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Impacts of Real-Time Monitoring on Adaptive Capacity: Lessons from a Communally Managed Irrigation Network in Northern New Mexico, USA

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Outline

Broader context

- Large reliance on winter snowpack to meet water demands throughout the summer in the Western US (Mote et al., 2018)
- Vulnerabilities of snow-dominated basins with warming climate (Barnett et al., 2005; Clow, 2010):
  - Volume of runoff

Broader context

- Rio Grande Basin climate change impacts (Harpold et al., 2012):
  - Increasing winter temperature
  - Decreasing winter precipitation, maximum SWE, snow covered days per decade
- Upper Rio Grande Basin projected climate change impacts (Chavarria & Gutzler, 2018; Llewellyn et al., 2013)
  - Decrease snowpack accumulation
  - Shift to earlier snowmelt runoff
  - Later portions of the runoff season left drier

Upper Rio Grande subbasins and gauging stations in CO and NM (Elias et al., 2015)

Managing drought and climate variability

- Many sectors stressed by variable and changing water resources
    - Irrigation systems
- Acequias
    - Communal irrigation systems
    - 200-400 years old (southwest USA)
    - Gravity-driven water delivery canals for irrigation purposes
    - Local governing organizations in charge of community-managed water allocations (mayordomo, commissioners, parciantes)
    - Drought prompts collaborative and dynamic water management approaches (Fernald et al., 2015; Guldan et al., 2013)
    - Resilient

Photo courtesy of NMAA

Acequia vulnerabilities

- 1,900 → 640 active acequias
- Challenges:
  - Warming climate (decreasing surface water availability)
  - Water rights transfers (out of acequia communities)
  - Lack of storage capacity (must use the water when it's available)
  - Development projects (more housing, less land)
  - Community structure (children moving to urban areas for education/employment opportunities)

Acequia vulnerabilities

- 1,927 → 640 active acequias
- Challenges:
  - Warming climate
  - Water rights transfers
  - Lack of storage capacity
  - Development projects
  - Community structure

Gap in community knowledge:

Acequia leaders from the Rio Hondo watershed expressed the need for more available and accessible data.

Gaps in literature

1. Importance of **stakeholder engagement**, **community science**, and actionable knowledge
   - Limitations of previous hydrologic research focused on stakeholder engagement (Buytaert et al., 2014; Paul et al., 2018):
     - Nonscientist roles limited to data gathering
     - Mostly water quality
2. **Interdisciplinary research** spanning hydrology and social sciences lacks clear integration methods (Seidl & Barthel, 2017)
3. Growing awareness of the need to proactively address and mitigate climate change impacts resulted in a demand for **adaptive capacity assessments** (Agrawal, 2010; Fernández-Giménez et al., 2015), but current assessment methods are not standardized (Engle, 2011)

Adaptive capacity:

The ability to experiment, learn, and test management strategies in response to change, disturbance, or challenges and is considered a precursor to resilience (Armitage, 2005; Eakin et al., 2011; Engle, 2011; Smit & Wandel, 2006).

Resilience:

A system's ability to withstand disturbance and reorganize efforts while enduring change and retaining its function, structure, and identity over time (Baival & Fernandez-Gimenez, 2012).

Study overview

- **Goal:** assess the role of improved data accessibility on adaptive capacity
- **Hypothesis:** increasing the accessibility and availability of water information for irrigation water management would increase adaptive capacity within a rural agricultural community in a semiarid valley
- **Process:** community science, telemetry monitoring, pretest-posttest survey design

