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Water Sustainability of the Arequipa Region: Quantity, quality and strategic management of water for 5 watersheds

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  - Dr Pablo Garcia
  - Dr. Kyle Murray
  - Jonathan Quiroz (MSc student)
  - Molly Rhymes (B.S. student)

- **Equipo UNSA**
  - MSc Gisella Martínez (PI)
  - Dr Teresa Tejada
  - Dr Kattia Martínez
  - Dr Héctor Novoa

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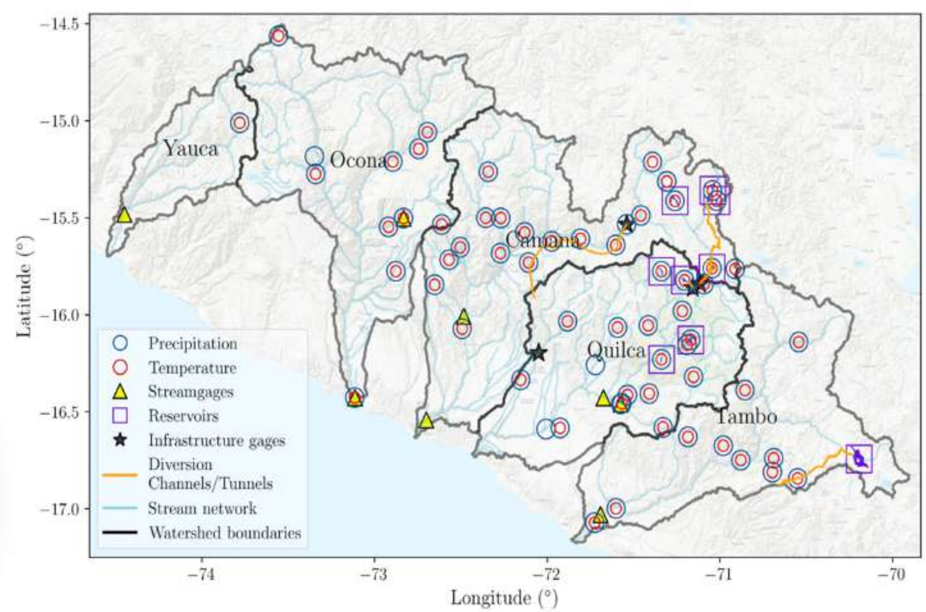
Watershed modeling, climate change, and water availability

Impacts of climate change & future land use on water resources in Southern Peru

- Water sustainability of Arequipa's 5 watersheds was previously unknown
- We developed future climate models specific to the region to drive hydrologic models to evaluate water resources.



- Considered different water-use scenarios
- Considered different or future land uses
- Evaluated future water availability compared to use on an annual basis.

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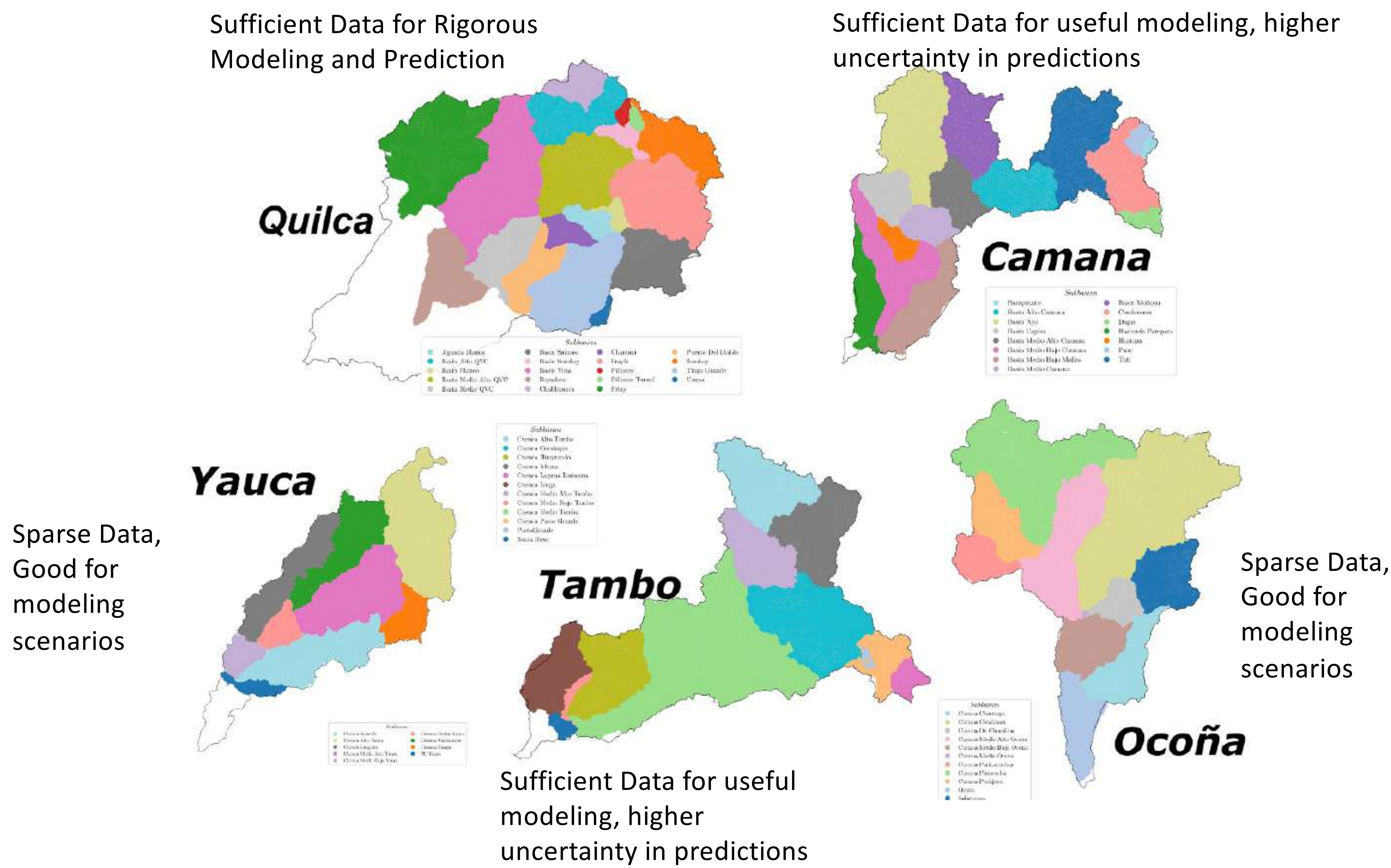
Watershed modeling, climate change, and water availability

