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Highlights

Surveyed from Afar: Household Water Security, Emotional Well-being, and the Reliability of Water Supply in the Ethiopian Lowlands

Anna Libey, Abinet Kebede, Jemal Ibrahim, Paul Hutchings, Lemessa Mekonta, John Butterworth, Evan Thomas

- Reliable borehole water supply is an appropriate climate adaptation strategy for Afar.
- Household water security experiences and emotional response are correlated.
- WRED was more sensitive than HWISE to gender and livestock ownership.
- Borehole pump runtime of > 6 hours measured by sensors lowered HWISE scores.

Surveyed from Afar: Household Water Security, Emotional Well-being, and the Reliability of Water Supply in the Ethiopian Lowlands

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Abstract

Almost half of the world's population is expected to experience water stress in their daily lives by 2050. The impacts of water scarcity on physical and psychosocial health are especially felt in arid regions of Ethiopia where pastoralist populations are heavily reliant on groundwater for domestic and livestock needs. Water security and improved well-being have substantial effects on household health and wealth, especially for pastoralists. However, functional water supply infrastructure and reliable service delivery remain a challenge. A cross-sectional water security household survey of 469 heads of households in Afar Region, Ethiopia, has three main findings. First, higher levels of household water insecurity experiences (HWISE) and water-related emotional distress (WRED) are positively correlated (0.57, $p < 0.01$) and are significantly associated with limited water service levels, the non-use of boreholes, and more vulnerable household demographics (female-headed

households and lower household incomes). Higher household water security ($p < 0.01$) and water-related emotional well-being ($p < 0.5$) are associated with increased borehole pump usage and reliability, with a cut-off point of 6 hours of pump usage per day measured with electronic sensors. Adding additional water points to the dry lowlands of Afar have led to overcrowding and rangeland degradation in the past, but, when it comes to climate resilience and adaptation, ensuring the reliability of what has already been constructed is a top priority for the regional government. Our findings suggest that increasing the reliability and daily usage of existing water supply systems over the short-sighted expansion of sources is worth the investment in services it will take to reach even the most far-flung communities.

Keywords: pastoralism, climate resilience, water supply, wash

1. Introduction

The number of people worldwide experiencing water stress in their daily lives could double by 2050 to half of the global population (Munia et al., 2020). The impacts of water scarcity are especially felt in arid and semi-arid regions like northeastern Ethiopia, where rural populations rely primarily on groundwater for domestic needs, and livestock are a significant source of household income. In 2017, only 11% of all Ethiopians had access to safely managed drinking water services, and 30% had access to basic services. In rural areas, access to safely managed services decreases to 4.6% (UNICEF, 2017).

11 Afar, one of the 11 regional states in Ethiopia, is the focus of this re-
12 search because the hot arid climate, lack of year-round surface water, and
13 deep aquifers have made the region a focus of interventions by national and
14 international development institutions - including the drilling of motorized
15 boreholes to supply water to communities. The deep mechanized borehole
16 schemes in the region are designed to reduce the dependence of communities
17 on expensive water trucking operations during drought emergencies, which
18 aligns with the federal government's Climate Resilient WASH initiative of
19 the One WASH National Program (Butterworth et al., 2018).

20 Ninety percent of the population in Afar practices pastoralism, where
21 communities raise livestock and herd animals over long distances to access
22 water and grazing (Nassef and Belayhun, 2012). Pastoralists are unique water
23 consumers, and water usage patterns in communities vary widely depending
24 on livestock herd compositions, time of year, recent rainfall, and degree of
25 villagization (Degefu et al., 2020). For decades, there has been misalign-
26 ment between traditional water management methods by Afar pastoralists
27 and the water institutions, namely community-based management of drilled
28 boreholes, established by development interventions (Nassef and Belayhun,
29 2012; Alexander et al., 2015; Behailu et al., 2016).

30 Afar is also a site of protracted ethnic conflict. The conflict has often
31 been viewed as a land dispute along the Afar/Somali Region border (OCHA,
32 2021). However, the causes of the continuation of the century-long violence
33 can more readily be tied to cultural identity than substantive issues (Alemu,

34 2017). This self-perpetuating conflict substantially affects water security, as
35 29,000 people were recently displaced and fighting often forces people to move
36 their settlements to areas with sub-optimal water access (OCHA, 2021).

