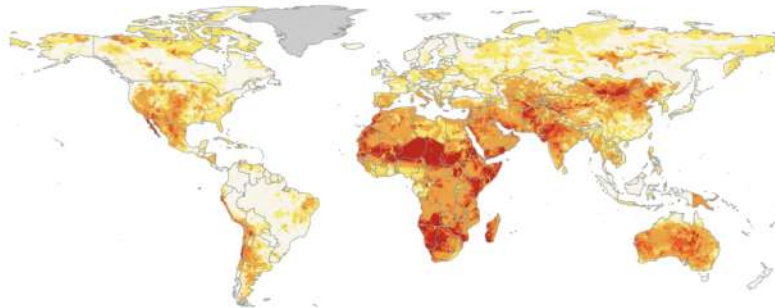


Thirsting for Solutions: How Climate-Induced Well Failures drive School Absenteeism

Lucile Dehouck

EEA 2025



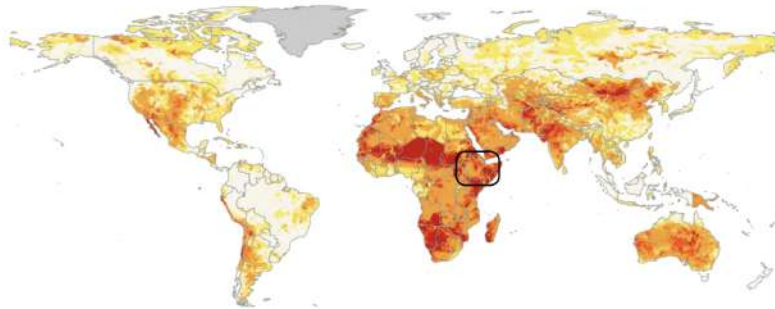


Water vulnerability index:



- Extremely high (2.75 to 5.00)
- High (2.30 to < 2.75)
- Medium (1.25 to < 2.30)
- Low (0.75 to < 1.25)
- Very low (0.0 to < 0.75)
- No data / not applicable

Source: UNICEF Risk Analysis and Preparedness Section, 2023



Water vulnerability index:



Source: UNICEF Risk Analysis and Preparedness Section, 2023

Motivation



Source: Oxfam, 2023

- Access to clean drinking water remains a challenge in Ethiopia.
 - ▶ WHO/UNICEF Joint Monitoring Program, 2023; Young et al., 2022
- Climate change is making water scarcity worse.
 - ▶ UNICEF, 2023; UN Water, 2021

This Paper in a Nutshell

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- Document patterns of well failure using novel datasets.

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 - ▶ Higher school absenteeism
 - ▶ For both girls and boys

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- What are the mechanisms?

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 - ▶ Households switch from groundwater to surface water
 - ▶ Leading to an increased water collection burden for children

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- What are the downstream impacts?
 - ▶ Reorganization of household tasks with increased reliance on children

Contribution

Climate, Education, and Labor

Jacoby and Skoufias (1997); Maccini and Yang (2009); Shah (2009); Beegle et al. (2006); Nauges and Strand (2017); Koolwal and van de Walle (2013); Devoto et al. (2012); Galiani et al. (2005)

→ Causal evidence on how climate-induced well failures affects children's schooling & labor

Welfare impacts of groundwater access

Sekhri and Hossain (2023); Sekhri (2014); Blakeslee et al. (2020); Fishman et al. (2017)

→ Provide descriptives on well failures

→ Estimates of school absenteeism and intra-household task reallocation

Predictive Analytics in Developing Country Contexts

Hansen et al. (2013); Yeh et al. (2020); Proctor et al. (2025); Sanford et al. (2025)

→ Uses remote sensing and machine learning to estimate climate-induced well failures

→ Applies multiple imputation to address potential measurement errors that could bias parameter estimates

Outline

1. Introduction

2. Data

3. Predicting Well Failures

4. Empirical Strategy

5. Results

6. Conclusion

7. Appendix

Data

- **Socio-Economic Data: Ethiopian Socio-Economic Survey** [▶ Details](#)
 - ▶ Household panel: 3 waves (2011-2015) & 2 waves (2018-2021)
 - ▶ Information on education, water collection, time use, health, migration...

- **Wells data**
 - ▶ mWater & Water.Point.Data.eXchange (WPdx)

- **Climate data: European Re-Analysis Fifth Generation (ERA5) reanalysis hourly data from 1970 until 2022**
 - ▶ Precipitation (& temperature) [▶ Graph](#)
 - ▶ SPEI [▶ Graph](#)

- **Groundwater depth data** [▶ Graph](#)
 - ▶ Bonsor et al., 2012
 - ▶ Fan et al., 2013
 - ▶ Pelletier et al., 2016

Combining mWater and WPdx [▶ Details](#)

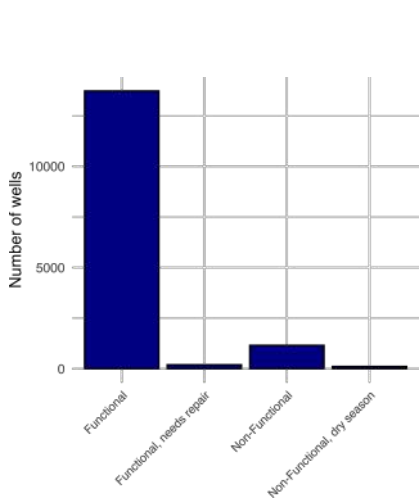


Figure 1: Functionality status

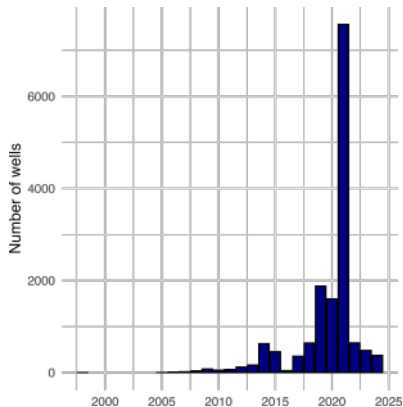


Figure 2: Year of monitoring

Stylized facts on well failures

- Community-managed wells tend to be more functional [▶ Graph](#)
- Handpumps are more likely to be functional. [▶ Graph](#)
- Older wells are less likely to be functional. [▶ Graph](#)
- Wells are less likely to be functional in drier places
 - ▶ measured with SPEI [▶ Graph](#)
 - ▶ measured with precipitation [▶ Graph](#)
- Wells are less likely to be functional where groundwater is deeper.
 - ▶ measured with depth to groundwater [▶ Graph](#)
 - ▶ measured with lagged precipitation [▶ Graph](#)

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Predicting well failures

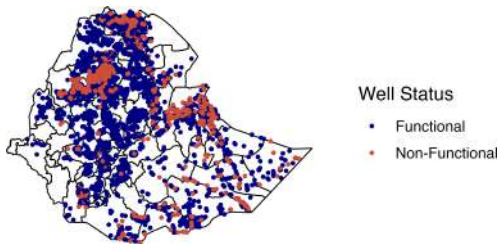


Figure 3: Inventory of Water Points

Leveraging machine learning to:

- Expand the sample size,
- Incorporate time-varying factors,
- Use an exogenous proxy for well failure.

Machine-Learning pipeline for predicting well failures

1. Hydro-environmental variables

- ▶ Climate, geology, hydrogeology ▶ [Details](#)
- ▶ Aggregated at the basin level

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4. Random Forest classifier

- ▶ Data split: 70% training, 30% testing
- ▶ Random downsampling applied to address class imbalance
- ▶ 5-fold cross validation; `mtry` is pre-tuned and set to 18

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→ **Monthly prediction of each EA's representative well functionality status**

Model performance: Variable importance

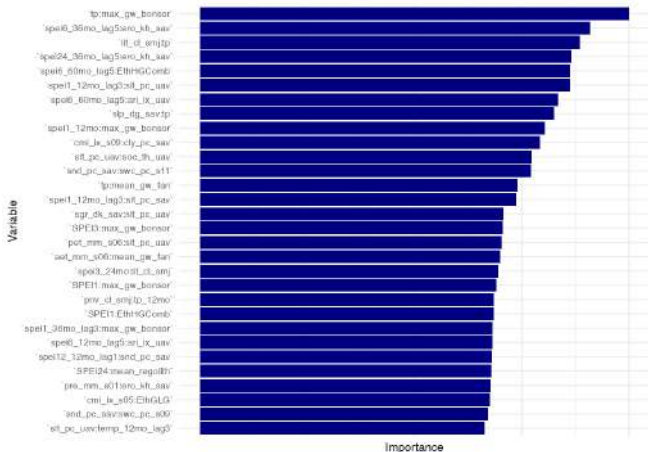


Figure 4: Variable importance

Model performance: ROC Curve

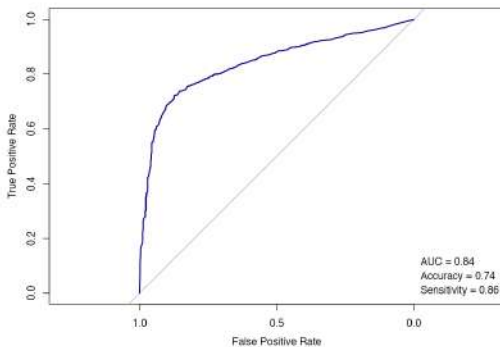


Figure 5: Model performance: ROC curve

■ Dealing with leakages:

