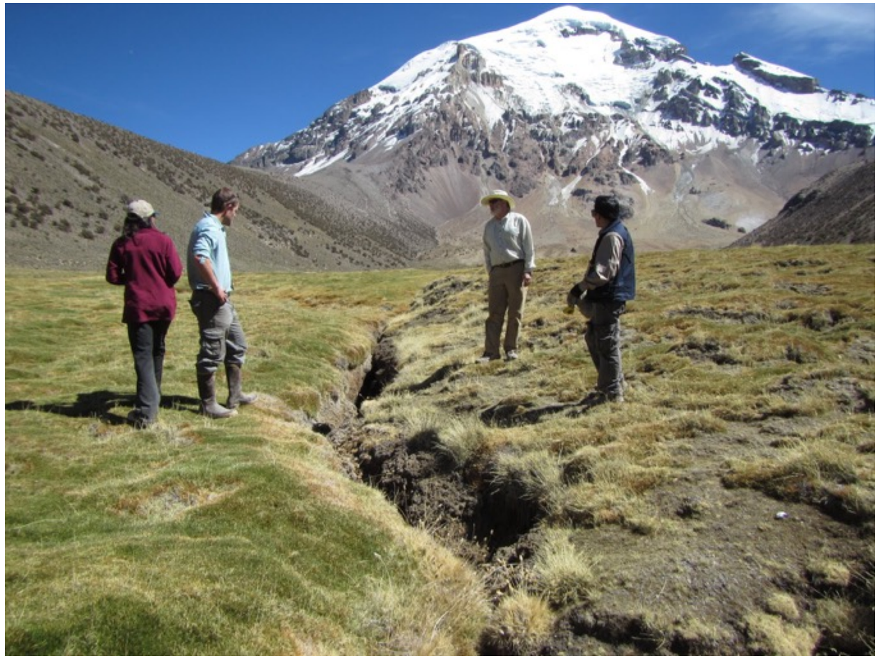
## Study Region:

- Glacier-associated regions of altiplano of Peru and Bolivia (typically 4500+ meters)
- Most vulnerable to climate change
- Fewest alternative livelihood options

# Threats

- Drying / Salinization
- Over-grazing / cattle
- Erosion
- Mining
- Dams




Healthy bofedal cushion…
Oct 2012


…without water for 1 season…
Mar 2014


…does not recover….
July 2016

# Research Objectives

**Principal questions**: What are the primary drivers of the degradation of bofedal systems in the tropical Andes? How will bofedales be impacted by predicted climate change? What are the implications for local communities?

**Land-use hypothesis**: increased land-use pressure by pastoralists is driving change

- Physical evidence?
- Sociological evidence?

**Climate hypothesis:** changes in precipitation may be directly (erosive), or indirectly (desiccation) causing degradation.

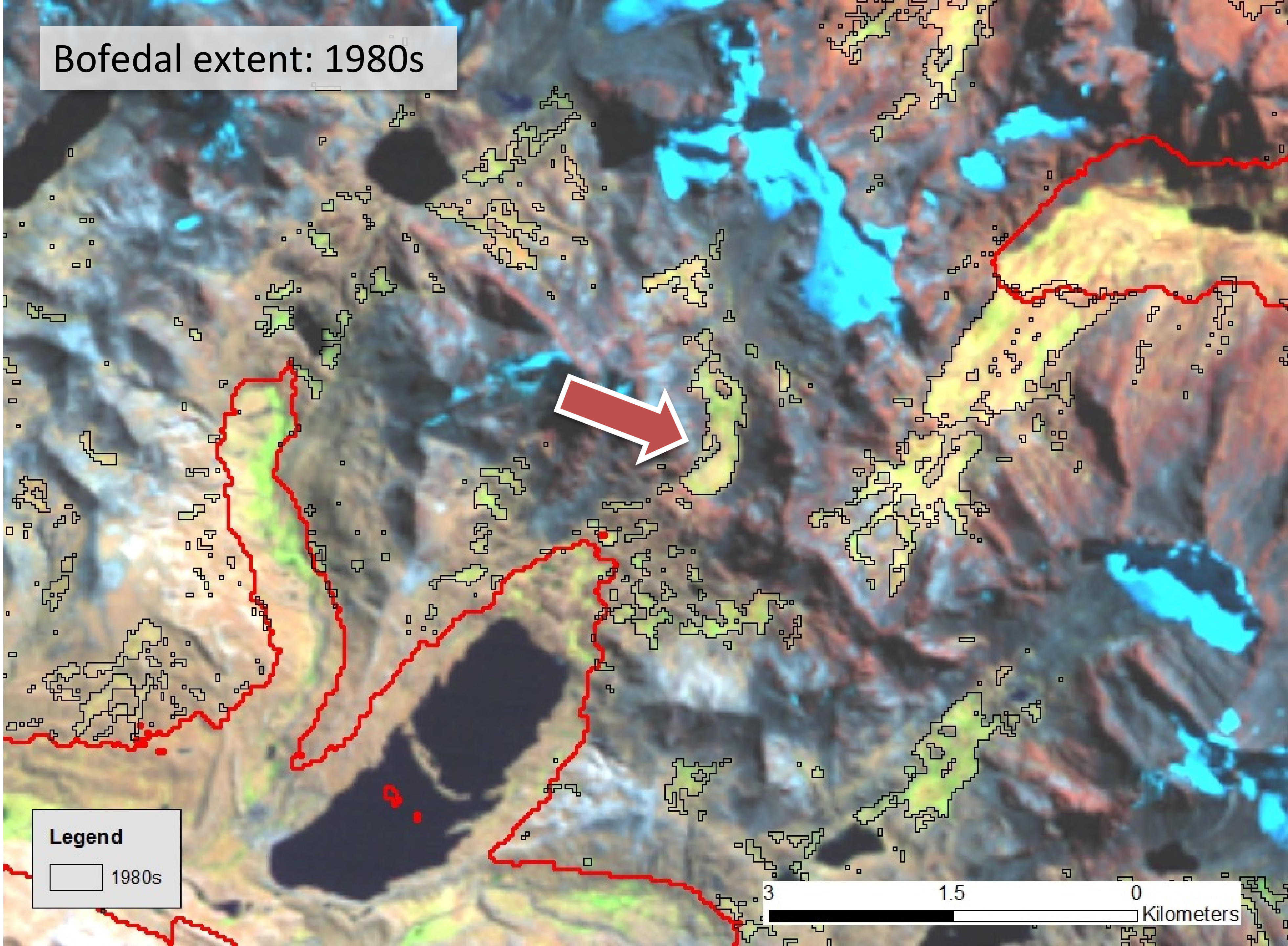
- Physical evidence?
- Model evidence?
- Sociological evidence?

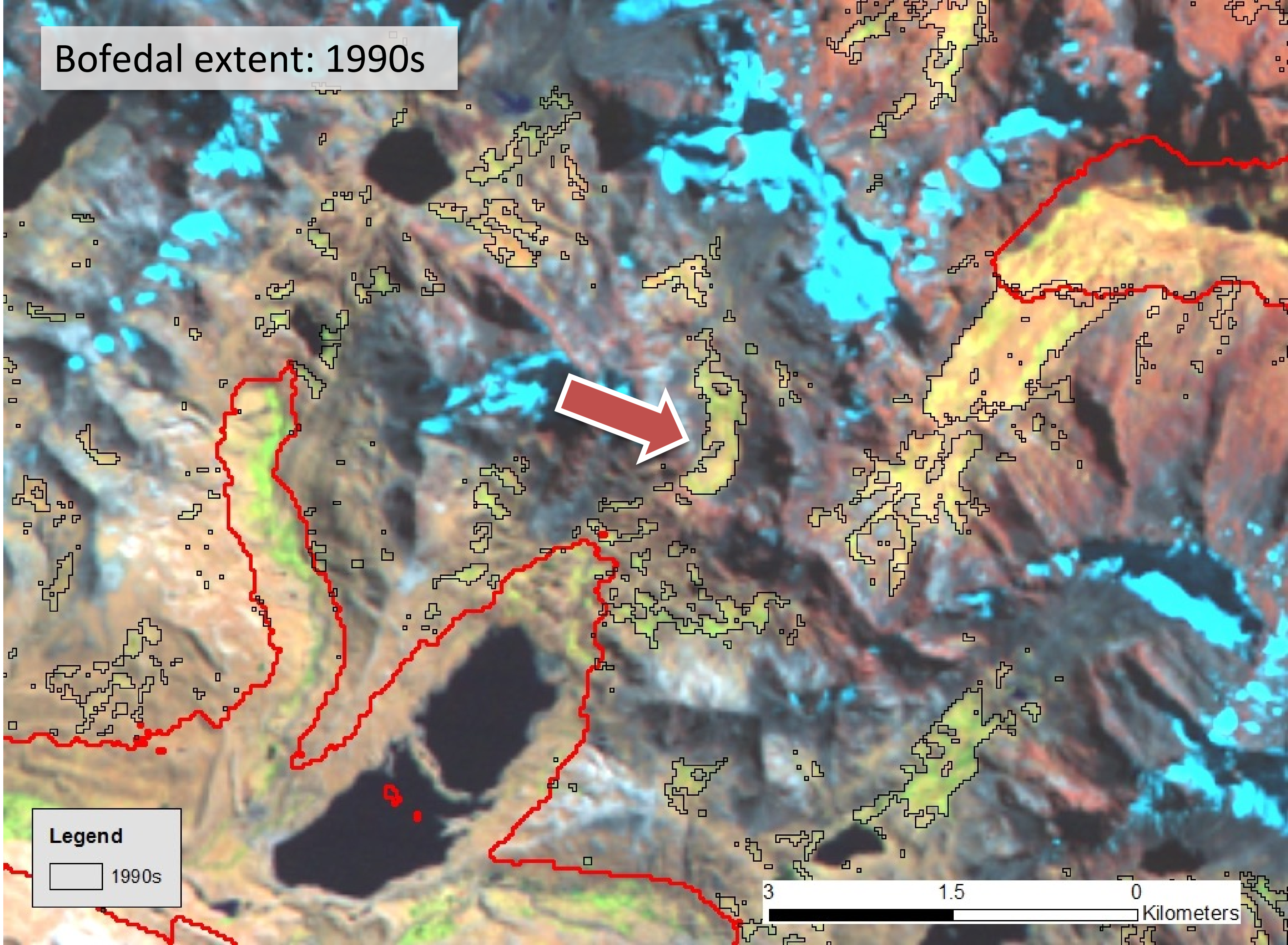
# Research Components

- Bofedal health:
  - Stability over time
  - Vulnerability to erosive degradation
- Regional climate:
  - Retrospective analysis of current climate
  - Projections of future climate, ~ 2030 – 2100
- Socioeconomic / land-use:
  - Focus groups
  - Household surveys
  - Participatory mapping