Data

Institution	Specialty	Data and Source
ANA	Watershed-scale management	Streamflow, weather data, watershed/subwatershed boundaries, and stream network (ANA, n.d.)
SENAMHI	Meteorological monitoring and forecast	Weather data from conventional and automatic stations, and the PISCO gridded dataset (Aybar et al., 2020). The PISCO gridded dataset has a spatial resolution of 1/10 degree
AUTODEMA	Reservoir management	Reservoir volumes, operations, precipitation, and evaporation for the reservoirs located inside the Camana and Quilca watersheds.
EGASA	Hydroelectric energy generation	Reservoir volumes and operations, for the reservoirs located inside the Camana and Quilca watersheds.
PERPG	Pasto Grande reservoir management	Reservoir volumes and operations for the Tambo watershed
JAXA	Japanese government's overall aerospace development and utilization	Digital elevation model ALOS World 3D-30 m (AW3D30) (JAXA, 2017)
ISRIC	Worldwide soil data	Clay, sand, and silt content from the gridded dataset SoilGrids™ (Hengl et al., 2017)
MINAM	Peruvian environmental topics	Landuses from the Ecological and Economic Zonation for different Peruvian departments (MINAM, 2017)
NASA NEX-GDDP-CMIP6	Global downscaled climate scenarios derived from the General Circulation Model (GCM) runs conducted under the Coupled Model Intercomparison Project Phase 6 (CMIP6) and across two of the four "Tier 1" greenhouse gas emissions scenarios known as Shared Socioeconomic Pathways (SSPs)	NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP). The spatial resolution is ¼ degree (Thrasher et al., 2022)


Sufficient Data for Rigorous Modeling and Prediction
Quilca
Sufficient Data for useful modeling, higher uncertainty in predictions
Camana
Yauca
Sparse Data, Good for modeling scenarios
Tambo
Sufficient Data for useful modeling, higher uncertainty in predictions
Ocoña
Sparse Data, Good for modeling scenarios

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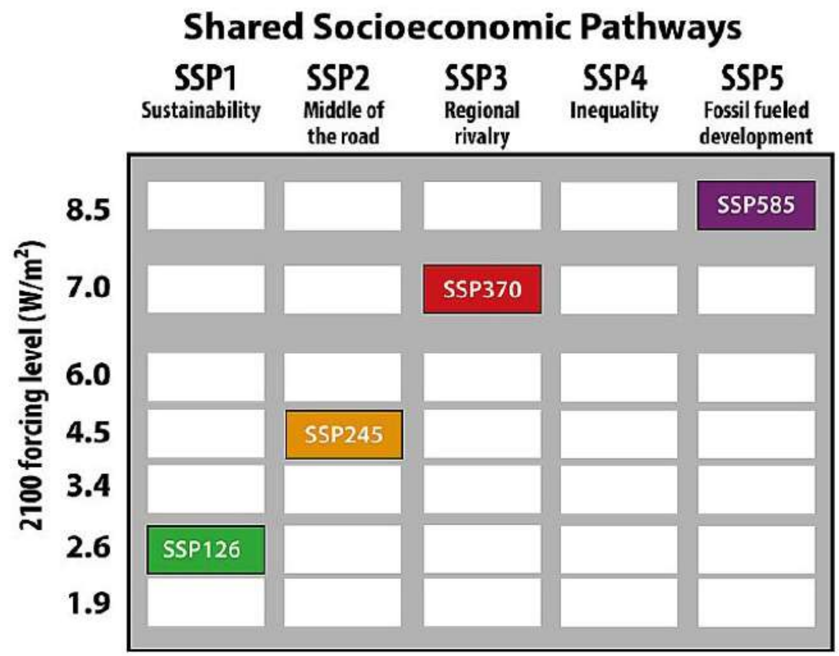
Climate Change Models

- Different models are available for predicted precipitation and temperature (P, T) different future carbon emissions scenarios

- Climate models specific to the scale and location of this region are not available.