- ▶ Spatial dimension: random unit level split [▶ Graph](#)
- ▶ Temporal dimension: random year level split [▶ Graph](#)

Model performance: Reported water source failures

	All Sources			Heterogeneity by Groundwater Use		
	(1)	(2)	(3)	(4)	(5)	(6)
well fail	0.164 (0.132)	0.157 (0.134)	0.155 (0.140)			
well fail=1				-0.055 (0.101)	-0.059 (0.102)	-0.070 (0.101)
Use groundwater=1				-0.147*** (0.025)	-0.144*** (0.024)	-0.137*** (0.025)
well fail=1 × Use groundwater=1				0.466*** (0.145)	0.468*** (0.146)	0.493*** (0.151)
spei12 24mo		-0.056 (0.037)	-0.048 (0.036)		-0.037 (0.034)	-0.031 (0.034)
Observations	3077	3077	2891	3077	3077	2891
R ²	0.161	0.164	0.183	0.200	0.202	0.218
Mean of dep. var.	0.11	0.11	0.11	0.11	0.11	0.11
Mean gw users	0.66	0.66	0.66	0.66	0.66	0.66
Fixed effects	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓
Controls			✓			✓

- (In progress: Somalian monitoring wells)

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Empirical strategy

$$Y_{h,v,t} = \alpha + \beta_1 \text{WellFail}_{v,t} + \beta_2 \text{Clim}_{v,t} + \beta_3 X_{h,t} + \delta_h + \delta_{z \times t} + \delta_m + \epsilon_{h,v,t} \quad (1)$$

- $\text{WellFail}_{v,t}$
 - ▶ predicted failure of the representative well in the EA on the month of the survey
 - ▶ Coefficient of interest: β_1

- $\text{Clim}_{v,t}$: climate controls

- $X_{h,t}$: household level controls

- $\delta_{h,v}$: household fixed effects

- $\delta_{k \times t}$: zone-wave fixed effects

- δ_m : month fixed effect

Threats to the identification

- Measurement errors in the predicted well failures may bias the results
 - ▶ Choice of controls: structure of the predicted well failures error ▶ [Details](#)
 - ▶ In progress: robust to multiple imputation (Carleton et al., 2025)
- Exclusion restriction of the predicted climate related well failures
 - ▶ Low pair-wise correlation between current EA-level drought measures and well failures ▶ [Graph](#)
 - ▶ Agricultural variables as outcome: no impact on the quantity harvested, irrigation, reported crop shock, farm size, plot size, number of plots ▶ [Results](#)
- Potential confounding factors (omitted variable bias)
 - ▶ Strong set of fixed effects and controls
 - ▶ Specific concern – conflict: results robust when restricting to low-conflict time (first panel: 2011–2015)

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- Potential confounding factors (omitted variable bias)
 - ▶ Strong set of fixed effects and controls
 - ▶ Specific concern – conflict: results robust when restricting to low-conflict time (first panel: 2011–2015)
- Additional?
 - ▶ Spatial correlation (Conley standard errors)

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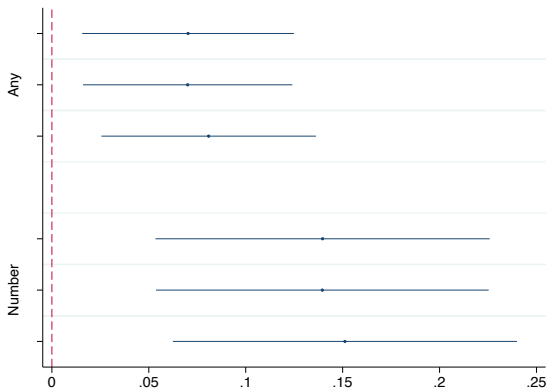
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Results – Increase in School Absenteeism

Figure 6: Impact of Predicted Well Failures on School Absenteeism



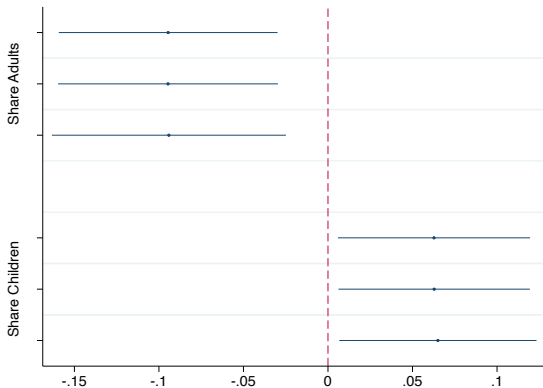
Results – Increase in School Absenteeism for both gender

	Impact on Female			Impact on Male		
	(1)	(2)	(3)	(4)	(5)	(6)
well fail	0.081*** (0.029)	0.081*** (0.029)	0.079*** (0.028)	0.073** (0.034)	0.073** (0.034)	0.085** (0.035)
spei12 24mo		0.016 (0.015)	0.014 (0.014)		0.004 (0.018)	0.011 (0.018)
Observations	13335	13335	12961	12761	12761	12386
R ²	0.476	0.476	0.481	0.484	0.484	0.499
Mean of dep. var.	0.15	0.15	0.15	0.16	0.16	0.16
Fixed effects	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓
Controls			✓			✓

- ▶ Robust to controlling for repetitive well failures
- ▶ Robust to different climate measures
- ▶ Not driven by migration or health

Results – Increased reliance on children for water collection

Figure 7: Impact of Predicted Well Failures on the Allocation of Water Collection Time Between Adults and Children



► Overall decrease in time to water

► Children more

► Adults more

Results – Switch from groundwater to surface water

- Do household switch away from groundwater as their main drinking water source?
 - ▶ Cross sectional evidence that households switch away from groundwater.

	Source of the day		
	(1)	(2)	(3)
well fail	-0.259* (0.146)	-0.243* (0.142)	-0.246* (0.139)
spei12 24mo		0.144*** (0.051)	0.132*** (0.050)
Observations	3081	3081	2894
R^2	0.263	0.272	0.285
Mean of dep. var.	0.66	0.66	0.66
Fixed effects	✓	✓	✓
Climate		✓	✓
Controls			✓

Results – Switch from groundwater to surface water

■ Do household switch away from groundwater as their main drinking water source?

- ▶ Cross sectional evidence that households switch away from groundwater and...
- ▶ ... switch towards surface water.

	Source of the day – Surface			Source of the day – Truck			Source of the day – Piped		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
well fail	0.312** (0.152)	0.310** (0.151)	0.307** (0.146)	-0.017 (0.018)	-0.019 (0.018)	-0.020 (0.018)	-0.032 (0.048)	-0.038 (0.047)	-0.027 (0.056)
spei12 24mo		-0.018 (0.034)	0.002 (0.034)		-0.016 (0.011)	-0.015 (0.011)		-0.056 (0.036)	-0.058 (0.036)
Observations	3081	3081	2894	3081	3081	2894	3081	3081	2894
R ²	0.220	0.221	0.234	0.093	0.095	0.103	0.271	0.274	0.295
Mean of dep. var.	0.16	0.16	0.16	0.02	0.02	0.02	0.14	0.14	0.14
Fixed effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓		✓	✓
Controls			✓			✓			✓

- ▶ No change of main source
- ▶ Timing of the interview
- ▶ Longest streak

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First Findings

- Impact of predicted climate-induced well failures on water collection behavior:
 - ▶ Households switch from groundwater to surface water
 - ▶ Leading to an increased water collection burden for children

- Document downstream impacts:
 - ▶ Higher school absenteeism
 - ▶ Reorganization of household tasks with increased reliance on children [▶ Details](#)

Next steps

- Improve algorithm
 - ▶ Dealing with leakages
 - ▶ Dealing with class imbalances (Synthetic Minority Over-sampling Technique?)
 - ▶ SuperLearner to combine Neural Network, Random Forest and Knn
- Robustness algorithm
 - ▶ Somalian water prices data
 - ▶ Performance only on wells observed several times
- Results
 - ▶ More on heterogeneity: distance to road, wealth, soil fertility index
- Robustness empirical strategy
 - ▶ Bootstrapping standard errors
 - ▶ Proxy with most important climate variable
 - ▶ Subsample groundwater users

Thank you!