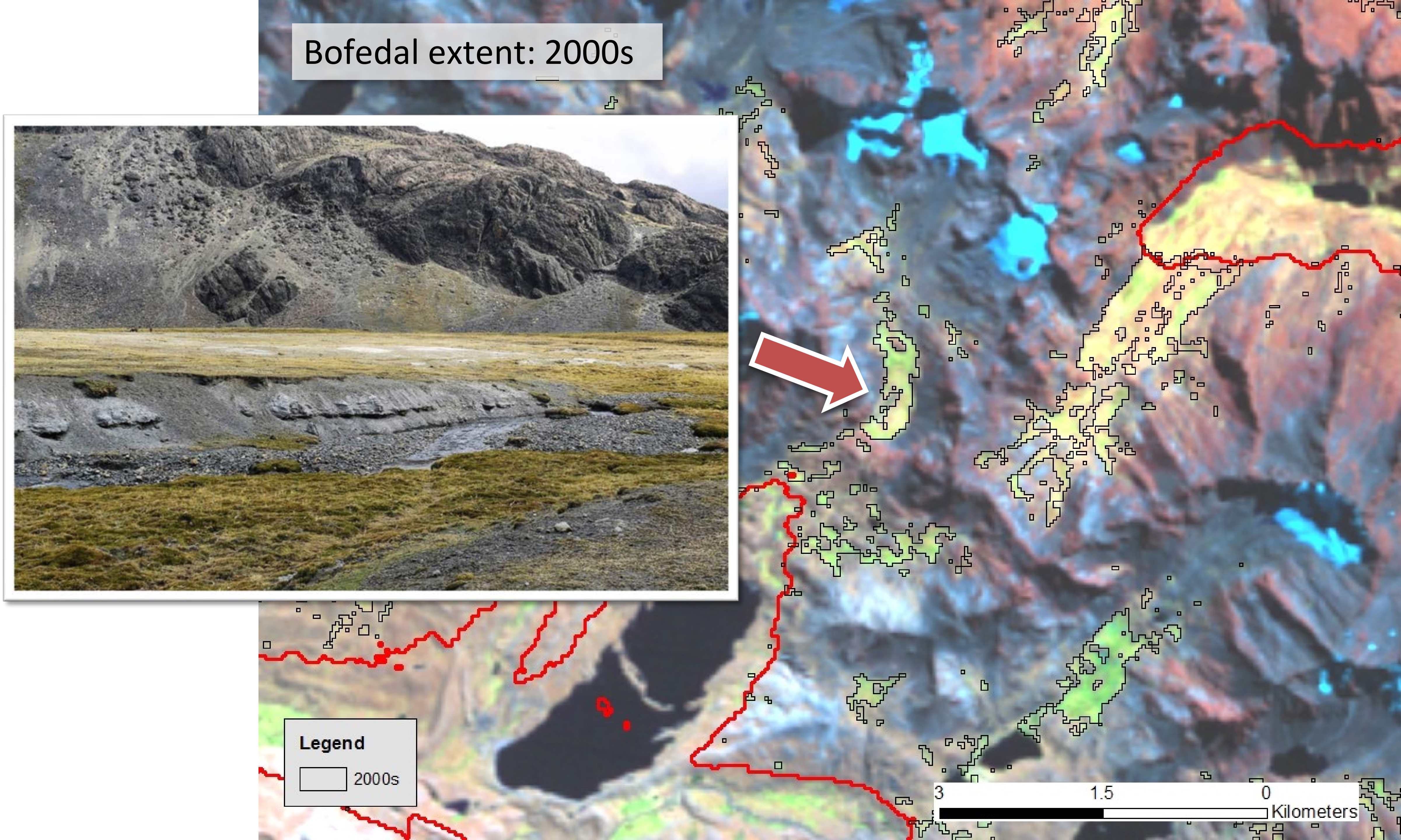
# Bofedal Health:

## Stability over time

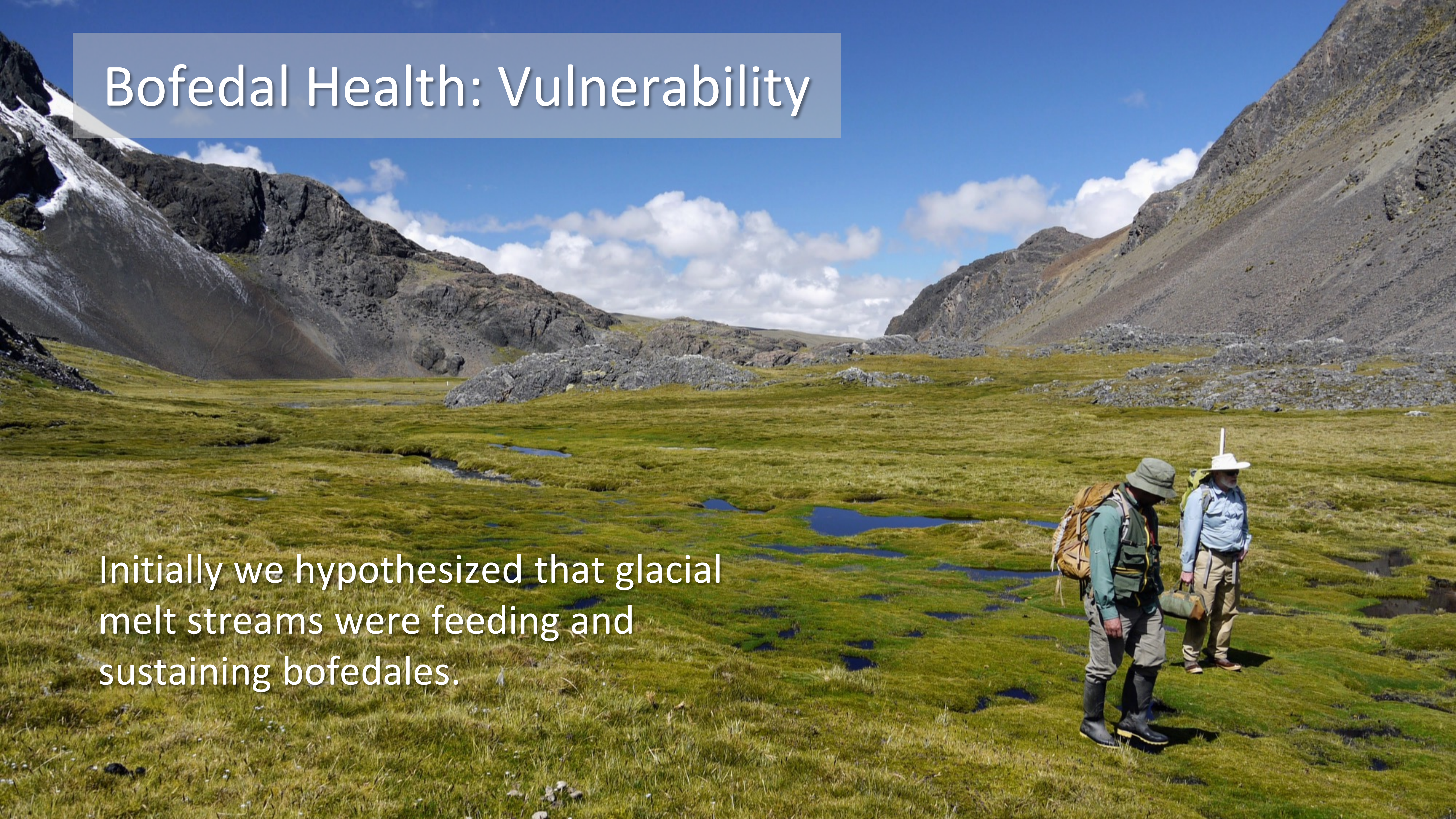




Bofedal extent: 1990s
Legend
1990s
3
1.5
0
Kilometers


Bofedal extent: 2000s
Legend
2000s
3
1.5
0
Kilometers

# Bofedal Health: Vulnerability

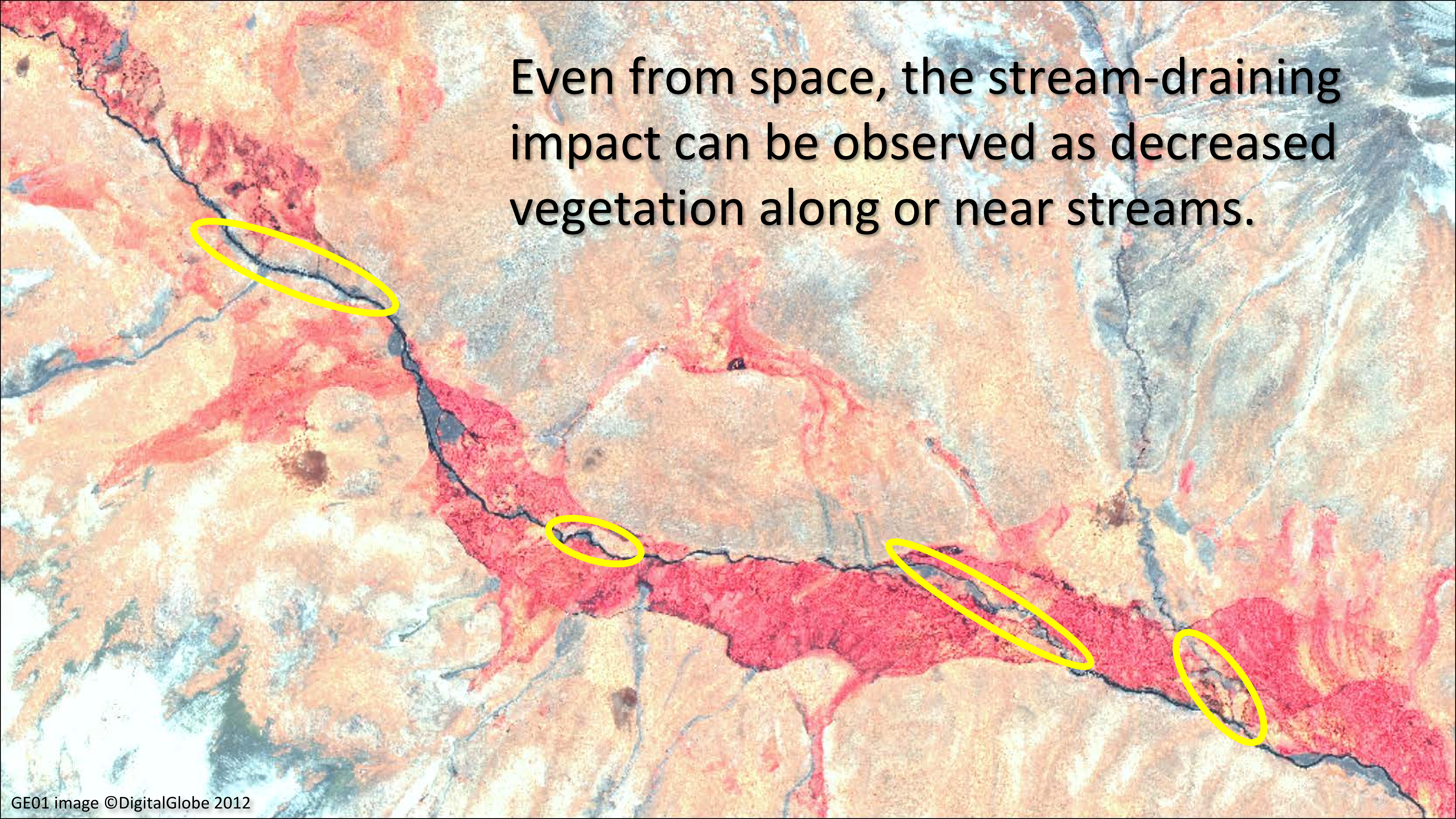


Initially we hypothesized that glacial melt streams were feeding and sustaining bofedales.


But…our previous project demonstrated that most water in bofedales was NOT glacial stream meltwater, but ground water.

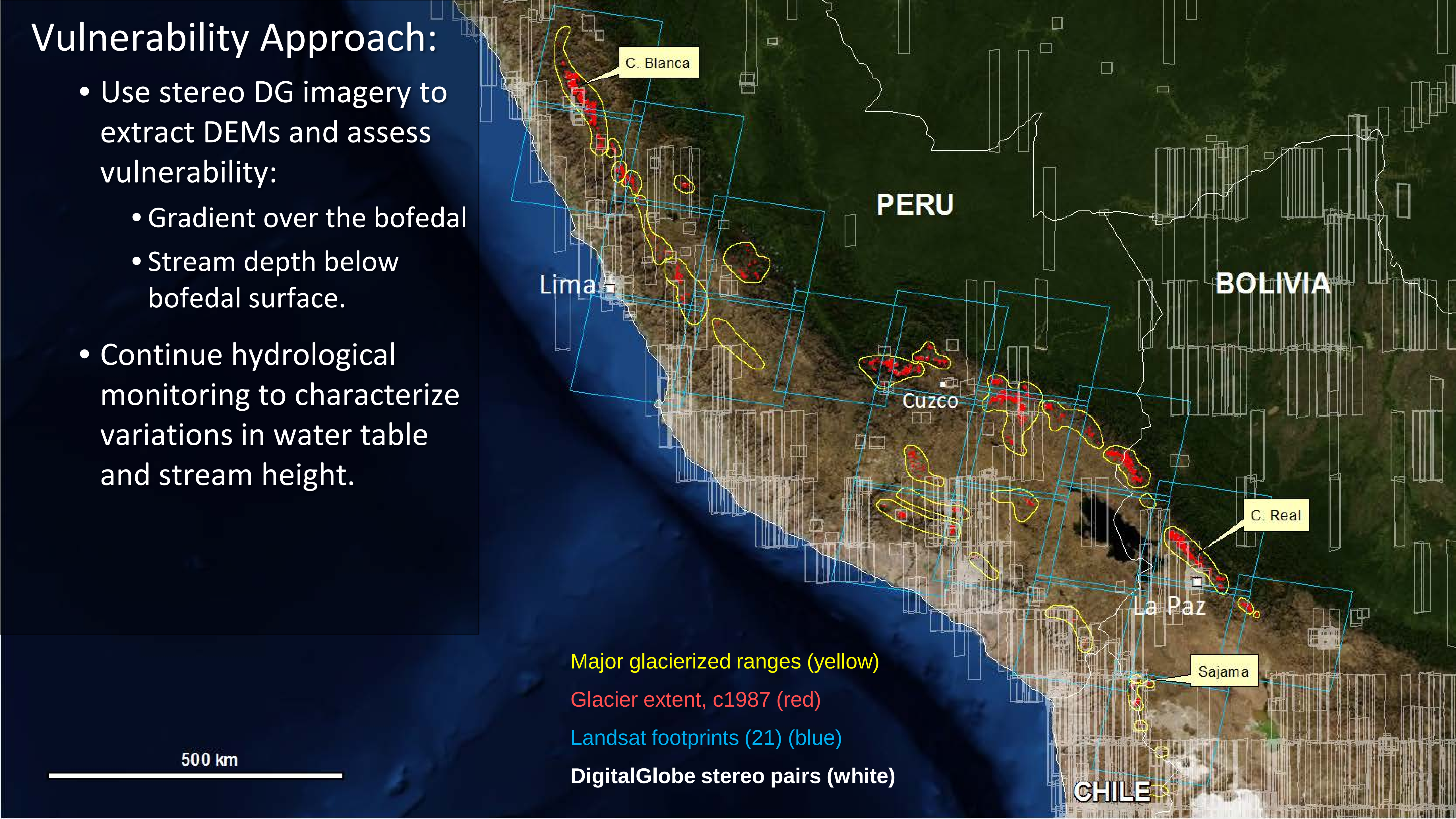

And we noticed many systems
being undercut by deep channels…

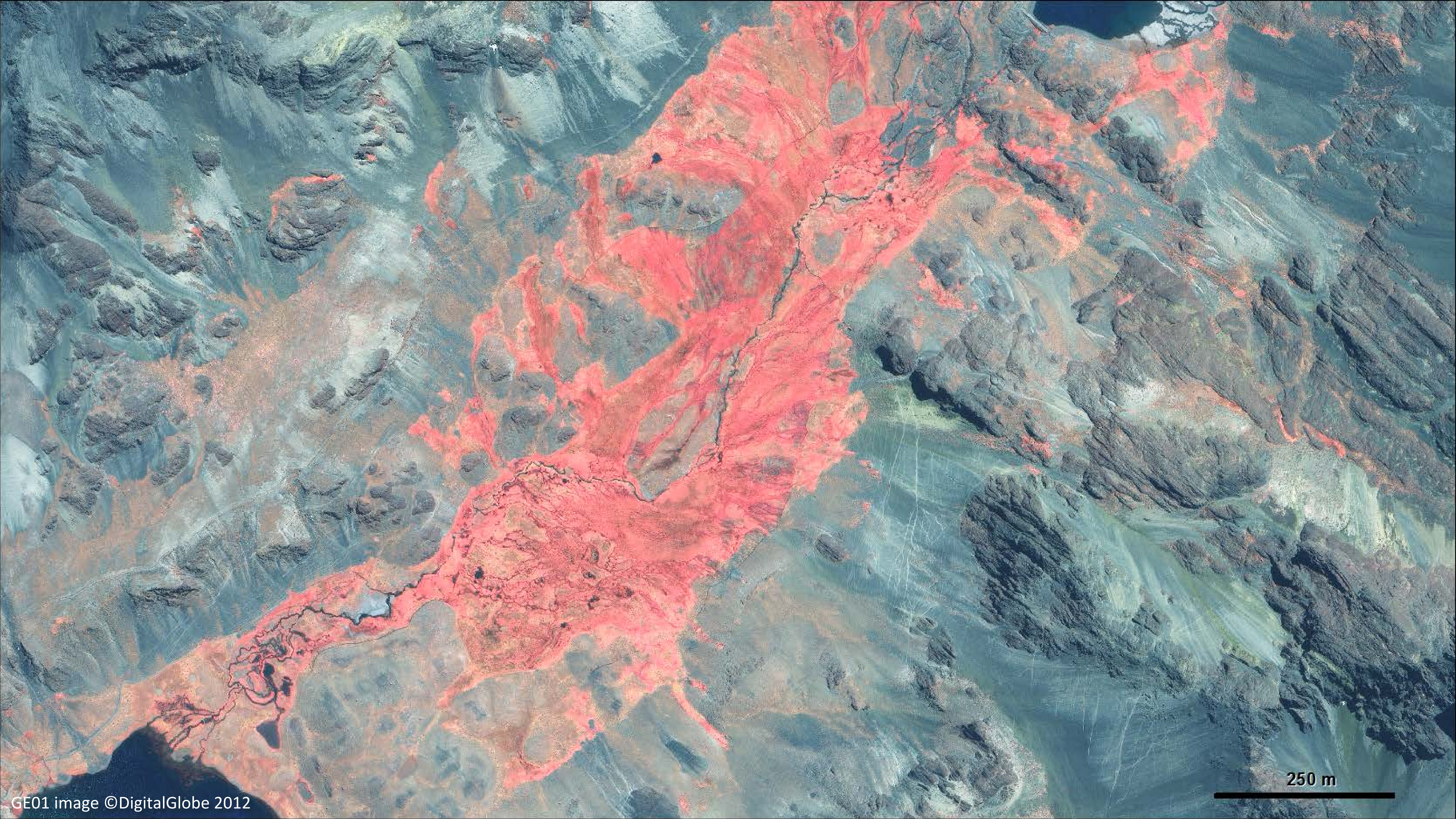

…which was clearly affecting
vegetation, which cannot
recover quickly.