- Climate models also have predicted P and T for the 1980's and 1990's.

- Evaluate different "current" models relative to P & T actually measured in the 5 watersheds.



- Used downscaling methods to choose the most appropriate climate models to drive hydrologic models.

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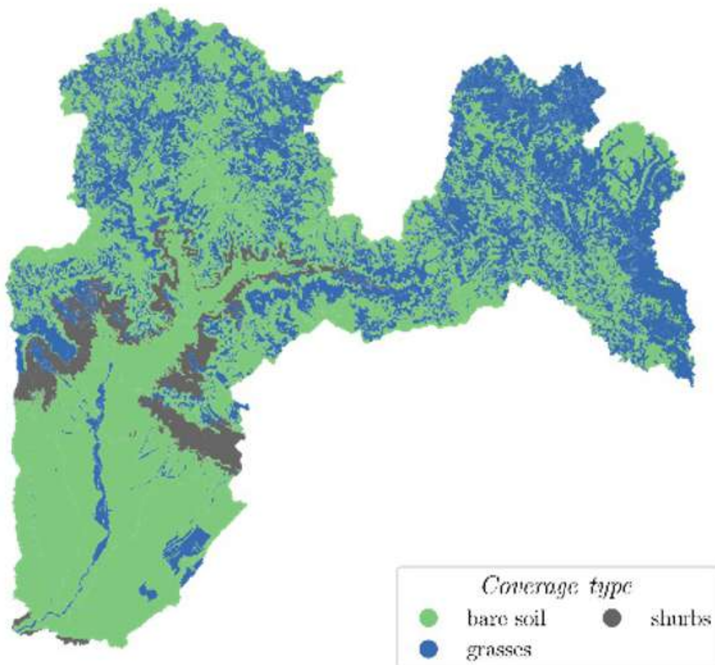
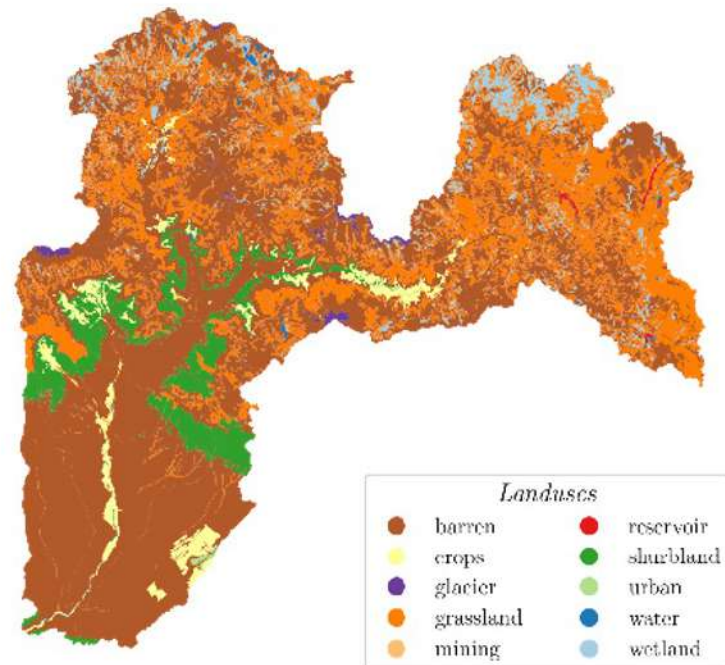
Land Use Analysis

Use current land uses for current model

Project changes in land use in the future

(more urban area, more agriculture, etc)





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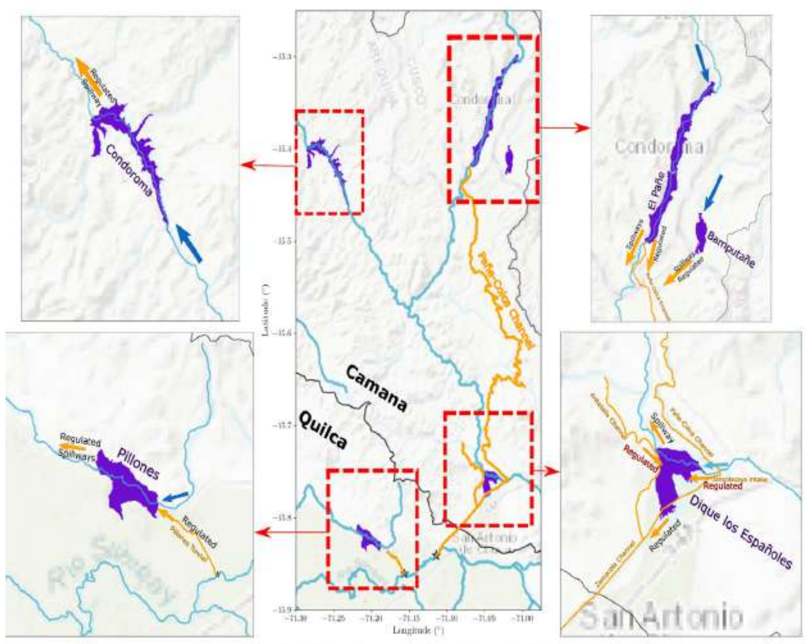
Water Sustainability Depends on Reservoir Sustainability