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- European Re-Analysis Fifth Generation (ERA5) reanalysis hourly data from 1970 until 2022
 - ▶ Combines weather station data with forecast models → considered more reliable than data based on interpolation from weather stations only (Auffhammer et al., 2013)

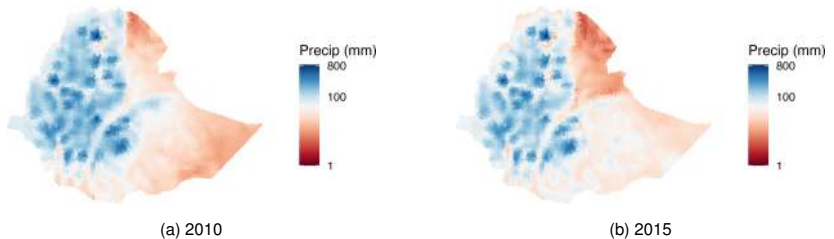


Figure 8: Mean monthly precipitation in 2010 and 2015

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Measuring Drought: Standardized Precipitation Evapotranspiration Index

- Compute the Standardized Precipitation Evapotranspiration Index (SPEI) using ERA5 (Vicente-Serrano et al., 2010; Begueria et al., 2014, Bertoli et al., 2022)

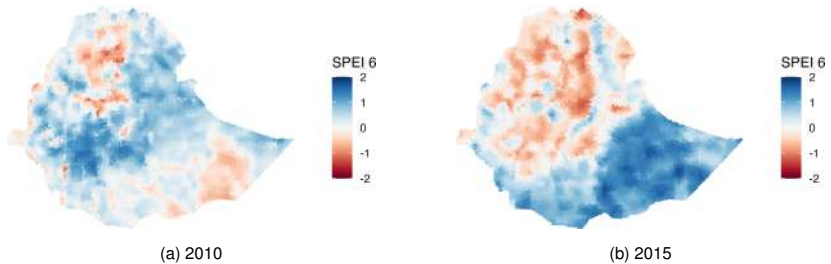


Figure 9: Mean 6 months-SPEI in 2010 and 2015

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Groundwater in Ethiopia

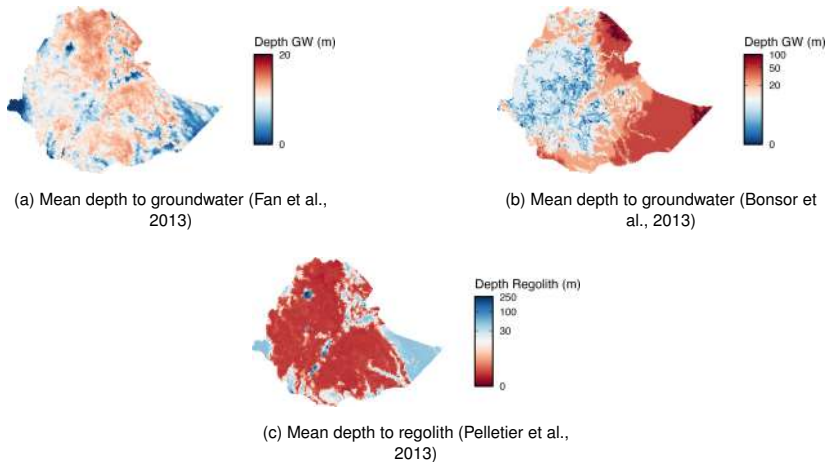


Figure 10: Variation in access to groundwater

Socio-Economic Data

■ Ethiopian Socio-Economic Survey (ESS)

- ▶ Panel 1: 2012, 2014, 2016
- ▶ Panel 2: 2019, 2021

	Mean	Std. Dev.	Min	Max	Observations
any_mig	0.49	0.50	0.00	1.00	14078
nb_mig	0.57	1.05	0.00	11.00	10839
nb_mig_female	0.23	0.58	0.00	5.00	10642
nb_mig_male	0.25	0.61	0.00	7.00	10211
nb_mig_excluding_educ	0.48	0.96	0.00	11.00	10839
nb_mig_excluding_educ_female	0.20	0.53	0.00	5.00	10642
nb_mig_excluding_educ_male	0.20	0.55	0.00	7.00	10211
nb_mig_marriage	0.18	0.53	0.00	7.00	10839
nb_mig_marriage_female	0.09	0.34	0.00	4.00	10642
nb_mig_marriage_male	0.05	0.25	0.00	3.00	10211
nb_seas_mig	0.32	0.95	0.00	12.00	14061
nb_seas_mig_female	0.13	0.53	0.00	9.00	13756
nb_seas_mig_male	0.20	0.58	0.00	6.00	13184
months_away	2.86	2.11	1.00	10.00	2430

Table 1: Migration

Socio-Economic Data

■ Ethiopian Socio-Economic Survey (ESS)

- ▶ Panel 1: 2012, 2014, 2016
- ▶ Panel 2: 2019, 2021

	Mean	Std. Dev.	Min	Max	Observations
water_hours	1.30	2.81	0.00	75.00	14061
water_hours_female	0.98	2.14	0.00	70.00	13756
water_hours_male	0.36	1.38	0.00	45.47	13184
water_hours_children	0.62	1.80	0.00	50.00	12640
water_hours_girls	0.49	1.53	0.00	50.00	10279
water_hours_boys	0.27	1.02	0.00	35.00	10528
nb_water_fetchers	1.42	1.06	0.00	11.00	14061
time_water_rainy	2.30	1.51	1.00	7.00	10300
time_water_dry	2.38	1.57	1.00	7.00	10278
no_water1mth	0.17	0.38	0.00	1.00	7479
gw_rainy	0.49	0.50	0.00	1.00	10837
gw_dry	0.49	0.50	0.00	1.00	10834
gw_wq	0.66	0.47	0.00	1.00	3084

Table 1: Access to drinking water

Socio-Economic Data

■ Ethiopian Socio-Economic Survey (ESS)

- ▶ Panel 1: 2012, 2014, 2016
- ▶ Panel 2: 2019, 2021

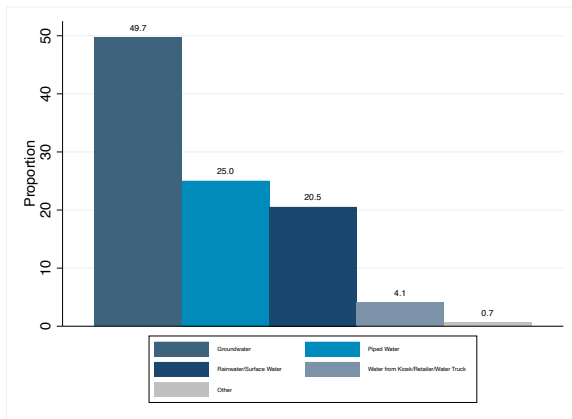


Figure 11: Water source

Combining mWater and WPdx (details)



Figure 12: Pictures of wells in Ethiopia (Source: WPDX)

► Details

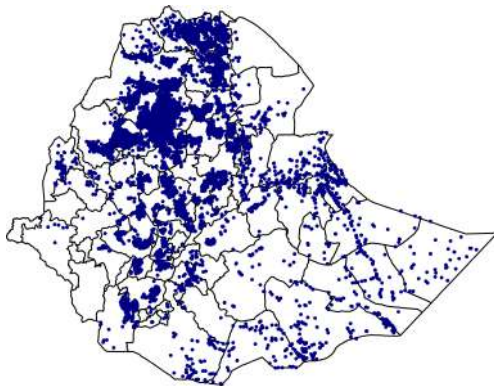


Figure 12: Location of wells

► Details

Community-managed wells tend to be more functional.

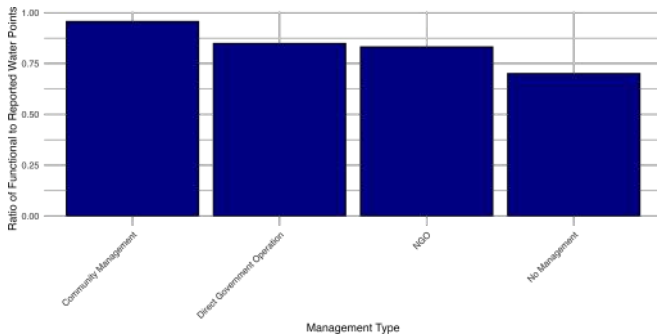


Figure 13: Functional wells per type of management

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Handpumps are more likely to be functional.

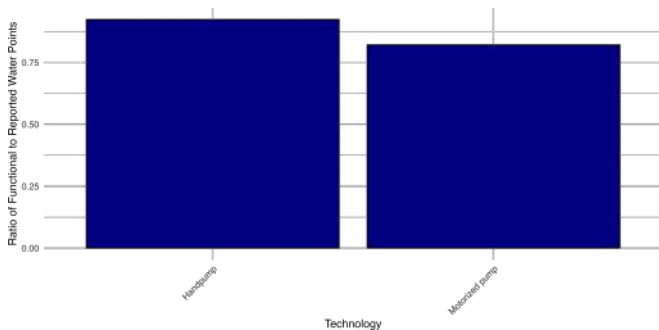


Figure 14: Functional wells per type of lifting device

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Older wells are less likely to be functional.

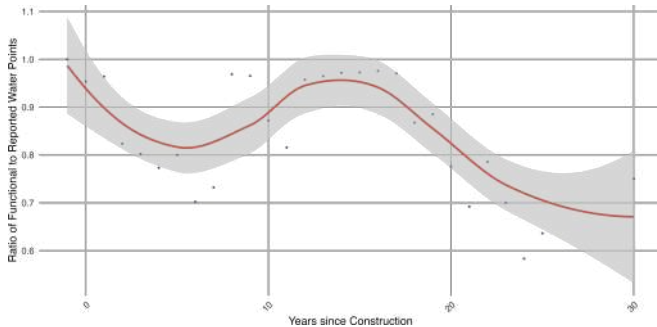


Figure 15: Functional wells per years since construction

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In drier places, wells are less likely to be functional.