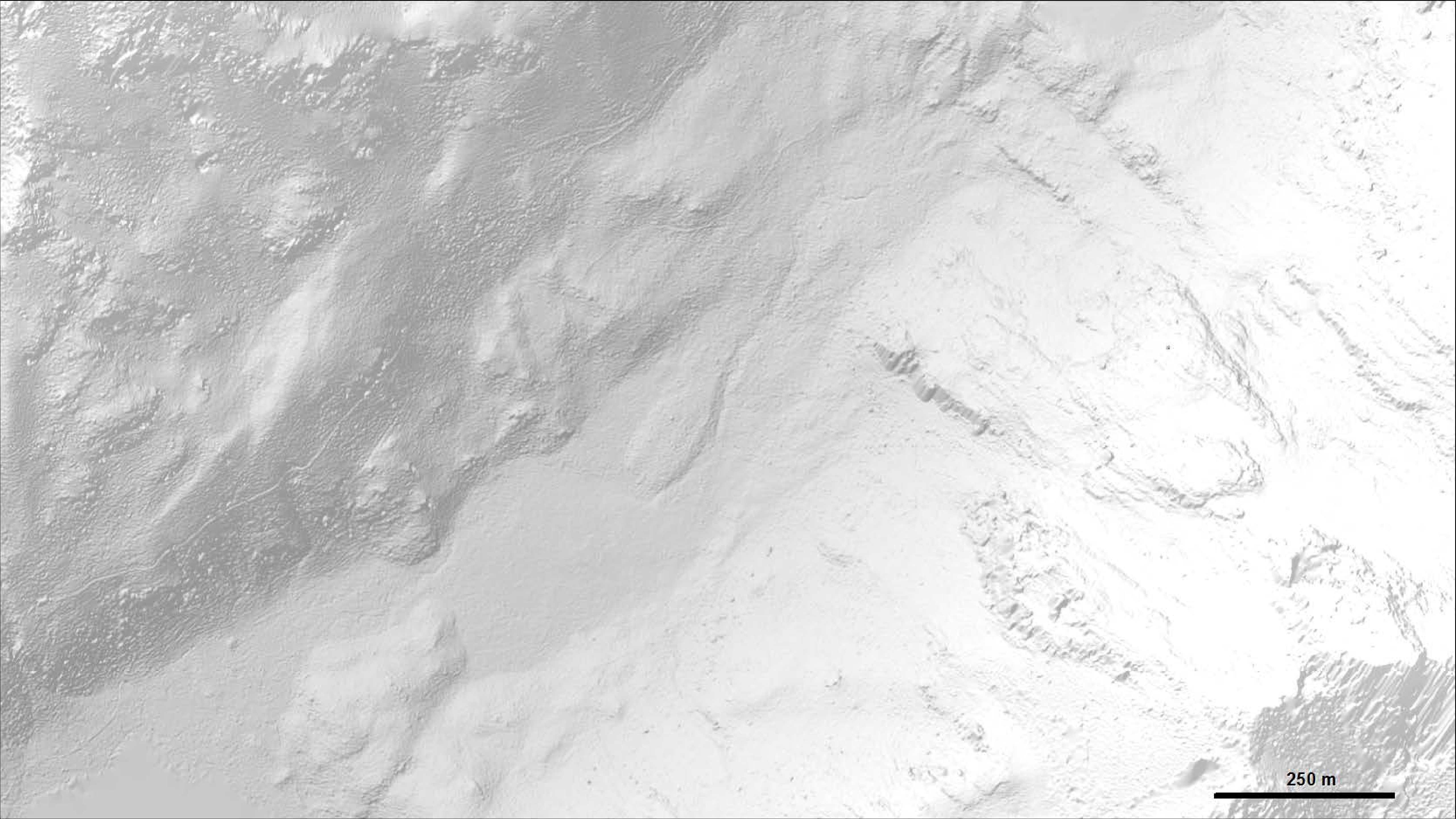

Even from space, the stream-draining impact can be observed as decreased vegetation along or near streams.
GE01 image ©DigitalGlobe 2012

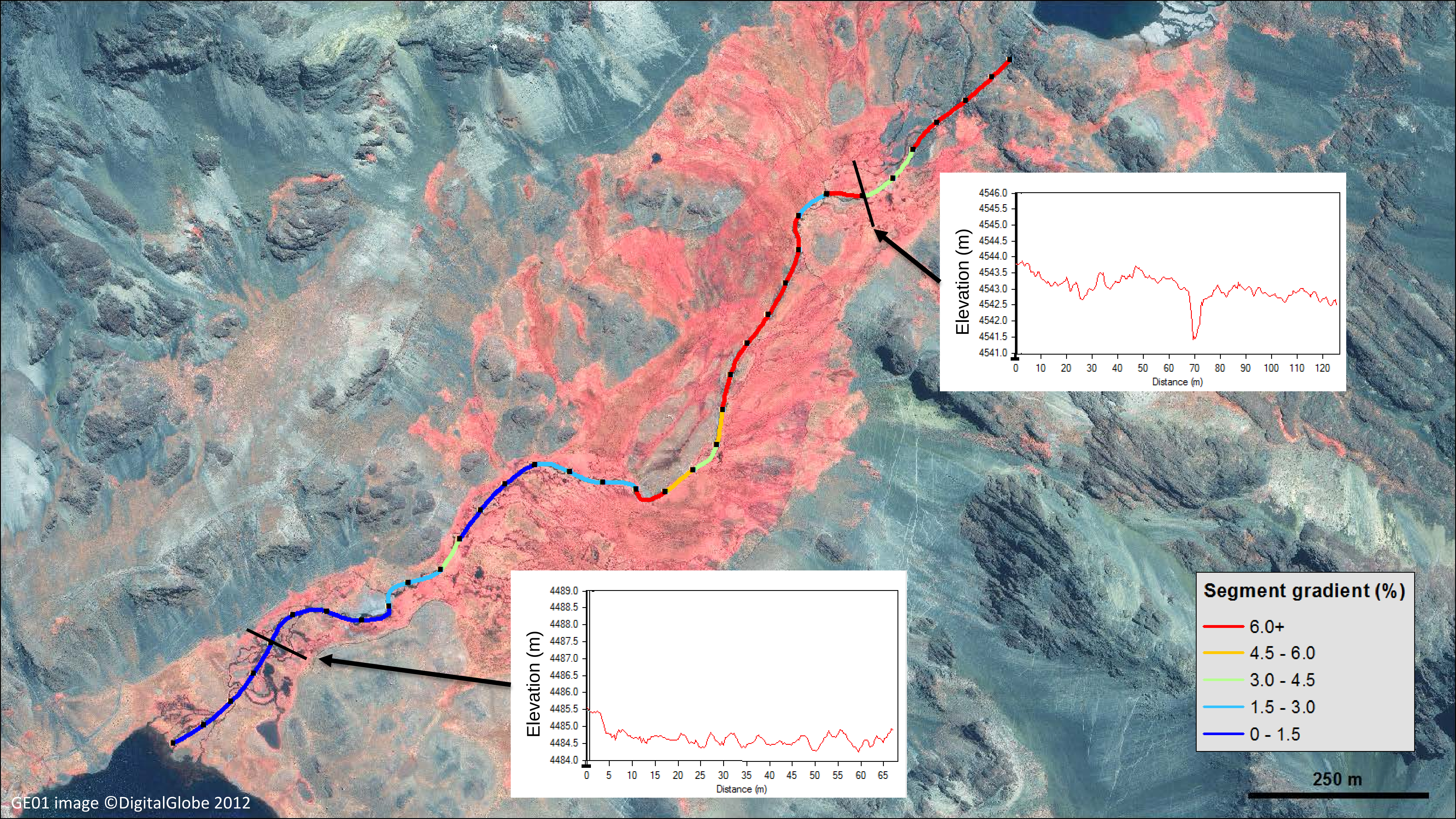
# Vulnerability Approach:

- Use stereo DG imagery to extract DEMs and assess vulnerability:
  - Gradient over the bofedal
  - Stream depth below bofedal surface.
- Continue hydrological monitoring to characterize variations in water table and stream height.