- Current hydrologic models in the Arequipa region do not account for reservoir dynamics (typical for many regions around the world).
- We simulated and calibrated all the main reservoirs of the Camaná, Quilca, and Tambo watersheds with hydrologic modeling and climate change analysis
- All reservoirs are now incorporated into hydrologic models of each watershed, such that reservoir dynamics could be considered for future reservoir operations and for sustainable water resources analysis.



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Model Results (example)

Model Calibration to Current Data

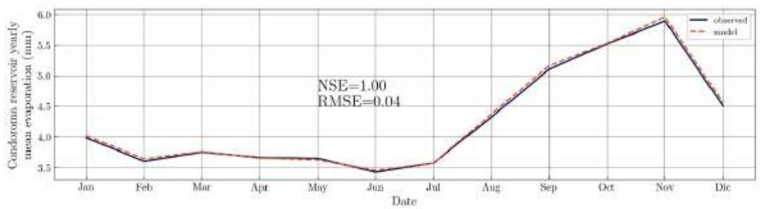

Figure 15. Calibrated monthly mean evaporation for the Condoroma reservoir.

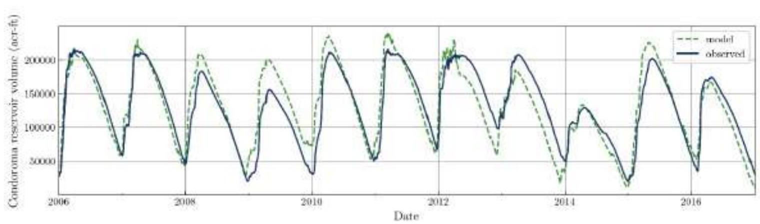

Figure 17. Calibrated reservoir volumes for the Condoroma reservoir.

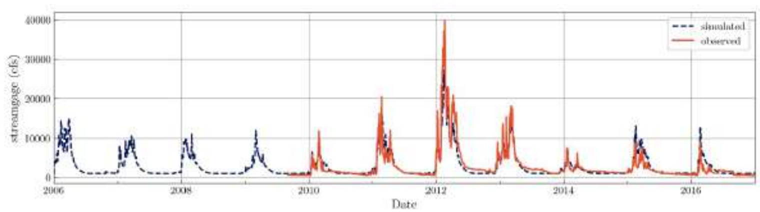

Figure 17. Calibrated streamflows for the Huatipa streamgage.

Future Simulations

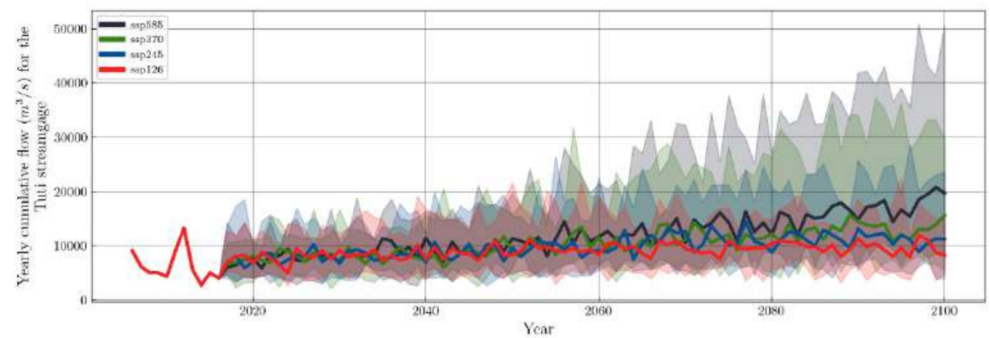

Figure 26. Yearly cumulative flow for the Tuti stream gage.

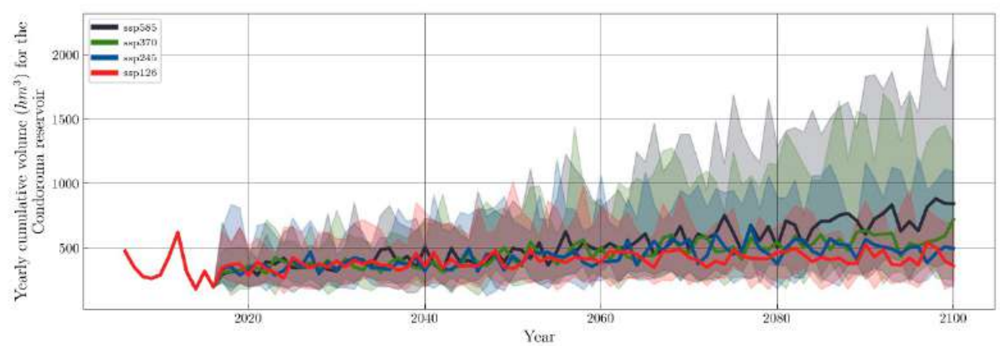

Figure 24. Yearly cumulative volume for the Condoroma reservoir.