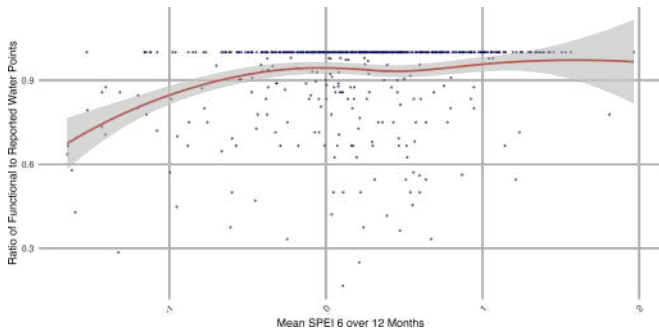


Figure 16: Functional wells per mean SPEI 12 over 12 months

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Where there is less precipitation, wells are less likely to be functional.

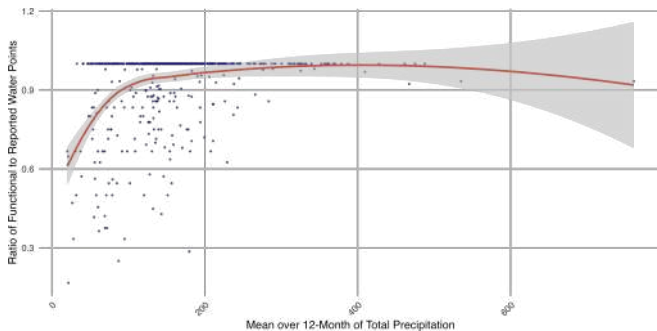


Figure 17: Functional wells per annual mean precipitation

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Where there is less precipitation, wells are less likely to be functional.

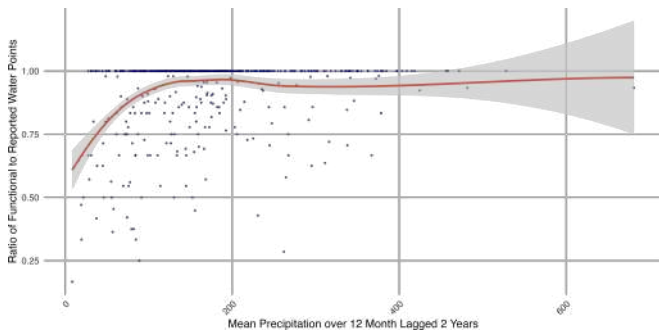
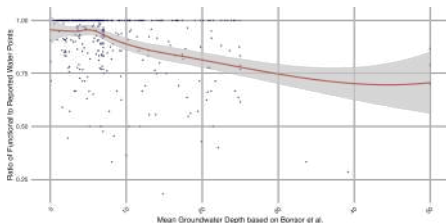
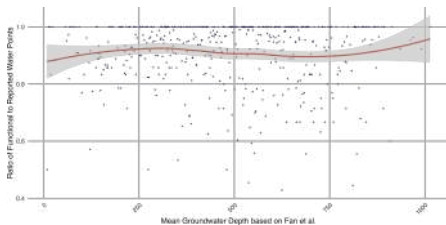


Figure 18: Functional wells per annual mean precipitation lagged 2 years

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(a) Groundwater depth from Bonsor et al.



(b) Groundwater depth from Fan et al.

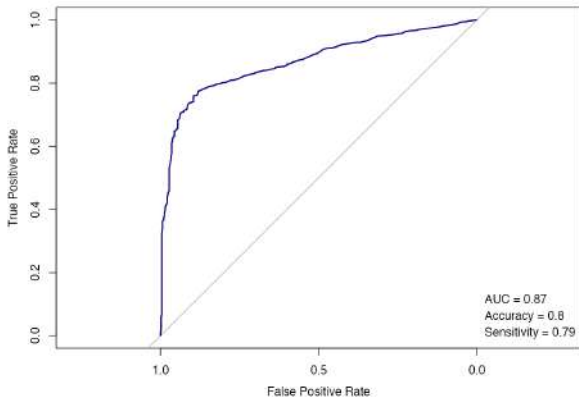


Figure 20: Model performance: ROC curve

ROC Curve - Random year split

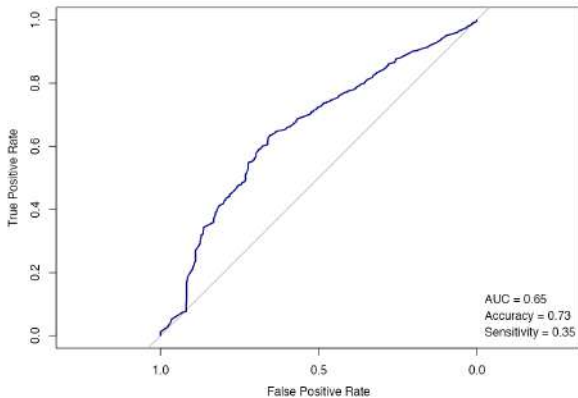


Figure 21: Model performance: ROC curve

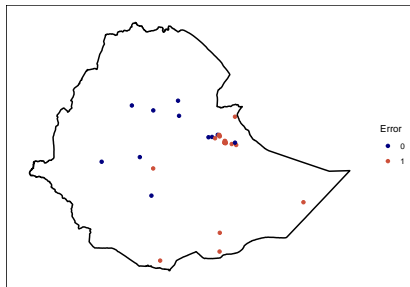
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Model performance: Somalian monitoring wells

Add graph

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Threat: measurement error



Threat: measurement error

var	n	No error		Error			Diff
		mean	sd	n	mean	sd	
time water rainy	90	2.52	1.09	135	3.07	2.06	0.544
time water dry	90	2.70	1.17	136	3.24	2.11	0.535
no water 1mth	42	0.05	0.22	152	0.35	0.48	0.301***
water hours	92	0.86	1.05	186	2.51	6.73	1.650
nb water fetchers	92	1.10	0.63	186	1.48	1.43	0.386
gw rainy	92	0.25	0.44	186	0.39	0.49	0.137
gw dry	92	0.27	0.45	186	0.41	0.49	0.137
nb mig	92	0.35	0.75	186	0.22	0.63	-0.127
nb seas mig	92	0.14	0.53	186	0.46	1.31	0.316
electricity access	92	0.27	0.45	186	0.65	0.48	0.373***
open defecation	92	0.57	0.50	186	0.46	0.50	-0.103
dist road	93	19.62	21.39	187	23.46	60.22	3.835
dist popcenter	93	33.18	23.20	187	24.33	35.33	-8.843
dist market	93	56.51	26.98	187	51.75	86.45	-4.752
agpct	93	29.53	18.45	187	23.61	16.29	-5.917
grn	54	201.33	27.61	121	141.36	57.41	-59.970***
sen	54	265.44	14.41	121	279.48	38.47	14.035
soil fertility index	93	0.35	0.28	187	-0.13	1.66	-0.484
crop shock	78	0.68	0.47	91	0.93	0.25	0.255**
harvest kg	78	964.09	3542.17	91	229.64	228.36	-734.447
nb plots	93	9.83	8.10	187	3.33	3.47	-6.502***
erosion protection	79	0.76	0.43	98	0.88	0.33	0.118
irrigated	74	0.34	0.48	28	0.11	0.31	-0.231*
avg plot size	87	0.14	0.12	152	0.28	2.56	0.149
farm size	87	1.22	1.22	152	1.22	10.24	-0.000
totcons	92	12618.49	14226.81	186	28699.95	26883.90	16,081.457***
cons quint	92	3.21	1.36	186	3.18	1.33	-0.024
hh asset index	92	-0.00	0.77	186	0.07	0.97	0.071
ag asset index	92	0.45	0.80	186	0.21	1.00	-0.238
livestock	87	0.92	0.27	153	0.79	0.41	-0.129*
spei12 12mo	93	0.06	0.53	187	0.02	0.52	-0.043
tp 12mo	93	123.13	100.27	187	39.98	12.15	-83.146**
temp 12mo	93	19.67	2.62	187	22.32	3.26	2.657**

Threat: measurement error

var	n	No error		Error			Diff
		mean	sd	n	mean	sd	
time water rainy resid	90	0.01	0.93	133	0.04	1.05	0.024
time water dry resid	90	0.01	0.93	134	0.02	1.17	0.011
no water1mth resid	42	0.02	0.20	152	-0.02	0.32	-0.035
water hours resid	92	0.02	1.01	186	0.06	2.97	0.039
nb water fetchers resid	92	0.07	0.63	186	0.01	0.99	-0.058
gw rainy resid	92	-0.00	0.16	186	0.03	0.21	0.027
gw dry resid	92	0.00	0.10	186	0.03	0.19	0.026
nb mig resid	92	-0.01	0.63	186	-0.02	0.57	-0.014
nb seas mig resid	92	0.02	0.49	186	-0.04	0.77	-0.057
electricity access resid	92	-0.02	0.31	186	-0.01	0.29	0.015
open defecation resid	92	0.00	0.37	186	0.01	0.35	0.005
dist road resid	93	-0.04	1.01	186	0.07	1.15	0.115
dist popcenter resid	93	0.09	0.84	186	0.01	0.97	-0.087*
dist market resid	93	0.09	0.84	186	0.01	1.01	-0.087*
agpct resid	93	-0.09	7.24	186	-0.09	4.82	0.001
grn resid	54	-0.00	0.00	121	-0.00	0.00	-0.000
sen resid	54	-0.00	0.00	121	0.00	0.09	0.001
soil fertility index resid	93	0.01	0.08	186	0.00	0.03	-0.006
crop shock resid	77	-0.01	0.35	89	-0.02	0.23	-0.011
harvest kg resid	77	-380.84	3572.72	89	-43.38	395.12	337.463
nb plots resid	93	-0.02	5.37	186	0.02	2.30	0.038
erosion protection resid	78	0.01	0.34	96	-0.01	0.21	-0.013
irrigated resid	73	-0.01	0.35	25	-0.00	0.20	0.008
avg plot size resid	87	0.00	0.08	151	0.00	2.46	-0.002
farm size resid	87	-0.03	0.98	151	0.02	9.84	0.057
totcons resid	92	-266.06	11359.06	186	-183.08	21198.65	82.972
cons quint resid	92	-0.07	1.07	186	0.04	1.04	0.103*
hh asset index resid	92	0.05	0.33	186	0.03	0.57	-0.020
ag asset index resid	92	0.07	0.50	186	0.05	0.63	-0.018
livestock resid	87	0.01	0.24	152	-0.01	0.33	-0.017