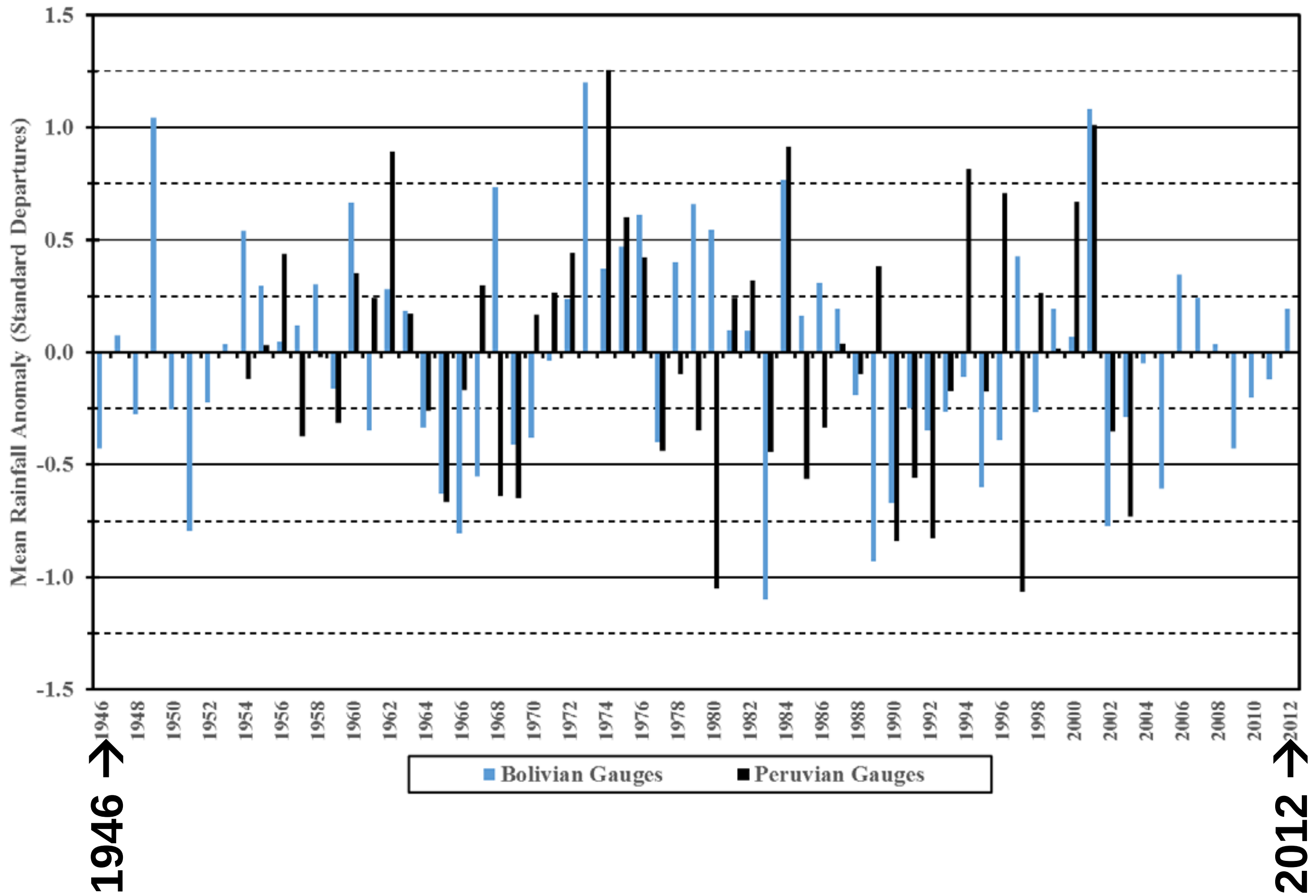

250 m
GE01 image ©DigitalGlobe 2012

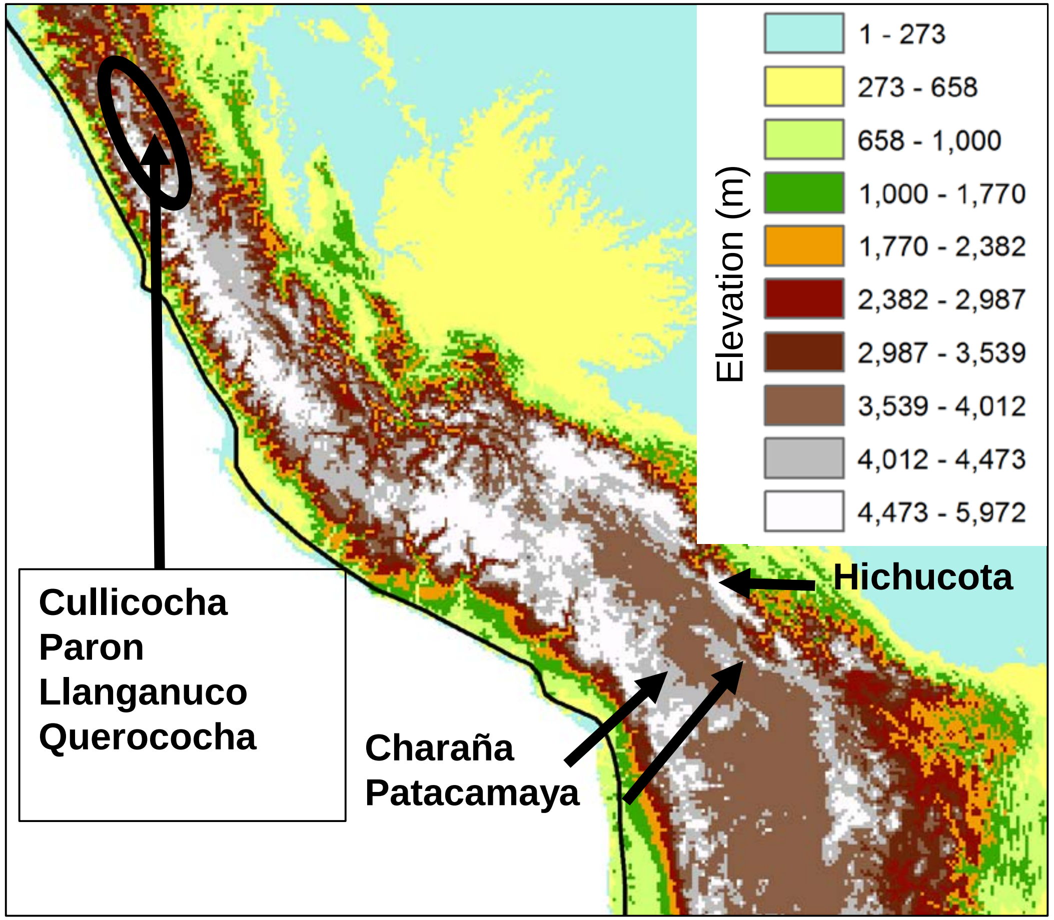

250 m



Elevation (m)
Distance (m)
4546.0
4545.5
4545.0
4544.5
4544.0
4543.5
4543.0
4542.5
4542.0
4541.5
4541.0
0 10 20 30 40 50 60 70 80 90 100 110 120
Elevation (m)
Distance (m)
4489.0
4488.5
4488.0
4487.5
4487.0
4486.5
4486.0
4485.5
4485.0
4484.5
4484.0
0 5 10 15 20 25 30 35 40 45 50 55 60 65
Segment gradient (%)
6.0+
4.5 - 6.0
3.0 - 4.5
1.5 - 3.0
0 - 1.5
250 m
GE01 image ©DigitalGlobe 2012

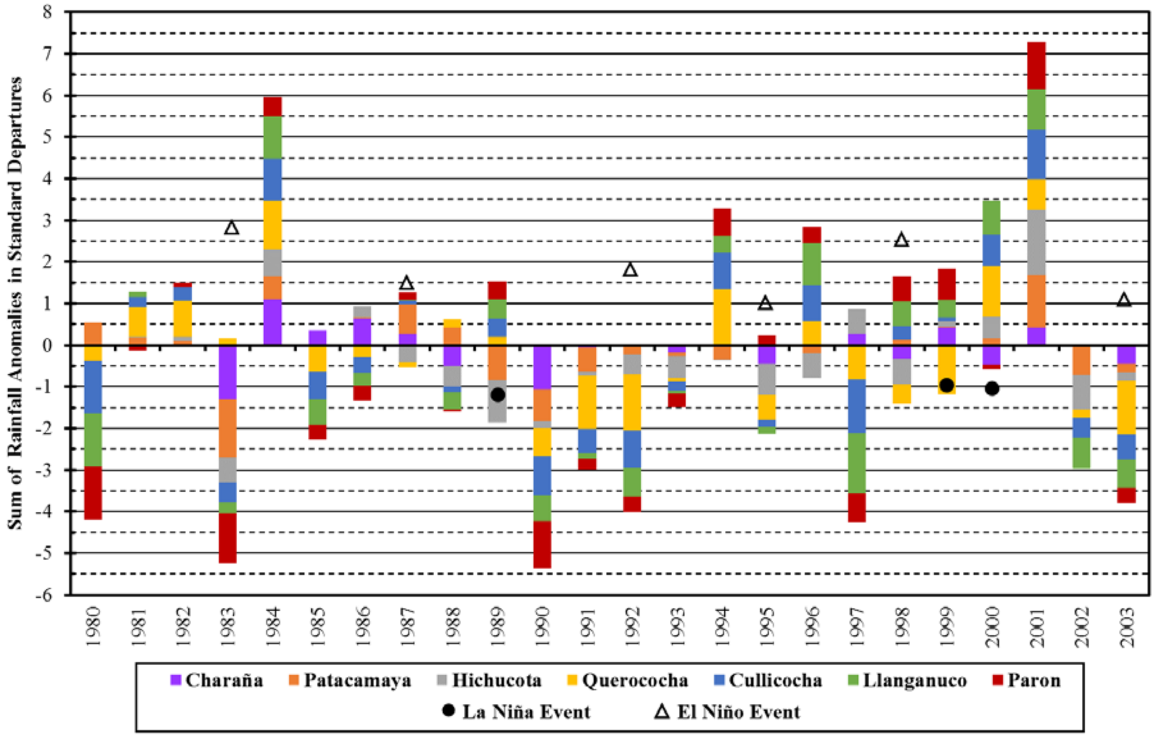
# Current Climate: Precipitation Variability

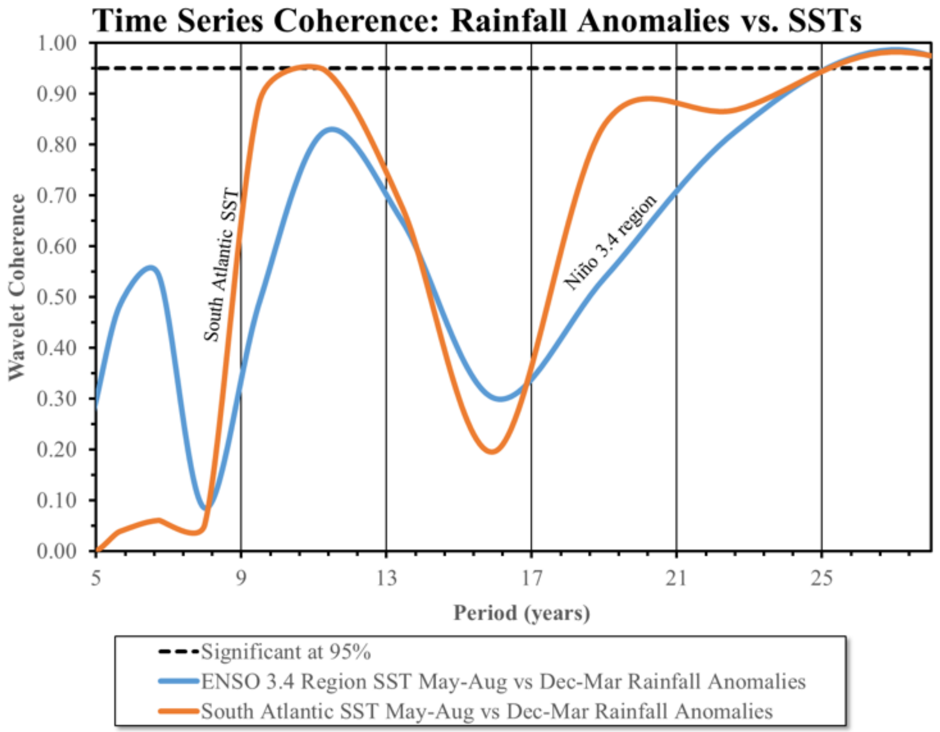



- Long term monthly and daily rain gauge data in Peru and Bolivia illustrates cycles of wetter and dryer than normal wet season precipitation.