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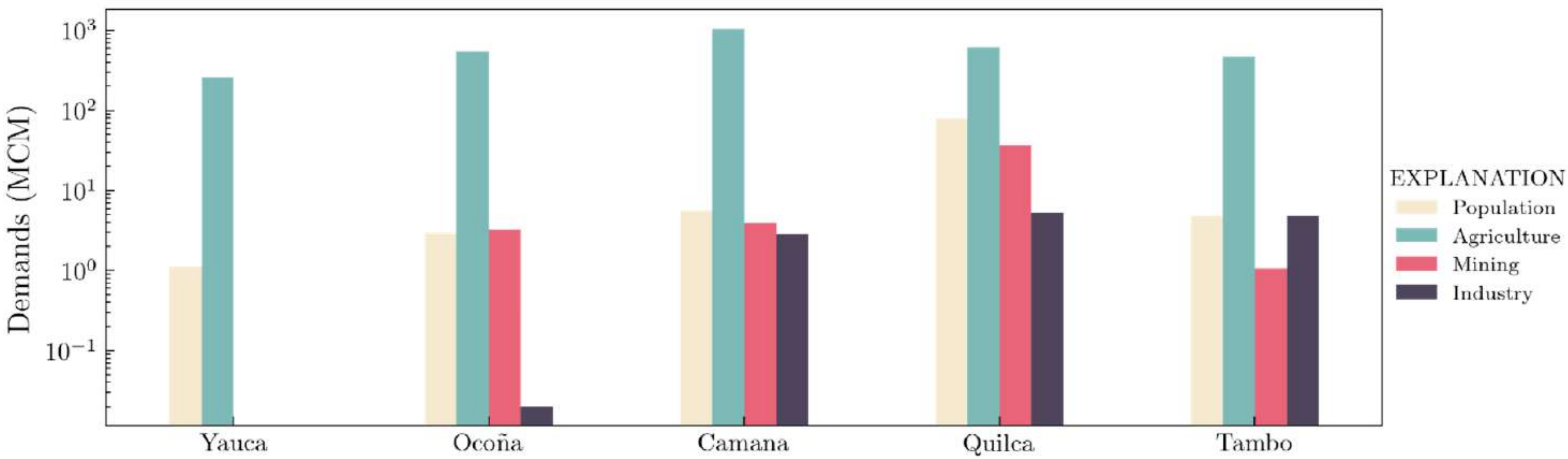
Compare to Projected Future Water Use



Current Annual Water Use in Million Cubic Meters (MCM)

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Conclusions of Future Water Resources Analysis

- Summer rainfall will increase under most scenarios
- Dry season flows are similar to present under most scenarios
- Dry season water shortages possible
- Need better accounting of monthly current and projected future water use to confirm.

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Conclusions (continued)

Water shortages can be avoided for future-use scenarios:

- If reservoir capacity is maintained/increased.
- Use of groundwater resources
  - Status of groundwater resources in the region are not known
  - Data is sparse in 4 of the 5 watersheds
- Stormwater capture and managed aquifer recharge to store water away from evaporation.

Intense storms during the wet season will increase, leads to huaycos (floods)

- This water should be stored, but water is lost, due to limited reservoir capacity

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CENTRO PARA MINERÍA SOSTENIBLE
COLORADO SCHOOL OF MINES - UNSA AREQUIPA

Publication

Translate ch *Article*

Water Resources Evaluation and Sustainability Considering Climate Change and Future Anthropic Demands in the Arequipa Region of Southern Peru

Jonathan Quiroz, Pablo A. Garcia-Chevesich, Gisella Martínez, Kattia Martínez, Teresa Tejada, John E. McCray

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Future Water Supply Sustainability Work Needed

- Reservoir filling with sediment - evaluation **urgently needed** to ensure water availability to supply growing demands
- Current **water storage capacities are** likely significantly lower than when reservoirs were built
- If sediments are a problem, solutions are available

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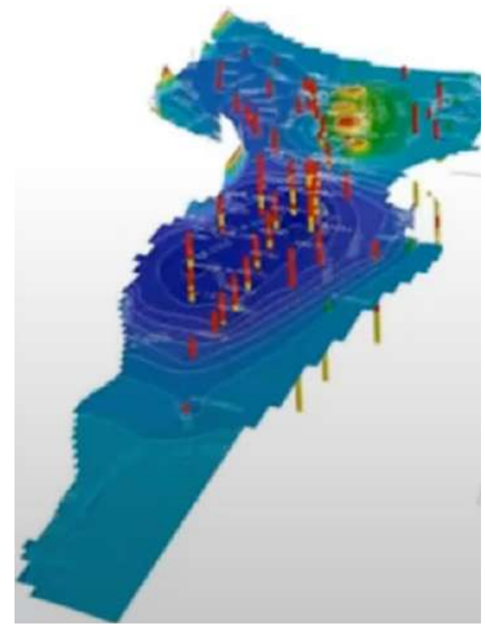
Future Water Supply Sustainability Work Needed

- The status of regional groundwater resources in Southern Peru are unknown.
- Data are very sparse for all watersheds except Quilca/Chili and Camana



- Development of an integrated groundwater-surface water-watershed model for Quilca and Camana watersheds would be very useful
- Need to determine status of groundwater in all watersheds and make recommendations for data collection.