Ag outcomes: Harvest quantity

	Well fail			Longest streak		
	(1)	(2)	(3)	(4)	(5)	(6)
well fail	0.042 (0.211)	0.038 (0.205)	0.046 (0.208)			
Longest wt functional well				-0.001 (0.003)	-0.001 (0.003)	-0.001 (0.003)
spei12 24mo		-0.144* (0.074)	-0.140* (0.074)		-0.126* (0.074)	-0.117 (0.075)
Observations	9556	9556	9143	9448	9448	9043
R ²	0.727	0.727	0.733	0.728	0.728	0.733
Mean of dep. var.	708.67	708.67	708.67	699.08	699.08	699.08
Fixed effects	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓
Controls			✓			✓

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Ag outcomes: Irrigation

	Well fail			Longest streak		
	(1)	(2)	(3)	(4)	(5)	(6)
well fail	-0.048 (0.044)	-0.048 (0.044)	-0.047 (0.043)			
Longest wt functional well				0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
spei12 24mo		0.001 (0.013)	0.003 (0.012)		0.000 (0.013)	0.003 (0.012)
Observations	8326	8326	7964	8255	8255	7897
R^2	0.694	0.694	0.703	0.695	0.695	0.704
Mean of dep. var.	0.11	0.11	0.11	0.12	0.12	0.12
Fixed effects	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓
Controls			✓			✓

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Ag outcomes: Crop shock

	Well fail			Longest streak		
	(1)	(2)	(3)	(4)	(5)	(6)
well fail	-0.043 (0.063)	-0.042 (0.062)	-0.048 (0.060)			
Longest wt functional well				-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)
spei12 24mo		0.039 (0.026)	0.036 (0.026)		0.037 (0.026)	0.034 (0.026)
Observations	9607	9607	9199	9499	9499	9099
R^2	0.569	0.570	0.585	0.569	0.569	0.585
Mean of dep. var.	0.77	0.77	0.77	0.77	0.77	0.77
Fixed effects	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓
Controls			✓			✓

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Ag outcomes: Farm size

	Well fail			Longest streak		
	(1)	(2)	(3)	(4)	(5)	(6)
well fail	0.941 (0.857)	0.942 (0.855)	1.103 (0.917)			
Longest wt functional well				-0.019 (0.016)	-0.019 (0.017)	-0.024 (0.018)
spei12 24mo		-0.128 (0.195)	-0.064 (0.204)		0.016 (0.187)	0.063 (0.206)
Observations	12201	12201	11789	12043	12043	11635
R ²	0.428	0.428	0.419	0.402	0.402	0.404
Mean of dep. var.	1.33	1.33	1.33	1.28	1.28	1.28
Fixed effects	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓
Controls			✓			✓

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Ag outcomes: Plot size

	Well fail			Longest streak		
	(1)	(2)	(3)	(4)	(5)	(6)
well fail	0.186 (0.151)	0.186 (0.150)	0.205 (0.159)			
Longest wt functional well				-0.002 (0.002)	-0.002 (0.002)	-0.003 (0.003)
spei12 24mo		-0.022 (0.029)	-0.014 (0.030)		-0.000 (0.027)	0.004 (0.030)
Observations	12201	12201	11789	12043	12043	11635
R ²	0.420	0.420	0.413	0.396	0.396	0.398
Mean of dep. var.	0.16	0.16	0.16	0.15	0.15	0.15
Fixed effects	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓
Controls			✓			✓

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Ag outcomes: Number of plots

	Well fail			Longest streak		
	(1)	(2)	(3)	(4)	(5)	(6)
well fail	-0.356 (0.384)	-0.356 (0.384)	-0.283 (0.382)			
Longest wt functional well				-0.002 (0.007)	-0.002 (0.007)	-0.003 (0.007)
spei12 24mo		-0.038 (0.268)	0.020 (0.267)		-0.031 (0.269)	0.031 (0.268)
Observations	13928	13928	13480	13751	13751	13307
R ²	0.856	0.856	0.861	0.855	0.855	0.860
Mean of dep. var.	8.65	8.65	8.65	8.71	8.71	8.71
Fixed effects	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓
Controls			✓			✓

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Results – Water collection behavior I

- Do household switch away from groundwater as their main drinking water source?
 - ▶ No clear evidence that household change their main water source.

	Rainy Season – Interviewed Dry Season			Dry Season – Interviewed Dry Season		
	(1)	(2)	(3)	(4)	(5)	(6)
well fail	-0.060 (0.065)	-0.056 (0.066)	-0.054 (0.068)	-0.131* (0.074)	-0.126* (0.075)	-0.133* (0.076)
spei12 24mo		-0.036 (0.037)	-0.036 (0.037)		-0.045 (0.035)	-0.050 (0.035)
Observations	9325	9325	8944	9322	9322	8942
R^2	0.625	0.625	0.632	0.617	0.618	0.626
Mean of dep. var.	0.53	0.53	0.53	0.53	0.53	0.53
Fixed effects	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓
Controls			✓			✓

▶ [Rainy Season](#)

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Results – Water collection behavior I

- Do household switch away from groundwater as their main drinking water source?
 - ▶ No clear evidence that household change their main water source.

	Main Source – Rainy Season			Main Source – Dry Season		
	(1)	(2)	(3)	(4)	(5)	(6)
Longest wt functional well	-0.001 (0.001)	-0.001 (0.001)	-0.001 (0.001)	-0.002 (0.001)	-0.002 (0.001)	-0.002 (0.001)
spei12 24mo		-0.044 (0.032)	-0.048 (0.032)		-0.055* (0.030)	-0.063** (0.031)
Observations	13701	13701	13305	13697	13697	13302
R ²	0.636	0.637	0.642	0.631	0.631	0.638
Mean of dep. var.	0.50	0.50	0.50	0.50	0.50	0.50
Fixed effects	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓
Controls			✓			✓

▶ Interview

▶ Back

Results – Water collection behavior I

- Do household switch away from groundwater as their main drinking water source?
 - ▶ No clear evidence that household change their main water source.

	Rainy Season – Interviewed Rainy Season			Dry Season – Interviewed Rainy Season		
	(1)	(2)	(3)	(4)	(5)	(6)
well fail	0.229 (0.235)	0.219 (0.242)	0.208 (0.241)	0.221 (0.238)	0.202 (0.243)	0.192 (0.242)
spei12 24mo		-0.025 (0.072)	-0.032 (0.072)		-0.049 (0.072)	-0.057 (0.073)
Observations	4240	4240	4228	4240	4240	4228
R^2	0.668	0.668	0.670	0.663	0.663	0.666
Mean of dep. var.	0.44	0.44	0.44	0.45	0.45	0.45
Fixed effects	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓
Controls			✓			✓

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Results – Water collection behavior: Source (Additional)

■ Do household switch away from groundwater as their main drinking water source?

- ▶ No clear evidence that household change their main water source.

	Rainy Season – Interviewed Dry Season			Dry Season – Interviewed Dry Season		
	(1)	(2)	(3)	(4)	(5)	(6)
Longest wt functional well	-0.002 (0.001)	-0.002 (0.001)	-0.002 (0.001)	-0.003** (0.001)	-0.003** (0.001)	-0.003** (0.001)
spei12 24mo		-0.033 (0.037)	-0.032 (0.037)		-0.037 (0.035)	-0.042 (0.035)
Observations	9215	9215	8838	9212	9212	8836
R ²	0.625	0.625	0.632	0.618	0.619	0.627
Mean of dep. var.	0.53	0.53	0.53	0.53	0.53	0.53
Fixed effects	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓
Controls			✓			✓

Results – Water collection behavior: Source (Additional)

■ Do household switch away from groundwater as their main drinking water source?

- ▶ No clear evidence that household change their main water source.