37 A review on the relationships between water security and well-being
38 found strong connections for physical and psychosocial health and human-
39 environment interactions (Kangmennaang and Elliott, 2021). One approach
40 to measuring the strength of these connections is through choice of emotional
41 words. Water-related emotional distress (WRED) measured with emotional
42 word choice is shown to be a risk to mental health (Cooper et al., 2019). Ex-
43 perienceing water stress, violence, and deprivation create a triple-vulnerability
44 among these already-marginalized populations, lowering their ability to cope
45 with current and future setbacks like the increasing frequency and severity
46 of drought due to climate change (Ebi and Bowen, 2016; Vins et al., 2015).

47 In a review of pastoralism in Ethiopia and the risks posed by climate
48 change, droughts, loss of human and animal life, damage from winds and
49 floods, and reduced economic productivity are frequent challenges, for which
50 adaptation and mitigation strategies are required (Chinasho et al., 2017).
51 Reliable clean water supply that is climate-resilient and appropriate for the
52 pastoralist lifestyle is an appropriate mitigation strategy, but concentration
53 of water sources that encourage sedentarization should be avoided because it
54 will lead to rangeland degradation (Cooper et al., 2019; Nassef and Belayhun,
55 2012).

56 In this study, high water security is classified when water users experience

57 satisfaction around their ability to access water that is reliable, affordable,
58 adequate, and safe, i.e., free from contamination (Jepson et al., 2017). Water
59 security through quality water management and service delivery is associated
60 with improved well-being and good health, but there is little empirical data
61 on whether interventions to provide water supply have ongoing effects on
62 water security, especially in challenging contexts (Miller et al., 2020). A
63 review identified a gap in the validation of tools to measure water-related
64 emotional distress (WRED), which this study will provide (Kangmennaang
65 and Elliott, 2021).

66 With an improved understanding of the drivers of household water inse-
67 curity and water-related emotional well-being or distress, water supply in-
68 stallations for pastoralist populations may be designed around an improved
69 understanding of water users’ needs and wants (Whitley et al., 2019). In-
70 stead of the traditional infrastructure-first approach, we advocate for water
71 security as a dynamic state where water users can “engage with and benefit
72 from the sustained hydro-social processes that support water flows, water
73 quality, and water services in support of human capabilities and well-being”
74 (Jepson et al., 2017).

75 **2. Materials and Methods**

76 *2.1. Study Setting*

77 The study site is Mile Woreda in Afar Region, Ethiopia. Mile Woreda was
78 estimated to contain 117,960 people in 2017, with an average household size

79 of eight (Ethiopia, 2012). Mile Woreda is located 64 km from the regional
80 capital of Semera and 530 km from Addis Ababa. The Woreda is divided
81 into ten rural kebeles (78% of the population) and two small towns (22% of
82 the population). Communities are semi-mobile and male pastoralists follow
83 seasonal nomadic migration routes for water and pasture for their herds, but
84 often congregate at permanent water sources during the dry season, if they
85 exist (Whitley et al., 2019).