# Decadal and Bi-Decadal Variability




- From wavelet time series analysis, regional rainfall anomalies and the SSTs in the South Atlantic and ENSO region have 3-6, 10-13, and 19-26 year wet-dry cycles.
- The coherence between time series (i.e., sign and magnitude) is not significant < decadal periods.
- Significant coherence between regional rainfall at decadal (Atlantic) and bi-decadal periods (Atlantic and Pacific).
- Suggests predictability of wetter than normal and drier than normal *regimes* at long time scales.
  - Lots of noise at the 3-6 year ENSO event timescale, particularly for individual locations.

# Future Climate Modeling

**Goal:**

- Investigate potential future precipitation characteristics in the Central Andes.

**Why:**

- Current techniques (global climate models and CORDEX) lack spatial and or temporal resolution to fully resolve Andean terrain and explicitly simulate precipitation.
- Limited observations.
- Region has high climatic sensitivity (Vera et al. 2014, Nieto-Moreno et al. 2016).

**Objectives:**

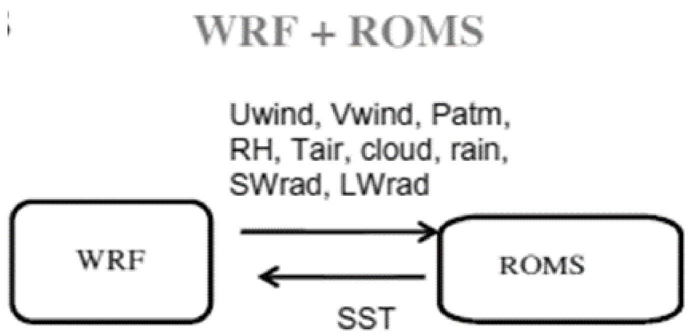
- Estimate potential for future change to precipitation climate
- “Precipitation climate”: Diurnal cycle, total rainfall, overall distribution
- Focus on wet season (Nov – Apr)

**What:**

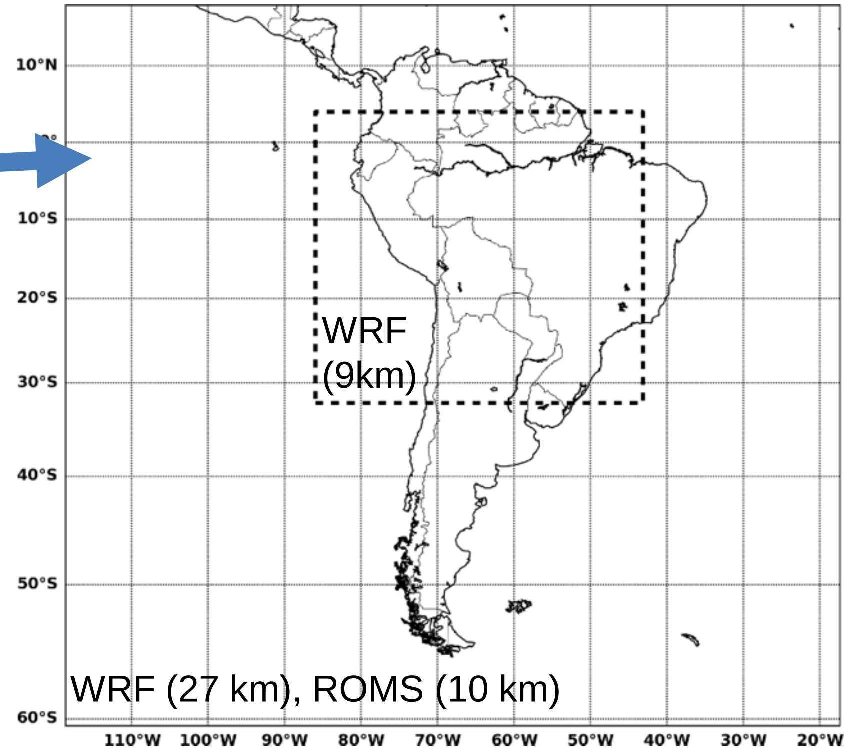
- Use COAWST Regional Climate Model
- Run year long snapshots spaced ~30 years apart: 2003, 2031, 2059, 2087

# Regional Climate Model (RCM)

- Coupled Ocean Atmosphere Wave Sedimentation Transport modelling system (COAWST)
- Atmosphere-Ocean coupling
- Resolution allows modeling of convective systems
- Can resolve precipitation diurnal cycle
- Model grid configuration
- “Snapshot” years: 2003, 2031, 2059, 2087
- Global climate model downscaling
  - 1) MIROC5 (Japan)
  - 2) GFDL-ESM2M (USA)
  - 3) CCSM4 (USA)
  - 4) IPSL-CM5A-MR (France)



RCM model configuration, Warner et al. 2010

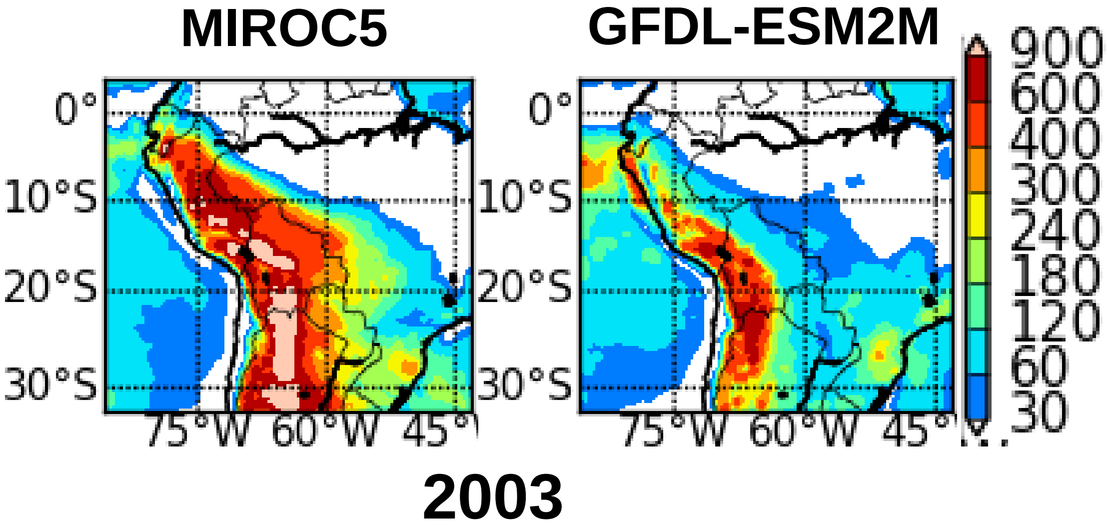


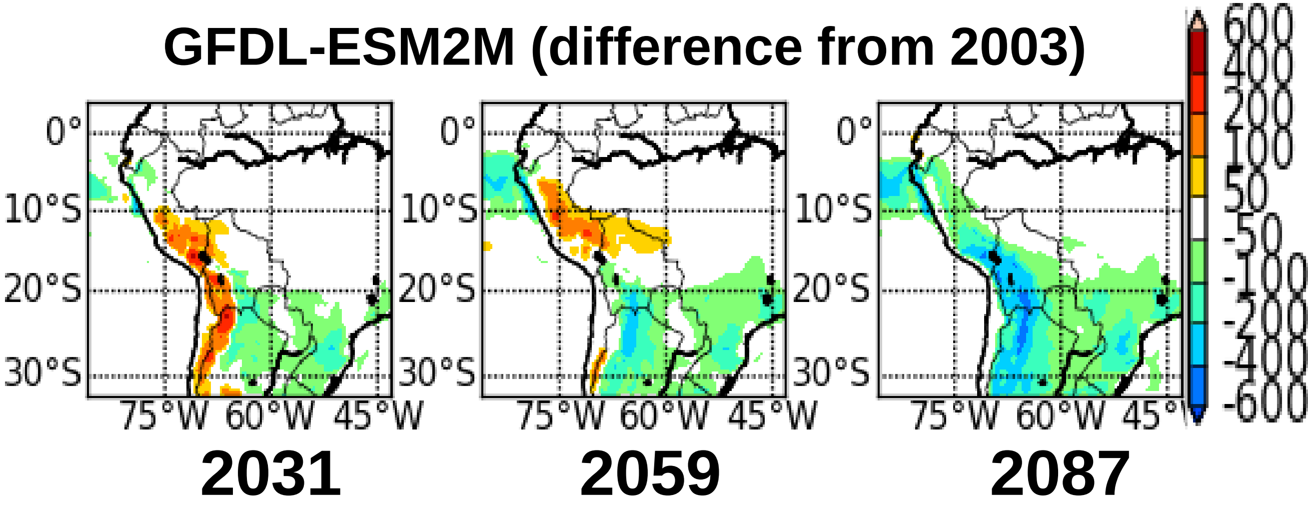
RCM model grid

# Wet Season (Nov 1 – Mar 31) precipitation (mm)

- 2003 Precipitation (accumulation, mm)
  - Same precipitation tendencies
  - Wetter (M & C) and drier (G & I) scenarios

- Future Precipitation (accumulation differences [year – 2003], mm)
  - Precipitation dipole (Amazon vs sub-tropical)
  - Weaker SALLJ (Exc. MIROC5)
  - N-Shifted, weaker Bolivian High
  - ENSO/Precipitation signal inconsistent