	Rainy Season – Interviewed Rainy Season			Dry Season – Interviewed Rainy Season		
	(1)	(2)	(3)	(4)	(5)	(6)
Longest wt functional well	0.002 (0.002)	0.001 (0.002)	0.002 (0.003)	0.003 (0.002)	0.002 (0.003)	0.002 (0.003)
spei12 24mo		-0.065 (0.068)	-0.072 (0.068)		-0.085 (0.069)	-0.094 (0.069)
Observations	4176	4176	4164	4176	4176	4164
R^2	0.676	0.677	0.678	0.672	0.673	0.675
Mean of dep. var.	0.44	0.44	0.44	0.45	0.45	0.45
Fixed effects	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓
Controls			✓			✓

▶ Back

Results - Water collection behavior: Time (Additional)

- How does the time taken to fetch water evolve?
 - ▶ No clear evidence when repetitive shocks.

	Time Water – Yesterday			Time Water – Rainy Season			Time Water – Dry Season		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Longest wt functional well	0.002 (0.002)	0.002 (0.002)	0.002 (0.002)	0.000 (0.003)	0.000 (0.003)	-0.001 (0.003)	0.005 (0.004)	0.005 (0.004)	0.004 (0.004)
spei12 24mo		-0.025 (0.059)	-0.019 (0.062)		-0.169 (0.109)	-0.134 (0.112)		-0.042 (0.111)	
Observations	13727	13727	13307	9664	9664	9112	9616	9616	9074
R^2	0.476	0.476	0.481	0.755	0.755	0.761	0.748	0.748	0.751
Mean of dep. var.	0.81	0.81	0.81	2.32	2.32	2.32	2.39	2.39	2.39
Fixed effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓		✓	✓
Controls			✓			✓			✓

▶ Back

Results - Water collection behavior: Time (Additional)

■ How does the time taken to fetch water evolve?

- ▶ Suggestive evidence that time to water decreases...
- ▶ but composition effect: children see their water collection burden increase.

	Nb Child Fetchers per Household Member			Water Time per Child Fetcher			Child Water Time per Household Member		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
well fail	0.019* (0.011)	0.019* (0.011)	0.018 (0.011)	-0.129 (0.250)	-0.130 (0.251)	-0.128 (0.273)	0.029 (0.024)	0.029 (0.024)	0.032 (0.025)
spei12 24mo		-0.002 (0.006)	-0.000 (0.006)		0.051 (0.065)	0.040 (0.073)		-0.002 (0.010)	0.000 (0.011)
Observations	11657	11657	11306	3449	3449	3263	11659	11659	11308
R ²	0.590	0.590	0.600	0.602	0.602	0.608	0.470	0.470	0.477
Mean of dep. var.	0.10	0.10	0.10	0.80	0.80	0.80	0.09	0.09	0.09
Fixed effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓		✓	✓
Controls			✓			✓			✓

▶ Back

Results - Water collection behavior: Time (Additional)

- How does the time taken to fetch water evolve?
 - ▶ Suggestive evidence that time to water decreases...
 - ▶ but composition effect: children see their water collection burden increase.

	Nb Adult Fetchers per Household Member			Water Time per Adult Fetcher			Adult Water Time per Household Member		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
well fail	-0.040** (0.017)	-0.040** (0.017)	-0.039** (0.018)	-0.233 (0.193)	-0.231 (0.192)	-0.198 (0.197)	-0.103** (0.051)	-0.103** (0.051)	-0.106** (0.053)
spei12 24mo		-0.003 (0.007)	-0.003 (0.007)		-0.037 (0.066)	-0.017 (0.071)		-0.019 (0.016)	-0.016 (0.016)
Observations	13875	13875	13475	9139	9139	8811	13875	13875	13475
R ²	0.628	0.628	0.636	0.527	0.527	0.529	0.509	0.510	0.523
Mean of dep. var.	0.22	0.22	0.22	0.93	0.93	0.93	0.20	0.20	0.20
Fixed effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓		✓	✓
Controls			✓			✓			✓

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- How does the time taken to fetch water evolve?
 - ▶ Suggestive evidence that time to water decreases...
 - ▶ but composition effect: children see their water collection burden increase.

ADD GRAPH

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Results - Absenteeism (Additional)

■ What activities are being crowded out?

- ▶ Increase in school absenteeism

	Count Months Non Functional			Longest wt Functional		
	(1)	(2)	(3)	(4)	(5)	(6)
well fail	0.160*** (0.057)	0.160*** (0.056)	0.175*** (0.058)	0.141*** (0.053)	0.142*** (0.053)	0.154*** (0.055)
spei12 24mo		0.018 (0.029)	0.023 (0.029)		0.018 (0.028)	0.022 (0.028)
Count 24 months	-0.005 (0.004)	-0.005 (0.004)	-0.006 (0.004)			
Longest wt functional well				0.001 (0.001)	0.001 (0.001)	0.001 (0.001)
Observations	13680	13680	13262	13727	13727	13307
R ²	0.490	0.490	0.500	0.490	0.490	0.500
Mean of dep. var.	0.15	0.15	0.15	0.15	0.15	0.15
Fixed effects	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓
Controls			✓			✓

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Results - Absenteeism (Additional)

■ What activities are being crowded out?

▶ Increase in school absenteeism

	Temp & Precip		Different SPEI					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
well fail	0.155*** (0.056)	0.146*** (0.054)	0.145*** (0.052)	0.158*** (0.054)	0.139*** (0.052)	0.151*** (0.054)	0.142*** (0.052)	0.154*** (0.053)
tp	-0.000 (0.000)	-0.000 (0.000)						
temp	0.026 (0.022)	0.027 (0.024)						
SPEI12			0.023 (0.019)	0.028 (0.019)				
SPEI3					-0.007 (0.018)	-0.001 (0.018)		
spei3_24mo							0.060 (0.059)	0.068 (0.059)
Observations	13680	13480	13904	13480	13904	13480	13904	13480
R ²	0.490	0.499	0.488	0.498	0.488	0.498	0.488	0.498
Mean of dep. var.	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Fixed effects	✓	✓	✓	✓	✓	✓	✓	✓
Climate	✓	✓	✓	✓	✓	✓	✓	✓
Controls		✓		✓		✓		✓

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Results – Firewood collection (Additional)

	Time Firewood			Time Firewood – Reliance Adult			Time Firewood – Reliance Children		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
well fail	-0.119** (0.060)	-0.119** (0.059)	-0.107* (0.060)	-0.119** (0.058)	-0.120** (0.058)	-0.115* (0.059)	0.067* (0.038)	0.067* (0.038)	0.065* (0.037)
spei12 24mo		-0.014 (0.023)	-0.017 (0.024)		0.014 (0.020)	0.012 (0.021)		0.001 (0.014)	0.003 (0.014)
Observations	13901	13901	13477	13903	13903	13479	12500	12500	12096
R ²	0.503	0.503	0.511	0.548	0.548	0.555	0.560	0.560	0.566
Mean of dep. var.	0.36	0.36	0.36	0.54	0.54	0.54	0.25	0.25	0.25
Fixed effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓		✓	✓
Controls			✓			✓			✓

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Results – Firewood collection (Additional)

	Nb Child Fetchers per Household Member			Firewood Time per Child Fetcher			Child Firewood Time per Household Member		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
well fail	0.017 (0.013)	0.017 (0.013)	0.016 (0.012)	-0.216 (0.403)	-0.216 (0.405)	-0.112 (0.473)	0.021 (0.029)	0.021 (0.029)	0.026 (0.030)
spei12 24mo		-0.000 (0.007)	-0.002 (0.006)		0.012 (0.129)	-0.034 (0.147)		-0.003 (0.013)	-0.007 (0.012)
Observations	11657	11657	11306	3002	3002	2807	11659	11659	11308
R^2	0.568	0.568	0.589	0.567	0.567	0.571	0.462	0.462	0.471
Mean of dep. var.	0.09	0.09	0.09	1.32	1.32	1.32	0.12	0.12	0.12
Fixed effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓		✓	✓
Controls			✓			✓			✓

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Results – Firewood collection (Additional)

	Nb Adult Fetchers per Household Member			Firewood Time per Adult Fetcher			Adult Firewood Time per Household Member		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
well fail	-0.048*	-0.048*	-0.048*	-0.249	-0.243	-0.156	-0.157***	-0.157***	-0.143**
	(0.027)	(0.027)	(0.027)	(0.168)	(0.166)	(0.173)	(0.055)	(0.054)	(0.056)
spei12 24mo		0.004	0.006		-0.052	-0.051		-0.010	-0.009
		(0.009)	(0.010)		(0.074)	(0.079)		(0.018)	(0.018)
Observations	13875	13875	13475	7347	7347	7025	13875	13875	13475
R ²	0.579	0.579	0.589	0.546	0.546	0.549	0.514	0.514	0.520
Mean of dep. var.	0.19	0.19	0.19	1.36	1.36	1.36	0.25	0.25	0.25
Fixed effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓		✓	✓
Controls			✓			✓			✓

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Results – Farming (Additional)

	Time Farm			Time Farm – Reliance Adult			Time Farm – Reliance Children		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
well fail	2.874*** (0.990)	2.879*** (0.983)	2.881*** (1.059)	0.036 (0.037)	0.036 (0.037)	0.034 (0.038)	0.066** (0.031)	0.066** (0.032)	0.067** (0.033)
spei12 24mo		-0.616 (0.552)	-0.580 (0.561)		0.011 (0.016)	0.009 (0.017)		-0.011 (0.011)	-0.008 (0.012)
Observations	13901	13901	13477	13903	13903	13479	12556	12556	12135
R ²	0.607	0.607	0.617	0.584	0.584	0.591	0.589	0.589	0.597
Mean of dep. var.	9.41	9.41	9.41	0.59	0.59	0.59	0.23	0.23	0.23
Fixed effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓		✓	✓
Controls			✓			✓			✓