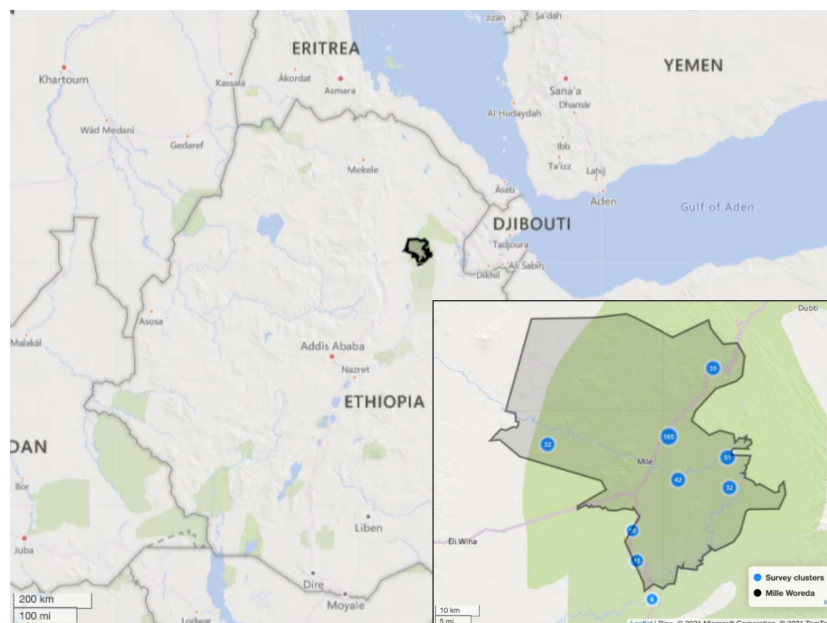


Figure 1: Map of Ethiopia with inset of Mille Woreda boundary and sampling clusters (Ethiopia woreda boundaries are slightly inaccurate in this map from mWater.co).

86 2.2. Survey Objective

87 This research uses a mixed qualitative and quantitative approach toward
88 evaluating water supply interventions designed to improve the effectiveness

89 and long-term sustainability of investments in rural water infrastructure
90 in the resource-constrained context of Mile woreda, Ethiopia. This cross-
91 sectional household survey is designed to characterize the multi-dimensional
92 relationships between measured groundwater borehole functionality and us-
93 age, household water insecurity, and emotional distress in rural pastoralist
94 communities.

95 Where available, a quantitative measurement of community water usage
96 is used to divide households into groups of high and low borehole utilization.
97 Borehole utilization is measured remotely as a continuous variable in hours
98 by electronic sensors installed on motorized boreholes in the region since 2017
99 by the USAID Lowland WASH Activity (Thomas et al., 2021). Five out of
100 ten clusters had a working sensor monitoring near-real-time borehole usage to
101 report breakdowns to the Afar Regional Water Irrigation and Energy Bureau
102 with a true positive rate of 82% and a true negative rate of 48% (Thomas
103 et al., 2021). After correcting for sensor accuracy, we calculate that boreholes
104 are 81% functional on average in Afar Region, and only 50% are turned on
105 and used every day (Butterworth et al., 2021).

106 This study examines differences in the proportion of households experi-
107 encing water insecurity and WRED according to demographic and infras-
108 tructure predictors of water service levels. Development interventions assume
109 water security and well-being improvements are associated with high-quality
110 services that guarantee adequate water quantity and reliability, but this has
111 not been proven empirically. The presence of an improved water source is

112 not useful for a community if it is not functional when needed.

113 There are three main survey hypotheses examined:

- 114 1. We hypothesize a positive correlation between household water insecur-
115 ity experiences and the respondent's WRED;
- 116 2. We hypothesize higher scores for water insecurity and WRED are as-
117 sociated with lower measured water service levels and more vulnera-
118 ble/less resilient household demographics;
- 119 3. We hypothesize that high reported household water security correlates
120 to high sensor-measured use of nearby electrical water pumps (>6 hours
121 per day).

122 *2.3. Sample Size and Randomization*

123 The population of Mile Woreda is an estimated 127,400 considering pop-
124 ulation growth since the last census, with an average of eight persons per
125 household (Ethiopia, 2012). For a conservative 50% baseline proportion of
126 outcome variables and a desired confidence level of 95%, the total sample
127 size needed for this cross-sectional descriptive study is 375 households.

128 In May 2021, the height of the dry season, a total of 409 households and
129 469 individuals were sampled, of which 60 were spouses of the head of the
130 household. Twenty-two percent of respondents sampled were urban, and 78%
131 were rural residents, matching the woreda population composition.