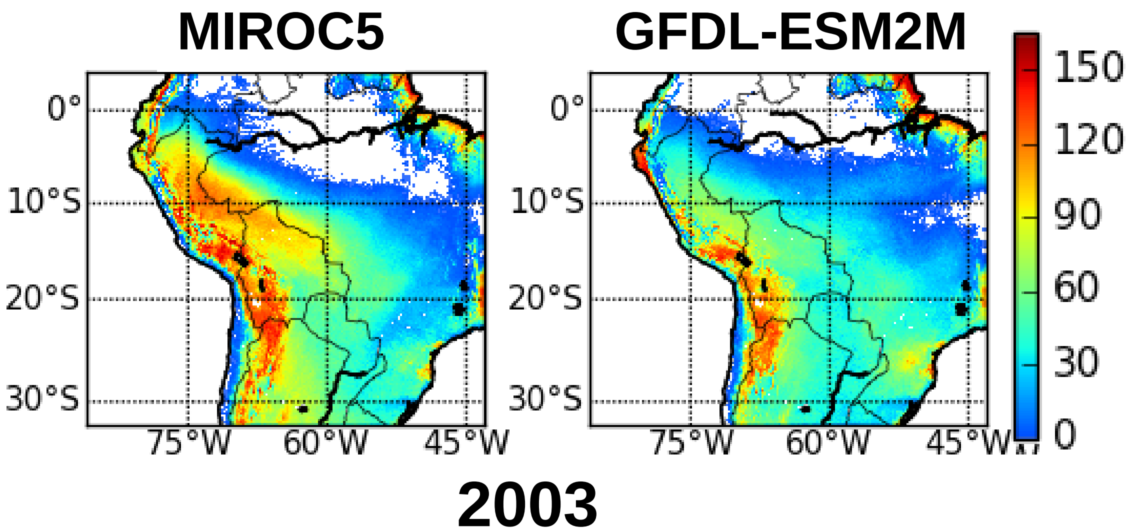
# Wet Season (Nov 1 – Mar 31) precipitation days

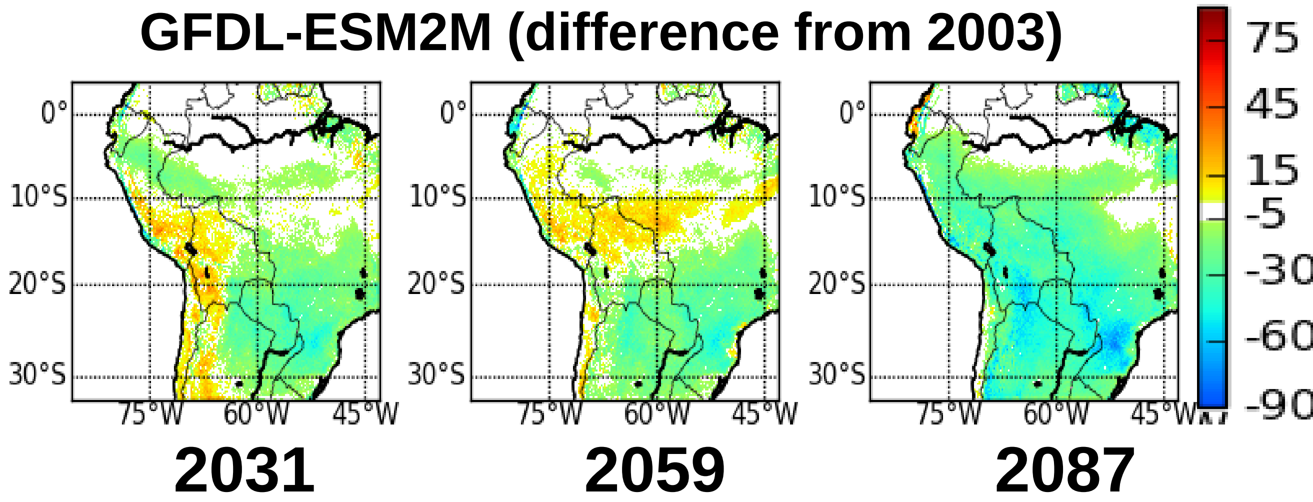
**General**

- Days with precipitation > 5 mm daily precipitation
- Well matched to total precipitation
- No definitive extreme bias (i.e., increase precip, constant days)
- Greatest variability in Amazon
- Highlands tend to have most days

**Altiplano**

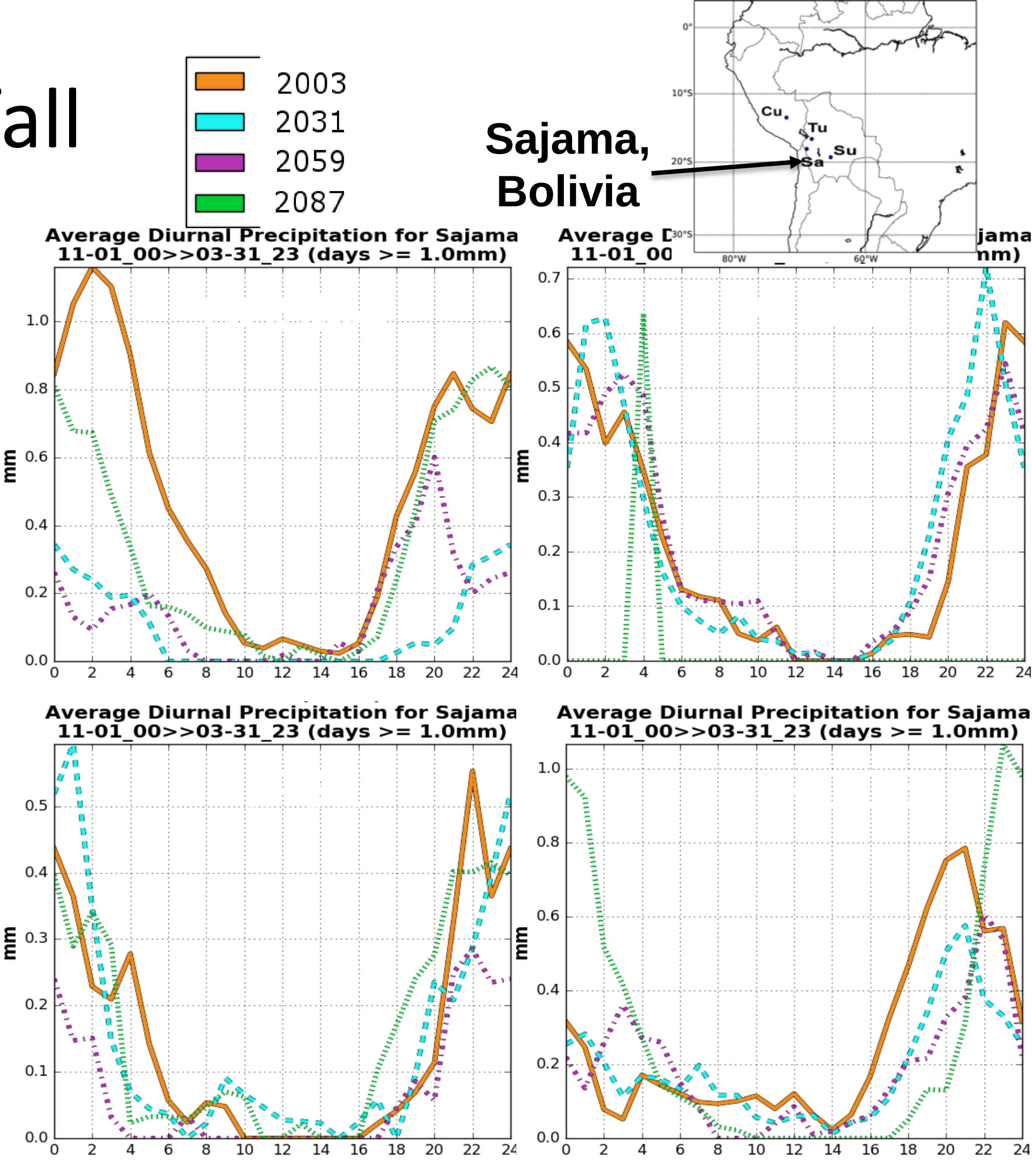
- Model results mixed (some wetter, some drier)
- Not strongly linked to short-term ENSO variability
- Model mean results:
  - 17 fewer precipitation days
  - 2 mm/day increase in precipitation rate



# Wet Season Diurnal Rainfall

- Analysis at four stations: Cuzco, Peru; Sajama, Bolivia; Tuni, Bolvia; Sucre, Bolivia
  - Sajama shown on right
  - Times in UTC (local is UTC - 5)
- Diurnal maximum magnitude changes, but not its timing
- Diurnal precipitation not slave to regional precipitation changes
  - Ex. MIROC5 2031 & 2059: Regional precipitation increases, yet diurnal precipitation decreases



# Future Climate – Summary

- Wetter (MIROC5, CCSM4) and drier (GFDL, ISPL) simulations
- Future precipitation climate
  - Area wide: Precipitation location and amount varies, no definitive shift towards extremes
  - **Altiplano**
    - **Simulations favor less precipitation (50-200 mm, 8-30% less)**
    - **Mean decrease of 17 precipitation days (27%)**
    - Daily precipitation **intensity increases 2 mm/day** by 2087 compared to 2003
    - Diurnal cycle timing steady, but magnitude changes
    - **Impacts more pronounced in higher elevations (1600 m +)**
- Most significant driver: CMIP5-driven boundary conditions
  - Models with better monsoons compare more favorably to TRMM (MIROC5)
- Next:
  - Analyzing details of model outputs in Central Andes
  - Runs at 3 km to ensure 9 km is adequate to model future precipitation climate

Goal: To understand the role of anthropogenic and climatic drivers in land cover change
*(And to use TEK to inform change analysis and processes)*