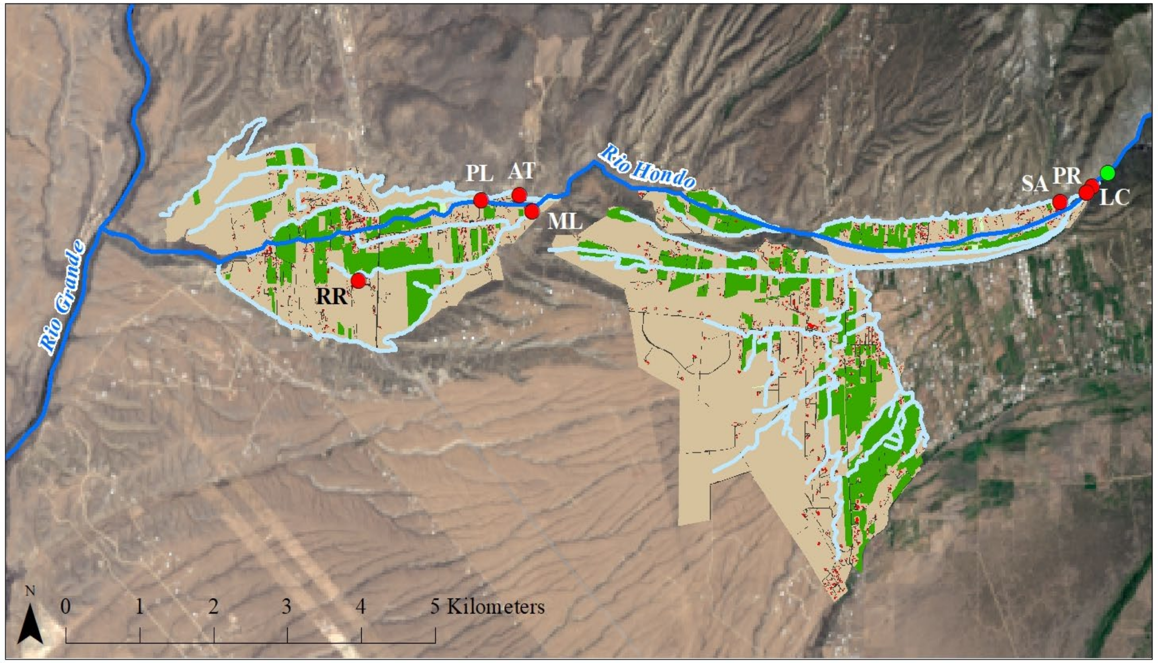
Methods

- Study area
- Telemetry monitoring system
- Adaptive capacity assessment

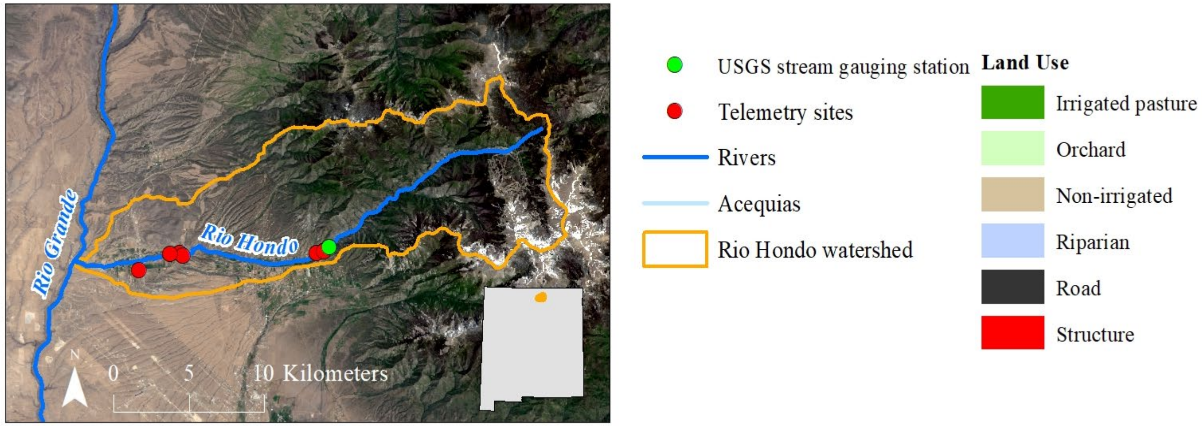
Study area

- Rio Hondo watershed
- 185 km^2
- Average elevation 2,200 m
- Drains into the Rio Grande
- Semiarid steppe climate
- Main inputs:
  - Snowmelt
  - Monsoons
- Communities
- Land use

a)

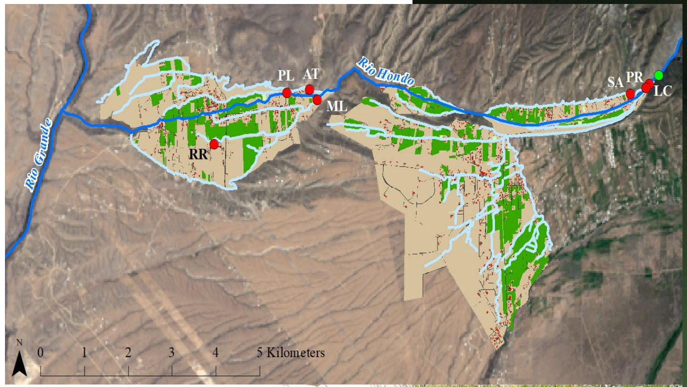


b)