132 The woreda population is divided into clusters located near each suitable
133 motorized borehole to identify households using the water schemes of inter-

134 est. The survey team selected nine rural clusters and one urban cluster for
135 their proximity to one or more working boreholes, ease of access (there was
136 conflict in the Eastern half of the woreda), and community size. Nine of the
137 chosen boreholes are located in rural kebeles, and three are in Mille town.
138 To avoid over-representing the urban population, we divide the population
139 into urban and rural strata for probability proportional one-stage cluster
140 sampling with 84 samples in town and 32 samples per rural borehole for a
141 minimum sampling requirement of 375 households.

142 There was no further randomization possible in the rural clusters. This
143 is typically the case when sampling nomadic communities due to the lack
144 of density and distance of male pastoralists from their settlements during
145 the day (Hutchings et al., 2022). For the urban schemes in Mille town, the
146 team consulted with the water utility to check which sections of the town
147 are served by each borehole selected for inclusion as a sampling block. Every
148 other household was sampled from a transect walked across a gridded area
149 until the sample size for the urban cluster was fulfilled.

150 *2.4. Ethics Review*

151 This study received approval from the University of Colorado Institutional
152 Review Board (Protocol #20-0693; Boulder, Colorado, United States) and
153 the Afar National Regional State Health Bureau (Ref No. 3011/3777; Afar,
154 Ethiopia). All participants were adults over 18 years of age. Oral informed
155 consent was obtained from all participants before each interview.

156 *2.5. Measurement Methods*

157 The household survey questions were broken into sections on material con-
158 ditions and demographics, livestock ownership, water service levels (JMP),
159 household water (in)security experiences (HWISE), and water-related emo-
160 tional distress (WRED). Respondents were asked about the current dry sea-
161 son and the previous rainy season in the rural areas only, with respondents
162 providing their own interpretation of what constitutes the rainy/dry seasons.
163 The complete list of survey questions are available in the Supplementary Ma-
164 terials.

165 *2.5.1. Water Service Level*

166 Water service levels were evaluated according to standardized Joint Mon-
167 itoring Programme (JMP) methodology (WHO/UNICEF Joint Monitoring
168 Programme for Water Supply, Sanitation, and Hygiene, 2018). The length of
169 time to collect, the container volumes, and the frequency of water collection
170 was also recorded for the dry and rainy seasons. Households were asked about
171 water storage, treatment, and coping practices with water shortages. Several
172 water quality measurements of *E. coli* presence/absence using the Aquagenx
173 CBT also informed service level calculations at six rural boreholes, one sur-
174 face water source, and two town tap stands.

175 *2.5.2. Household Water Security*

176 The HWISE section includes questions with a four-week recall on ex-
177periences that respondents have around their daily tasks, household needs,

178 and water usage. The 12 HWISE questions ask how often respondents ex-
179 perience feeling worry, water supply interruptions, inability to wash clothes,
180 interruptions to plans, challenges with food preparation, hand washing, body
181 washing, feeling thirst, feeling anger, sleeping thirsty, being completely out of
182 water, or feeling shame or stigma due to their water situation. All questions,
183 guidance for enumerators, and suggested avenues of probing are available in
184 the HWISE manual (Network, 2019).

185 Household water insecurity experiences (HWISE) scale scores are calcu-
186 lated by summing responses to each question. Four response categories are
187 used: never (0 times) is scored as zero; rarely (1-2 times), is scored as one;
188 sometimes (3-10 times), is scored as two; often and always (more than 10
189 times) are both scored as three. Scores range from 0-36, where higher scores
190 indicate greater water insecurity. A score was not generated for the household
191 if a participant responded with “I don’t know” or “not applicable” to any
192 item. Households with an HWISE scale score of 12 or higher are considered
193 water insecure. The final HWISE water insecurity score and the cut-off point
194 of 12 are cross-compatible worldwide, as verified in a published protocol on
195 the scale development (Young et al., 2019).