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Results – Farming (Additional)

	Nb Child Farmers per Household Member			Farm Time per Child Farmer			Child Farm Time per Household Member		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
well fail	0.053*** (0.016)	0.053*** (0.016)	0.054*** (0.017)	4.301 (3.377)	4.301 (3.389)	4.497 (3.422)	1.901*** (0.552)	1.902*** (0.553)	1.941*** (0.553)
spei12 24mo		-0.011 (0.007)	-0.011 (0.007)		-0.017 (1.334)	0.317 (1.366)		-0.054 (0.223)	0.004 (0.231)
Observations	11657	11657	11306	4825	4825	4622	11659	11659	11308
R ²	0.638	0.638	0.649	0.656	0.656	0.666	0.589	0.589	0.596
Mean of dep. var.	0.16	0.16	0.16	22.56	22.56	22.56	3.06	3.06	3.06
Fixed effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓		✓	✓
Controls			✓			✓			✓

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Results – Farming (Additional)

	Nb Adult Farmers per Household Member			Farm Time per Adult Fetcher			Adult Farm Time per Household Member		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
well fail	0.025 (0.026)	0.025 (0.026)	0.028 (0.026)	1.360 (2.184)	1.358 (2.185)	0.932 (2.168)	1.211 (0.846)	1.214 (0.839)	1.173 (0.880)
spei12 24mo		-0.008 (0.011)	-0.007 (0.010)		0.126 (1.015)	0.125 (1.022)		-0.513 (0.430)	-0.537 (0.428)
Observations	13875	13875	13475	10171	10171	9831	13876	13876	13476
R ²	0.658	0.658	0.666	0.615	0.615	0.625	0.584	0.584	0.595
Mean of dep. var.	0.34	0.34	0.34	21.82	21.82	21.82	6.80	6.80	6.80
Fixed effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓		✓	✓
Controls			✓			✓			✓

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Results – Casual Work (Additional)

	Time Casual Work			Time Casual – Reliance Adult			Time Casual – Reliance Children		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
well fail	0.046 (0.246)	0.046 (0.248)	0.139 (0.246)	-0.027 (0.023)	-0.027 (0.023)	-0.024 (0.024)	0.015** (0.006)	0.015** (0.006)	0.016** (0.006)
spei12 24mo		0.068 (0.115)	0.116 (0.108)		0.020 (0.013)	0.018 (0.013)		0.002 (0.003)	0.002 (0.003)
Observations	13901	13901	13477	13902	13902	13479	13754	13754	13333
R ²	0.445	0.445	0.439	0.455	0.455	0.463	0.469	0.469	0.477
Mean of dep. var.	0.46	0.46	0.46	0.07	0.07	0.07	0.01	0.01	0.01
Fixed effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓		✓	✓
Controls			✓			✓			✓

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Results – Casual Work (Additional)

	Nb Child in Casual Work per Household Member			Casual Time per Child Casual Worker			Child Casual Time per Household Member		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
well fail	0.006** (0.003)	0.006** (0.003)	0.007** (0.003)	0.000 (.)	0.000 (.)	0.000 (.)	0.108 (0.087)	0.108 (0.087)	0.120 (0.091)
spei12 24mo		0.001 (0.001)	0.001 (0.001)		0.000 (.)	0.000 (.)		0.015 (0.030)	-0.006 (0.026)
Observations	11657	11657	11306	10	10	10	11660	11660	11309
R ²	0.512	0.512	0.523	0.716	0.716	1.000	0.475	0.475	0.472
Mean of dep. var.	0.00	0.00	0.00	10.20	10.20	10.20	0.05	0.05	0.05
Fixed effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓		✓	✓
Controls			✓			✓			✓

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Results – Casual Work (Additional)

	Nb Adult in Casual Work per Household Member			Casual Time per Adult Casual Worker			Adult Casual Time per Household Member		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
well fail	-0.012 (0.008)	-0.012 (0.008)	-0.011 (0.008)	-12.467** (5.138)	-19.827** (9.389)	-10.214 (26.275)	-0.067 (0.212)	-0.067 (0.213)	0.018 (0.215)
spei12 24mo		0.003 (0.004)	0.003 (0.004)		20.573** (7.909)	4.668 (41.121)		0.040 (0.105)	0.097 (0.103)
Observations	13875	13875	13475	90	90	79	13878	13878	13478
R ²	0.465	0.465	0.463	0.798	0.815	0.925	0.441	0.442	0.437
Mean of dep. var.	0.02	0.02	0.02	16.68	16.68	16.68	0.42	0.42	0.42
Fixed effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓		✓	✓
Controls			✓			✓			✓

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- How does the time taken to fetch water evolve?

Results – Water collection behavior

- How does the time taken to fetch water evolve?
 - ▶ Suggestive evidence that time to water decreases.

	Time Water – Yesterday			Time Water – Rainy Season			Time Water – Dry Season		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
well fail	-0.217 (0.172)	-0.217 (0.171)	-0.200 (0.174)	-0.462** (0.188)	-0.481** (0.193)	-0.416** (0.200)	-0.334* (0.195)	-0.338* (0.197)	-0.293 (0.204)
spei12 24mo		-0.026 (0.058)	-0.020 (0.062)		-0.164 (0.108)	-0.125 (0.112)		-0.034 (0.111)	-0.044 (0.115)
Observations	13904	13904	13480	9766	9766	9212	9720	9720	9176
R ²	0.481	0.481	0.485	0.755	0.755	0.761	0.748	0.748	0.750
Mean of dep. var.	0.81	0.81	0.81	2.32	2.32	2.32	2.40	2.40	2.40
Fixed effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓		✓	✓
Controls			✓			✓			✓

- ▶ Longest streak
- ▶ Back

Results – Household switch from groundwater to surface water

- Do household switch away from groundwater as their main drinking water source?

Results – Household switch from groundwater to surface water

- Do household switch away from groundwater as their main drinking water source?
 - ▶ No clear evidence that household change their main water source.

	Main Source – Rainy Season			Main Source – Dry Season		
	(1)	(2)	(3)	(4)	(5)	(6)
well fail	0.007 (0.071)	0.007 (0.071)	0.007 (0.071)	-0.048 (0.078)	-0.048 (0.077)	-0.048 (0.077)
spei12 24mo		-0.038 (0.032)	-0.038 (0.032)		-0.051* (0.031)	-0.051* (0.031)
Observations	13878	13878	13878	13874	13874	13874
R ²	0.634	0.634	0.634	0.627	0.628	0.628
Mean of dep. var.	0.50	0.50	0.50	0.50	0.50	0.50
Fixed effects	✓	✓	✓	✓	✓	✓
Climate		✓	✓		✓	✓
Controls			✓			✓

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Lower school attendance increases reliance on children for

- Farming [▶ Results](#)
- Casual work [▶ Results](#)
- (In progress: no effect on wage work or activities in non-agricultural businesses)

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Underlying Data sources for inputs