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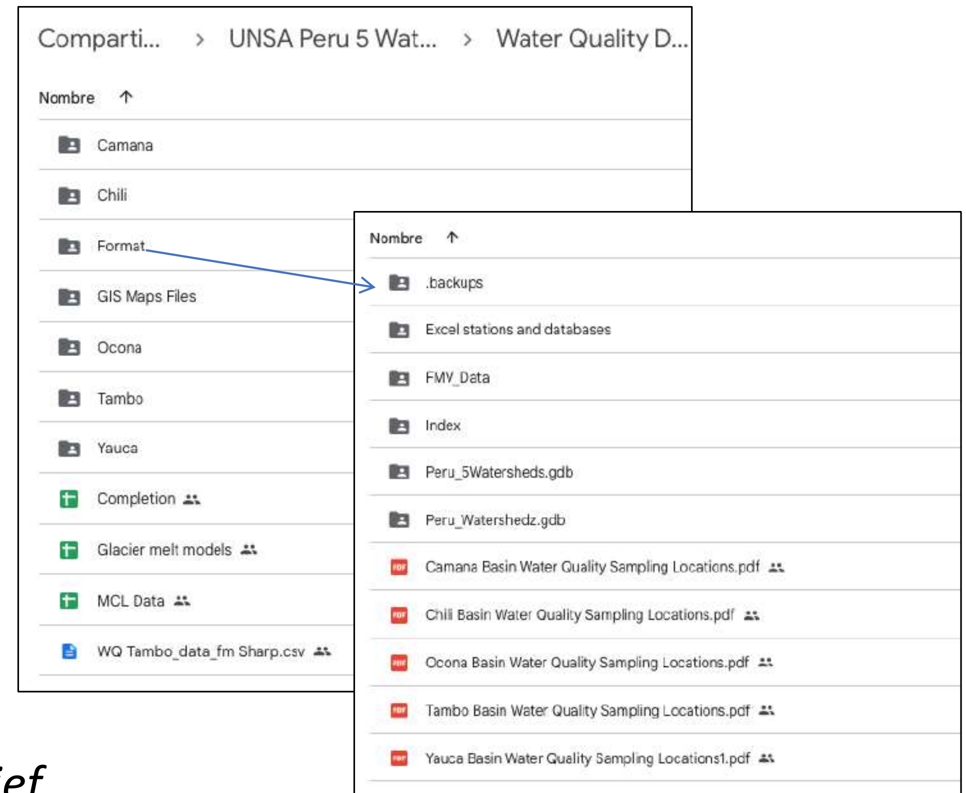
Water Quality Sustainability

- Hydrological and water quality information currently dispersed in many institutions in Arequipa (and Peru)
- We collected historical data from different sources (many times manually) and formed a large database
- Database needed for better analysis and decision making
- Database will be available to the public



Journal publication in preparation for *Data in Brief*

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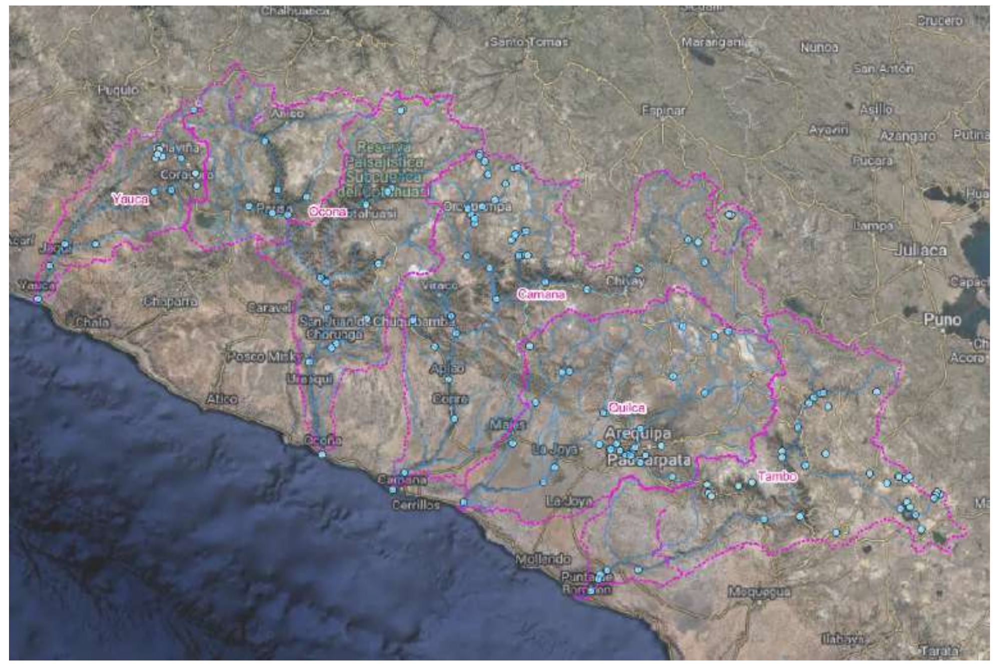
Water Quality: Current Status & Future Sustainability

- Poor water quality in Arequipa Region
  - Fertilizers, Nutrients (N, P)
  - Metals
- Use GIS models to analyze impacts of past land-use on water quality, project future changes.
- Recommend actions to prevent continued degradation.