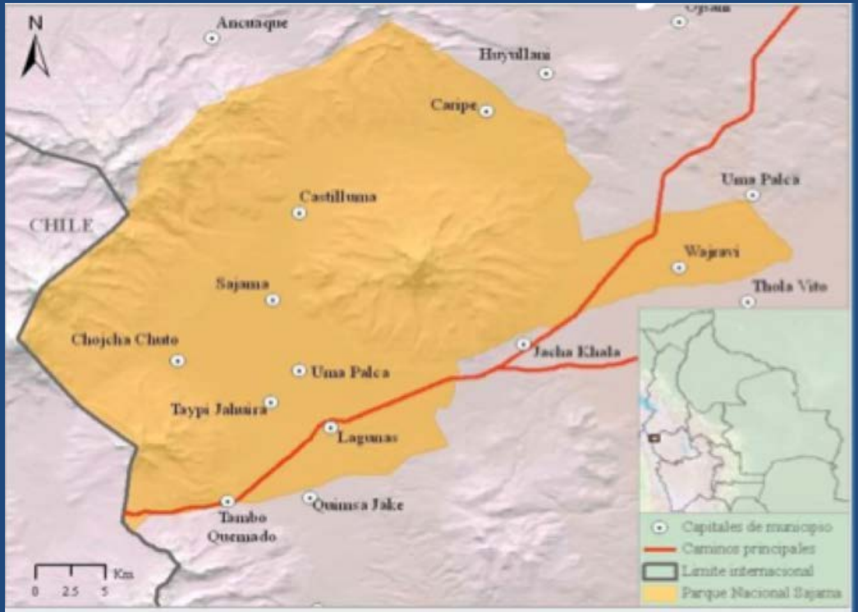
Methodology:

- Social Science (Anthropology, Sociology, Economics, Range Management, AgroPastoralism)
- Collect Quantitative and Qualitative Data to inform LCLUC Analysis and Regional Climate Data Analysis
- Data Integration of remote sensing, climate modeling, and local anthropogenic processes

Dr. Corinne Valdivia
(University of Missouri-Columbia, MO)

Dr. Karina Yager
(SSAI/GSFC & Stony Brook University, NY)

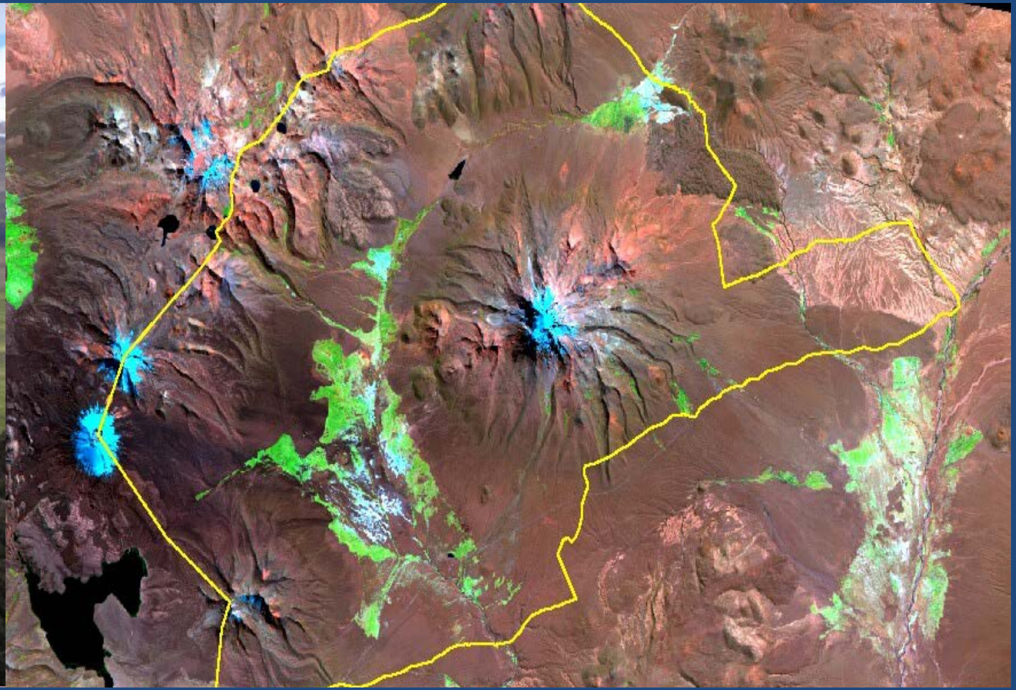
- Bolivia largest producer of llamas in world (~ 2.6 million), second to Peru in producer of alpacas
- Total camelid population in Bolivia ~3.1 million
- Case study in two regions: Tuni-Cordillera Real (Department of La Paz) and Sajama- Cordillera Occidental (Department of Oruro)




# SAJAMA NATIONAL PARK

- Created in 1939 Elevation: 4200 – 6542 m
- Area: 1,000 km$^2$ / 100,000 hectares

- Herding population ~50,000 (49% llama, 43% alpaca, 8% sheep)
- 5 Aymaran communities (2k individuals, 300 households) 34% outmigration



# Overview

YEAR 1: (2016)

- Focus Groups in Each Community

YEAR 2: (2017)

- Household Surveys

(Quantitative Data, sample 25-30% of total population in each region, ~150 questions per household (coded for statistical analysis)

- Participatory Mapping

(High res data w/ Explicit Mapping of Systems and Local Drivers (Herd size, pasture management, hydrology)

Year 3: (2018)

- Data Integration
- Final Focus Group (Identify Local Strategies for Future Management)

# Focus Groups: *Local perceptions of drivers of change and condition of bofedales*

- Community Based Maps
- Matrices of Bofedal Condition
- Consensus at community level
- Perspectives of climate change and bofedal health
- Estimation of degradation/Drivers
- Timeline activity (social memory of past climate events) *Local perception of climate and condition of bofedales*


## Maps and Models

- Past, present and future changes


*"tholares will be pajonales, pajonales will be arenales, bofedales will become colpares"*

*"Sajama will be with little snow. The strong heat will diminish the thickness of its head. Only ice pinnacles will remain, but they will be thin. The snows will no longer come, there will be avalanches, landslides, and the mountain will be deformed."*

# Observations of peatlands

- Participatory mapping, identification of areas of drastic change and vulnerability

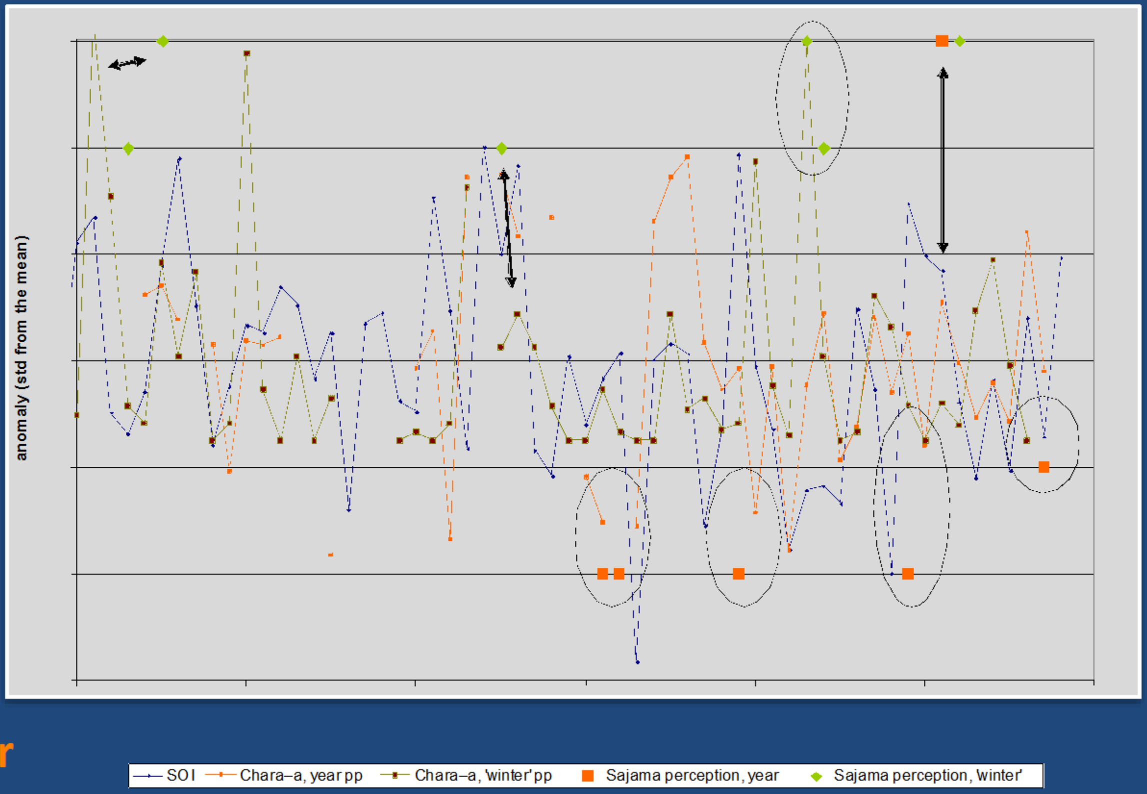
*"There used to be a lot of grass or kora* because it rained at the right time. Now they [the grasses] don't grow any more; some areas have temporarily dried up and there is insufficient food for livestock. There is a larger expanse of the colpares [salt flats] than there used to be."*

- Tasks in Mapping:
- -Use High res data to map pasture area
- -Map and inventory total area of pasture zone
- -Camelid numbers
- -Link with household survey on management practices (Fencing, animal loss, pasture degradation, irrigation, replanting)

# Timeline activity

## Social memory of past climate events and outcomes

- 1953- Blizzard
- 1955- Blizzard
- 1975- Blizzard
- 1981- Drought
- 1983- Drought
- 1993- Blizzard
- 1994- Blizzard
- 1999- Drought
- 2000-2001- Flooding
- 2002- Blizzard
- 2005- Warmest'year'ever
- 2007- Drought- Coldest'year



Data integration (Mapping, Surveys, Modeling):
*Future of Andean Pastoralism?*

Quantitative and Qualitative Data identifies:

1) Principal management practices
2) Livestock Density & Rangeland Carrying Capacity
3) Link local present and past management with landcover outcomes (socio-economic drivers of change) to understand future trajectories of change
4) Identify mitigation and adaptation strategies and trends (Past coping strategies and future possibilities)
5) Future Challenges


Questions?
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