Category	Attribute	Source Data	Citation	Columns
Climate	Current SPEI (1, 3, 6, 12, 24, 96)	ERA-5		SPEI
	Mean SPEI over 12, 24, 60 months	ERA-5		spei
	Lagged Mean SPEI (1-5 years)	ERA-5		spei
	Current precipitation	ERA-5		tp
	Mean precipitation over 12, 24, 60 months	ERA-5		tp
	Lagged Mean precipitation (1-5 years)	ERA-5		tp
	Current temperature	ERA-5		temp
	Mean temperature over 12, 24, 60 months	ERA-5		temp
	Lagged Mean temperature (1-5 years)	ERA-5		temp
	Snow Cover Extent *	MODIS/Aqua	Hall & Riggs 2016	snw_pc_
	Climate Zones *	QENS		clz_cl_
	Climate Strata *	QENS	Metzger et al. 2013	cls_cl_
	Air Temperature *	WorldClim v1.4	Metzger et al. 2013	tmp_dc_
	Precipitation *	WorldClim v1.4	Hijmans et al. 2005	pre_mm_
	Potential Evapotranspiration *	Global-PET	Zomer et al. 2008	pet_mm_
	Climate Moisture Index *	WorldClim & Global-PET	Hijmans et al. 2005	cmi_ix_
	Global Aridity Index *	Global Aridity Index	Zomer et al. 2008	ari_ix_
Actual Evapotranspiration *	Global Soil-Water Balance	Taibucco & Zomer 2010	act_mm_	
Soil Water Content *	Global Soil-Water Balance	Taibucco & Zomer 2010	swc_pc_	
Hydrology	Groundwater Table Depth *	Global Groundwater Map	Fan et al. 2013	_tan
	Groundwater Table Depth		MacDonald et al. 2012	_bonsor
	Aquifer productivity	African Groundwater Atlas		EthHGComb
	Natural Discharge *	WaterGAP v2.2	Döll et al. 2003	ds_m3_
	Land Surface Runoff *	WaterGAP v2.2	Döll et al. 2003	run_mm_
	Inundation Extent *	CIEMS-D15	Fruet-Chouillard et al. 2015	iru_pc_
	Limnicity (% Lake Area) *	HydroLAKES	Messageur et al. 2016	lka_pc_
	Lake Volume *	HydroLAKES	Messageur et al. 2016	lvr_mc_
	Reservoir Volume *	GRanD v1.1	Lehner et al. 2011	rev_mc_
	Degree of Regulation *	HydroSHEDS & GRanD	Lehner et al. 2011	dor_pc_
	River Area *	HydroSHEDS & WaterGAP	Lehner & Grill 2013	rla_ha_
	River Volume *	HydroSHEDS & WaterGAP	Lehner & Grill 2013	rv_tz_
	Landcover	Potential Natural Vegetation Classes *	EarthStat	Ramankutty & Foley 1999
Potential Natural Vegetation Extent *		EarthStat	Ramankutty & Foley 1999	pnv_pc_
Physiography	Elevation *	EarthEnv-DEM90	Robinson et al. 2014	ele_mt_
	Terrain Slope *	EarthEnv-DEM90	Robinson et al. 2014	slp_dg_
	Stream Gradient *	EarthEnv-DEM90	Robinson et al. 2014	sgr_dk_
Soils & Geology	Depth to regolith		Pelletier et al. 2016	_regolith
	Rock type	African Groundwater Atlas		EthGLG
	Soil Erosion *	GIOSEM v1.2	Borrelli et al. 2017	ero_kh_
	Karst Area Extent *	Rock Outcrops v3.0	Williams & Ford 2006	kar_pc_
	Lithological Classes *	GLM	Hartmann & Moosdorf 2012	li_cl_
	Soil Water Content *	Global High-Resolution Soil-Water Balance	Taibucco & Zomer 2010	swc_pc_
	Organic Carbon Content in Soil *	SoilGrids1km	Hengl et al. 2014	soc_th_
	Sand Fraction in Soil *	SoilGrids1km	Hengl et al. 2014	snd_pc_
	Silt Fraction in Soil *	SoilGrids1km	Hengl et al. 2014	sil_pc_
	Clay Fraction in Soil *	SoilGrids1km	Hengl et al. 2014	clay_pc_

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Selected Variables after 1st LASSO

Category	Attribute	Definition
Climate	SPEI 1	Current 1 month SPEI; Binary variables of whether the current SPEI 1 was below -1, -1.5 and -2; Mean SPEI 1 over 24 and 60 months; Mean SPEI 1 over 24 months lagged 2 years; Mean SPEI 1 over 12, 24, and 36 months lagged 3 years; Mean SPEI 1 over 24, 36, and 60 months lagged 5 years.
	SPEI 3	Current 3 months SPEI; Binary variables of whether the current SPEI 3 was below -1, -1.5 and -2; Mean SPEI 3 over 12, 24, and 60 months; Mean SPEI 3 over 24 and 60 months lagged 2 years; Mean SPEI 3 over 12 and 36 months lagged 3 years; Mean SPEI 3 over 24, 36, and 60 months lagged 5 years.
	SPEI 6	Current 6 months SPEI; Binary variables of whether the current SPEI 6 was below -1, -1.5 and -2; Mean SPEI 6 over 12, 24, and 60 months; Mean SPEI 6 over 24 and 60 months lagged 2 years; Mean SPEI 6 over 24 months lagged 3 years; Mean SPEI 6 over 12, 24, 36, and 60 months lagged 5 years.
	SPEI 12	Current 12 months SPEI; Binary variables of whether the current SPEI 12 was below -1, -1.5 and -2; Mean SPEI 12 over 12 months; Mean SPEI 12 over 12, 24, and 60 months lagged 1 year; Mean SPEI 12 over 60 months lagged 3 years; Mean SPEI 12 over 12, 24, and 36 months lagged 5 years.
	SPEI 36	Current 36 months SPEI; Binary variables of whether the current SPEI 36 was below -1, -1.5 and -2; Mean SPEI 36 over 12 months; Mean SPEI 36 over 12 and 36 months lagged 1 year; Mean SPEI 36 over 12, 24, and 36 months lagged 3 years; Mean SPEI 36 over 12, 36, and 60 months lagged 5 years.
	Temperature (ERA-5)	Current mean temperature; Mean temperature over 12 months lagged 1 year; Mean temperature over 12 and 24 months lagged 2 years; Mean temperature over 12, 24, 36 and 60 months lagged 3 years; Mean temperature over 12, 24, 36, and 60 months lagged 5 years.
	Precipitation (ERA-5)	Current mean total precipitation; Mean precipitation over the year; Mean precipitation over 12 and 36 months lagged 1 year; Mean precipitation over 24 and 36 months lagged 2 years; Mean precipitation over 12 and 24 months lagged 3 years; Mean precipitation over 12, 36, and 60 months lagged 5 years.
	Climate Zones	Spatial majority in basin.
	Climate State	Spatial majority in basin.
	Temperature (WorldClim)	Annual average in total watershed upstream of basin; Annual minimum and maximum in basin; Long term monthly average in February, March, April, May, June, July, August, September, October and December.
Precipitation (WorldClim)	Annual average in total watershed upstream of basin; Long term monthly average in March, April, May, June, July, August, September, October, and December.	
Potential Evapotranspiration	Annual average in the basin and in total watershed upstream of basin; Long term monthly average in January, February, April, June, July, August, September, October, and December.	
Actual Evapotranspiration	Long term monthly average in January, March, May, June, July, August, September, October, November, and December.	
Hydrology	Groundwater Table Depth	Mean groundwater depth for the basin in Fan et al. 2013 and MacDonald et al. 2012; Minimum groundwater depth for the basin in Fan et al. 2013 and MacDonald et al. 2012; Maximum groundwater depth for the basin in Fan et al. 2013 and MacDonald et al. 2012.
	ESHGComb	Aquifer productivity.
	Natural Discharge	Annual basin average, minimum and maximum.
	Land Surface Runoff	Annual basin average.
	Inundation Extent	Annual basin minimum, maximum and long term maximum; Annual minimum and long-term maximum in total watershed upstream of basin.
	Livnosity	Spatial extent in basin and in total watershed upstream of basin.
	Lake volume	Sum in total watershed upstream of basin.
	Reservoir volume	Sum in total watershed upstream of basin.
	Degree of Fragmentation	Index in basin.
	River Area	Sum in basin and in total watershed upstream of basin.
River Volume	Sum in basin and in total watershed upstream of basin.	
Landcover	Potential Natural Vegetation Classes	Spatial majority in basin.
	Potential Natural Vegetation Extent	Extent by class in basin and in total watershed upstream of basin.
Physiography	Elevation	Average, minimum, and maximum in the basin.
	Slope	Average in the basin and in total watershed upstream of basin.
	Stream Gradient	Average in the basin.
	Global Acidity Index	Average in basin and in total watershed upstream of basin.
	Climate Moisture Index	Long term monthly average, in basin, in January, February, March, April, March, June, July, September, November, December.
Soils & Geology	Depth to regolith	Mean, minimum and maximum in basin.
	ENGLG	Rock type.
	Soil Erosion	Average in basin and in total watershed upstream of basin.
	Soil Water Content	Annual average in basin and in total watershed upstream of basin; Long term monthly average, in basin, in January, February, March, July, August, September, November, and December.
	Karst Area Extent	Spatial extent in basin and in total watershed upstream of basin.
	Lithological Classes	Spatial majority in basin.
	Organic Carbon Content in Soil	Average in basin and in total watershed upstream of basin.
	Sand Fraction in Soil	Average in basin and in total watershed upstream of basin.
	Silt Fraction in Soil	Average in basin and in total watershed upstream of basin.
	Clay Fraction in Soil	Average in basin and in total watershed upstream of basin.

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Selected Variables for Interaction

Category	Attribute	Source Data	Citation	Columns
Climate	Global Aridity Index *	Global Aridity Index	Zomer et al. 2008	ari_ix_
Hydrology	Groundwater Table Depth *	Global Groundwater Map	Fan et al. 2013	_fan
	Groundwater Table Depth	African Groundwater Atlas	MacDonald et al. 2012	_bensor
	Aquifer productivity			ETHHGComb
Landcover	Potential Natural Vegetation Classes *	EarthStat	Ramankutty & Foley 1999	prv_d_
Physiography	Elevation *	EarthEnv-DEM90	Robinson et al. 2014	ele_mt_
	Terrain Slope *	EarthEnv-DEM90	Robinson et al. 2014	slp_dg_
Soils & Geology	Depth to regolith		Pelletier et al. 2016	_regolith
	Rock type	African Groundwater Atlas		ETHGLG
	Soil Erosion *	GIOSEM v1.2	Borrelli et al. 2017	ero_mh_
	Karst Area Extent *	Rock Outcrops v3.0	Williams & Ford 2006	kar_pc_
	Lithological Classes *	GLIM	Hartmann & Moosdorf 2012	lit_d_
	Sand Fraction In Soil *	SoilGrids1km	Hengl et al. 2014	snd_pc_
	Silt Fraction In Soil *	SoilGrids1km	Hengl et al. 2014	silt_pc_
	Clay Fraction In Soil *	SoilGrids1km	Hengl et al. 2014	clay_pc_

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