Citation: Murray, K.E., K. Burget, R. Galemba, P. Garcia-Chevesich, G. Martinez, K. Martinez, T. Tejada, and J. E. McCray. 2023. Impact of land use on water quality in southern Peru and implications for future management,
Journal: *Sustainability* **Status:** Data analysis and modeling in progress

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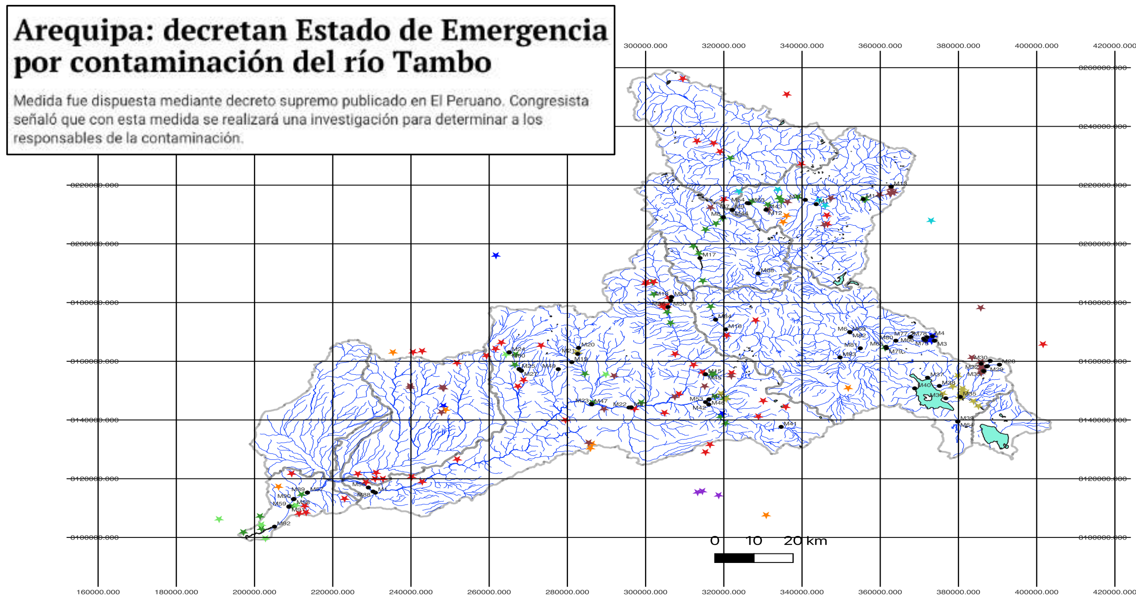
CENTRO PARA MINERÍA SOSTENIBLE

Publicaciones (en preparación, con Prof. Sharp)

- The Tambo River is highly polluted
- The origins of the contaminants are unknown
- We correlate pollution levels with land uses
- Geographic and temporal analysis
- Conclusion: pollution is due to mostly anthropogenic and some natural causes



Citation: G. Martínez, P. Garcia-Chevesich, K. Martínez, T. Tejada, F. Alejo, J. Zea, J. Ticona, V. García, S. Acker, G. Vanzin, J. O. Sharp., J. McCray. 2023. A Meta-analysis of human and natural pollution sources in the highly contaminated Tambo river, Southern Peru.

Journal: Sustainability **Status**: Finishing data analysis

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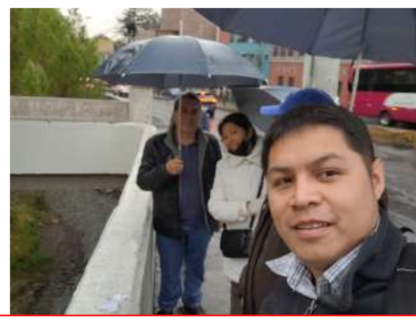
Publicaciones (submitted next week)

- The quality of urban stormwater runoff in Arequipa is unknown
- They drain directly into the Chili River
- We collected samples during storms over two summers.



Citation: Martínez, G., M. Guilllen, P. Garcia-Chevesich, T. Tejada, S. Ticona, K. Martínez, F. Alejo, J. Crespo, H. Novoa, J. McCray. 2023. Urban stormwater quality in Arequipa, Perú: an initial assessment.