Telemetry monitoring system

- Stakeholder involvement
- Equipment overview
  - Flumes
  - Stilling well
  - Monitoring equipment
  - Telemetry (cell + radios + Wi-Fi)
- Data collection
  - 15 min
  - Stage, discharge, water temp, conductivity
  - Verification
- Data delivery
  - Web interface
  - Campbell Scientific Konect Global Data Services



Adaptive capacity assessment

- Objective: assess the role of improved data accessibility on adaptive capacity

Define sampling methodology
- Population of interest
- Sampling frame
- Snowball sampling

→

Distribute presurvey
- Dec 2019 – Feb 2020
- Targeting 8 adaptive capacity indicators, quantitative

→

Real-time irrigation monitoring
- Mar 2020 – Oct 2020

→

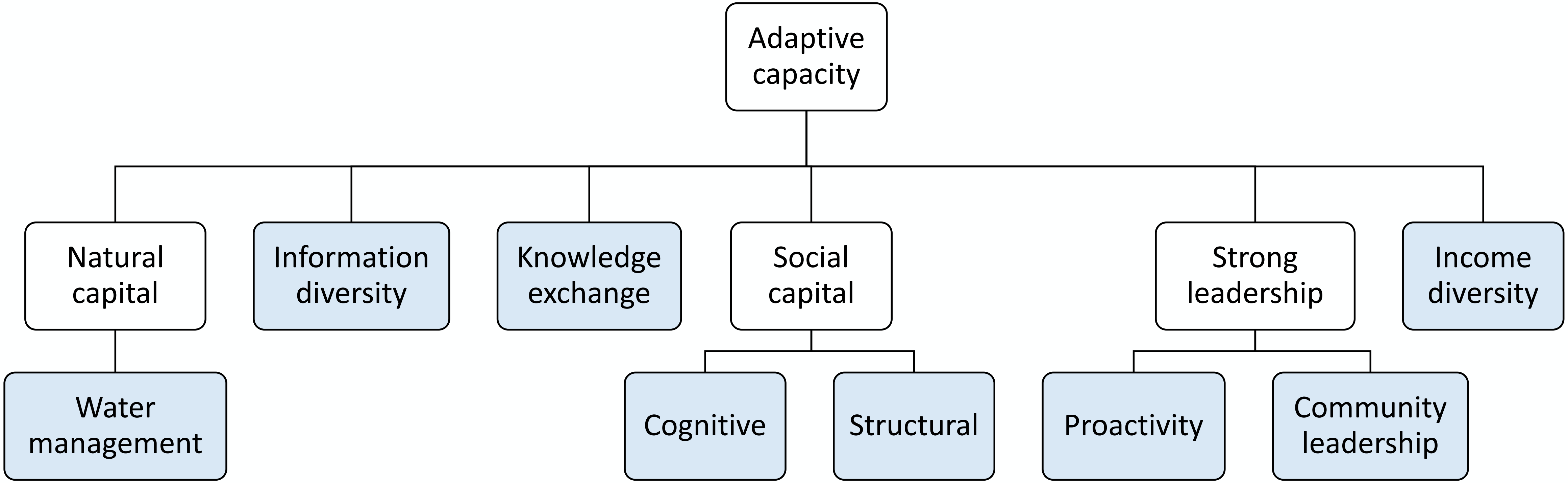
Distribute postsurvey
- Nov 2020 – March 2021
- Targeting 8 adaptive capacity indicators & web interface feedback, quantitative