Journal: *Sustainability* **Status**: Submitted to journal

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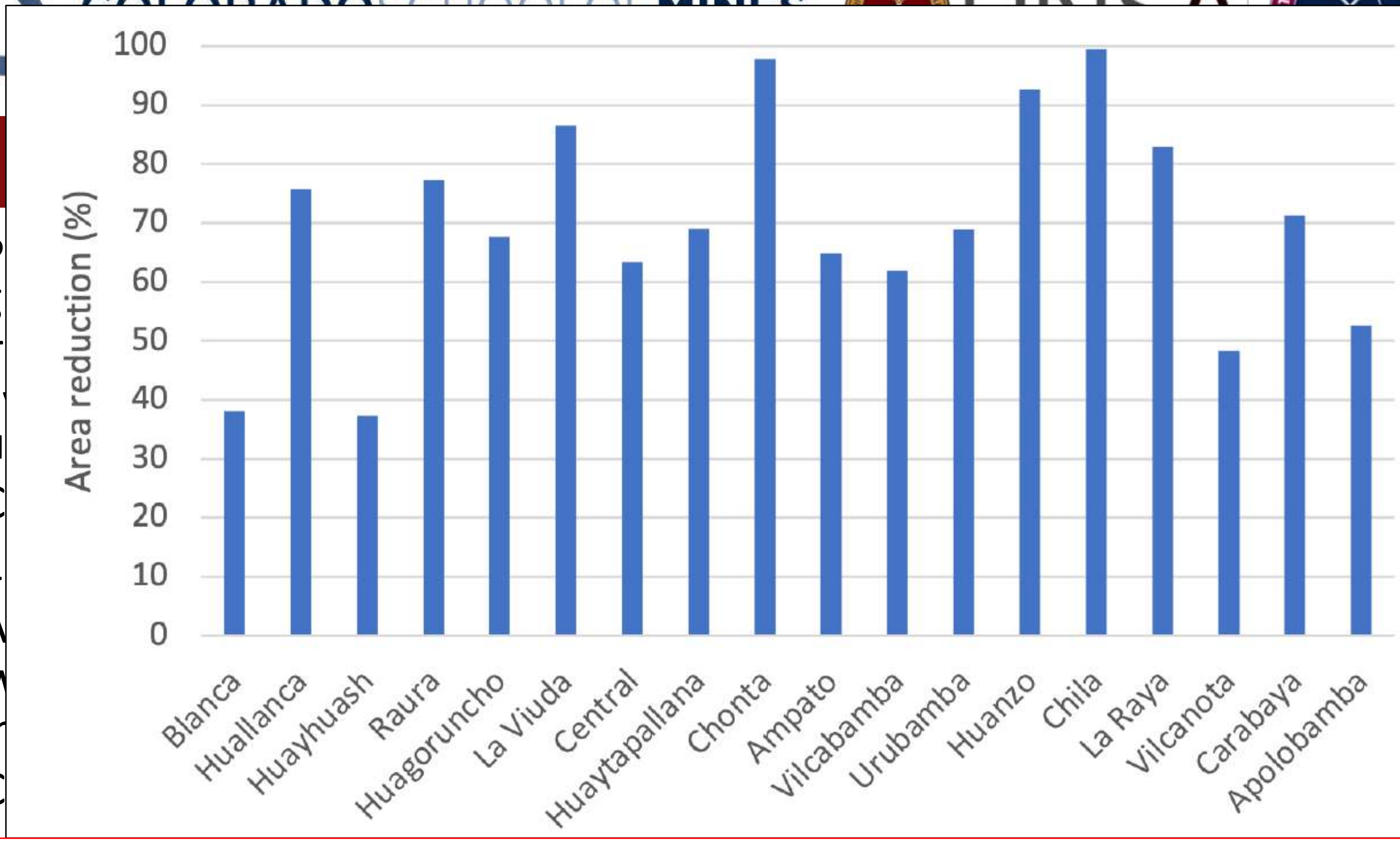

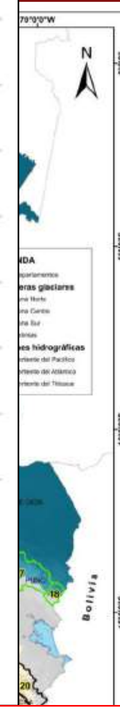

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Citation: Bustamante, M. G., P. Garcia-Chevesich, G. Martínez, J. Iparra, K. Burgert, J. McCray, et al. 2024. Glacier retreat in Peruvian Andes and its implications on future water availability.

Journal: Not determined. **Status**: Finishing data analysis

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La UNSA y Colorado School of Mines ganan premio internacional por libro sobre la gestión actual de sedimentos

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JOURNAL OF CONTEMPORARY WATER RESEARCH & EDUCATION
ISSUE 178, PAGES X-X, ANTICIPATED APRIL 2023

Perspective Piece

The Relevance of Water Education in Children: Perspectives from the Americas

*Pablo A. Garcia-Chevesich[1,2], Rafael Val[3], Gisella Martínez[4], Adriana Álvarez[5], Oscar Luna[3], Paloma Maya[3], Roberto Pizarro[6], Maite Pizarro-Granada[7], and John E. McCray[1]

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