→

Analysis
- Monte Carlo paired *t* tests

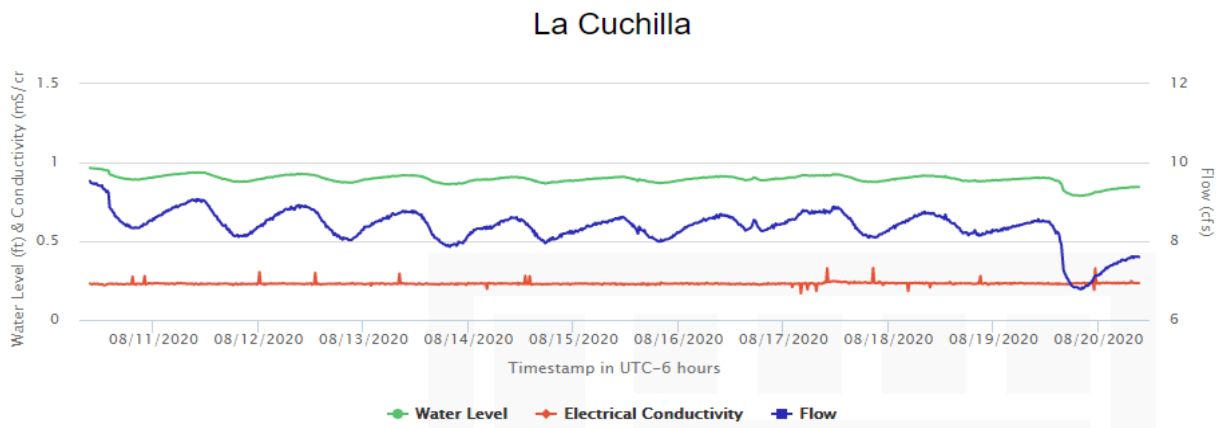
*changes considered significant at α = 0.05

Adaptive capacity assessment (cont.)



Results & Discussion

- Acequia monitoring web interface
- Adaptive capacity assessment



Current flow:

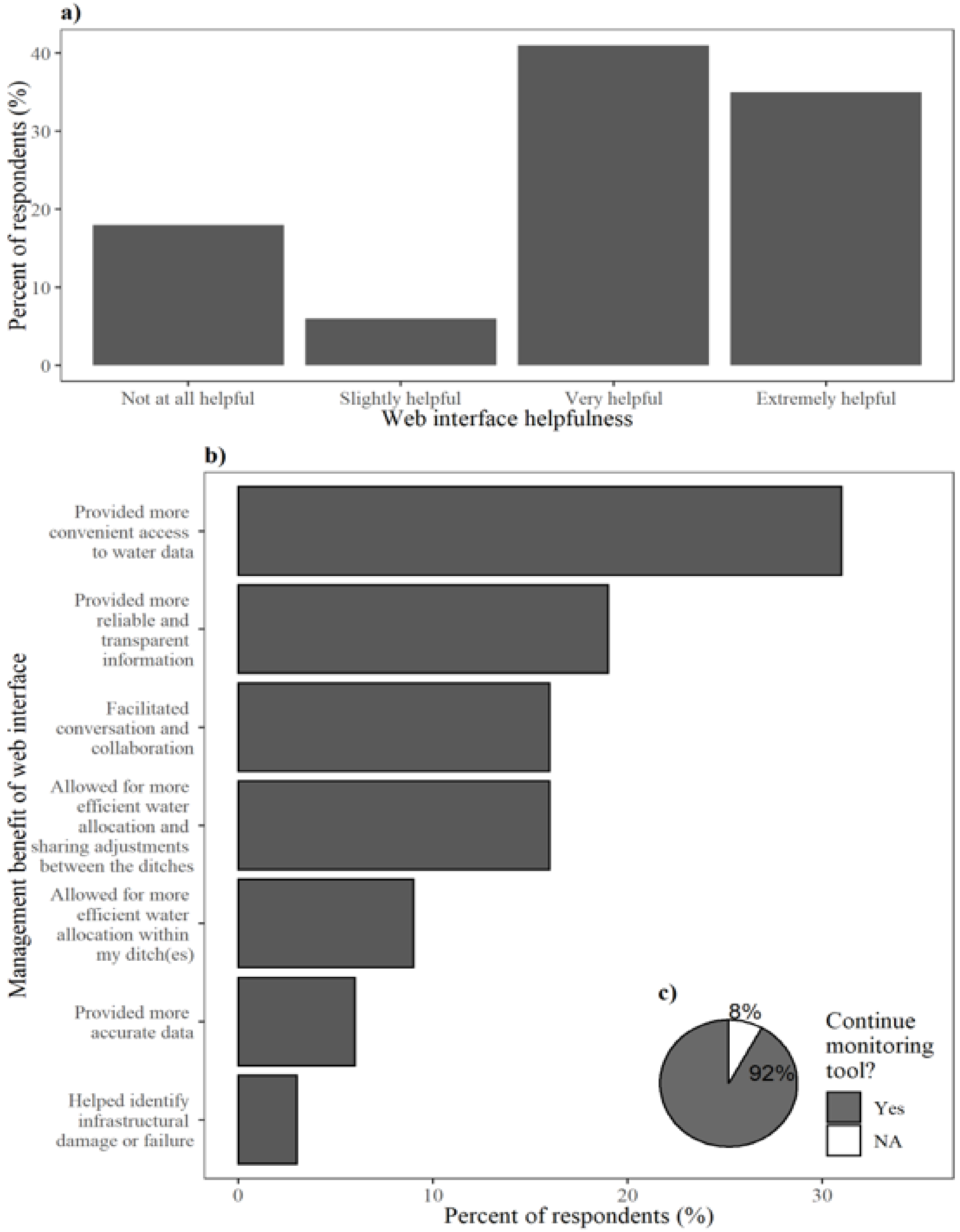
7.6 cfs

Daily Averages

Timestamp (UTC-6 hours)	Lvl_ft_Avg	NMSU_flow_cfs_Avg	Cond_Avg
08/20/2020 00:00	0.861	7.881	0.232
08/19/2020 00:00	0.898	8.44	NaN
08/18/2020 00:00	0.904	8.52	0.235
08/17/2020 00:00	0.899	8.45	0.229
08/16/2020 00:00	0.89	8.32	0.229
08/15/2020 00:00	0.889	8.3	0.23
08/14/2020 00:00	0.894	8.37	0.23
08/13/2020 00:00	0.903	8.51	0.231
08/12/2020 00:00	0.91	8.62	0.23
08/11/2020 00:00	0.931	8.97	NaN

Acequia monitoring web interface

An example of the water data displayed for each acequia on the web interface. In this case, La Cuchilla on 20 August 2020.



Acequia monitoring web interface

A compilation of survey feedback regarding a) the web interface's general level of helpfulness (n = 17), b) most helpful attributes and added benefits of the web interface (n = 13), and c) interest from respondents to continue this or a similar web monitoring tool for future irrigation seasons (n = 23).

Adaptive capacity assessment

Indicator (score range)	Presurvey mean	Postsurvey mean	t	p	95% CI
Water management (0-48)	14.40	17.04	1.162	0.4650	(0.4552, 0.4748)
Information diversity (0-5)	3.40	4.60	4.157	**0.0022***	(0.0014, 0.0033)
Knowledge exchange (0-10)	5.92	5.52	-0.499	0.814	(0.8061, 0.8215)
Cognitive social capital (0-26)	13.95	14.86	0.722	**0.0177***	(0.0152, 0.0205)
Structural social capital (0-10)	3.00	3.00	0.000	1.000	(0.9996, 1.0000)
Proactivity (0-5)	3.24	3.44	1.000	**0.0004***	(0.0001, 0.0010)
Leadership (0-16)	11.44	13.04	2.157	**0.0070***	(0.0055, 0.0088)

Comparison of each adaptive capacity indicator between the presurvey and postsurvey (n = 25). Monte Carlo paired sample t tests assessed the differences and underwent 10,000 permutations. The t statistic, p value (α = 0.05), and 95% confidence interval are reported for each adaptive capacity indicator. Upper-tail p values are reported.

Adaptive capacity assessment

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The number of sources community members can reference to get information about local water resources

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An individual’s trust and ease with other community members

The ability to interact with others about issues before they worsen

Local leadership can mobilize community members in response to the premonition or occurrence of challenging events

Recognition of the COVID-19 pandemic

- 68% of survey respondents indicated that they felt the pandemic greatly impacted their irrigation season
  - Individuals could not attend or organize regular water allocation meetings due to social restrictions
  - Many individuals are members of vulnerable populations (elderly, preexisting conditions) and avoided others
- Potential confounding variable? Ultimately helpful for assessment.
  - Better to measure adaptive capacity with exposure to adverse circumstances (Engle, 2011, 2013)
  - Likely dampened the results of knowledge exchange & structural social capital

Other studies

- Telemetry monitoring to meet community need has significant, positive benefits on adaptive capacity
- Findings consistent with other studies:
  - Providing irrigation districts and communities with real-time water data allows stakeholders to make effective water management decisions and changes during times of low flow (Ellison et al., 2019)
  - Real-time urban water use data improves water conservation efforts (Cominola et al., 2021)

Final remarks

- Real-time web-based monitoring of irrigation diversions helps traditional irrigation systems manage water during times of low flow by increasing elements of adaptive capacity
- A community science approach based on stakeholder engagement and co-production of actionable knowledge ensures monitoring system relevancy, encourages use, and facilitates success
- Survey methodology successfully quantified adaptive capacity and incorporated social factors into hydrologic research (and can be modified)

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Photo courtesy of Sylvia Rodriguez

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