196 *2.5.3. Water-related Emotional Distress*

197 Water-related emotional distress (WRED) is a proxy for water insecurity
198 due to the relationships between mental health, stress, and other emotions to
199 water insecurity (Cooper et al., 2019). Rather than observing water use, these

200 questions are designed to capture how people respond to their water situation
201 emotionally in the present day and when they recall the last season (dry or
202 rainy). First, respondents assess their life, water, and security situation
203 satisfaction levels using a Likert scale. Respondents were then asked to pick
204 three emotional words from a list of 12 to describe their feelings about for each
205 of eight questions on aspects of their water situation, including their ability
206 to cope in times of drought, having sufficient quantities of water for domestic
207 needs, and for livestock in the dry and rainy seasons, and the distance traveled
208 to collect water in the dry and rainy seasons. These questions were only asked
209 in the rural clusters because of the lack of livestock ownership or seasonal
210 differences in water supply in the town.

211 Next, respondents were asked whether they have experienced conflict over
212 their water situation in the last six months and the location of that conflict
213 in the home, village, clan, region, or outside of their region.

214 The frequency of responses determines the analytical outcome for WRED
215 measurement as a proportion. Here we compare emotional categories (quad-
216 rants of the circumplex in Figure 2) to capture emotional experiences of a
217 person’s water situation. Twelve emotion words representing strong or weak
218 (active/passive) and positive or negative emotional states, were chosen from
219 the 19 most frequently used emotion words in focus group discussions and
220 interviews in nearby Dulessa Woreda, Afar Region (Cooper et al., 2019). Pre-
221 vious studies have scored the questions individually (Hutchings et al., 2022),
222 but the contribution we present here is an aggregated score for higher-level

223 monitoring of an intervention. In this study, the responses to each question
 224 are scored from one to four based on the emotional circumplex quadrants,
 225 summed, and divided by 24. A final score of four is the maximum emo-
 226 tional distress (100% negative active responses), and one is the minimum
 227 emotional distress (100% positive active responses). The weighted WRED
 228 score = $(4 * \text{negative} - \text{active} + 3 * \text{negative} - \text{passive} + 2 * \text{positive} - \text{passive} +$
 229 $\text{positive} - \text{active}) / 24$.

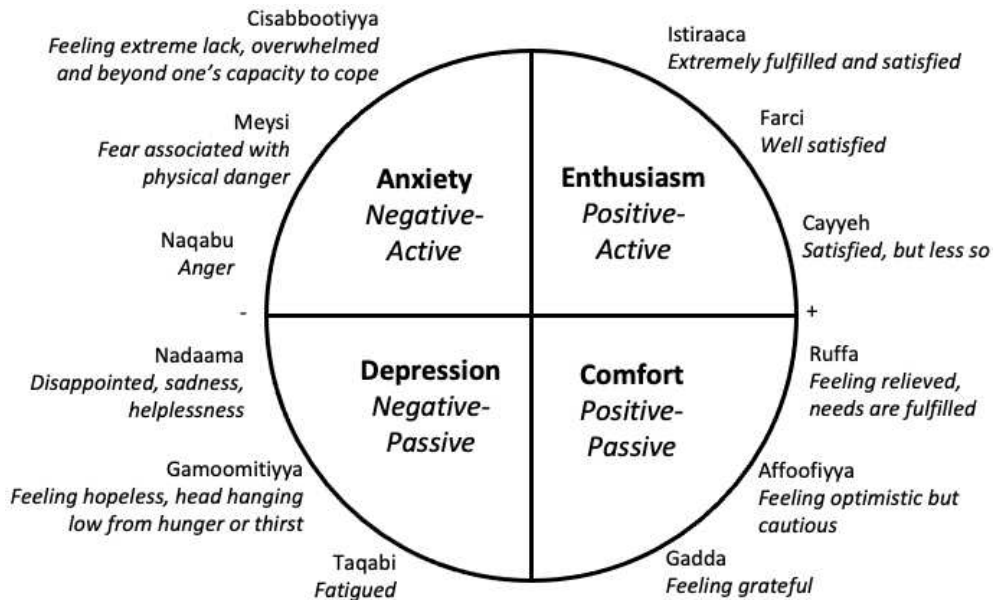


Figure 2: Emotional quadrants in the Afarigna language are divided by enthusiasm, comfort, depression, and anxiety. Originally published by Cooper et al., (2019). Alternate spellings and expanded definitions are available in the supplementary materials Table A.6.

230 Where spouses were available and consented to be surveyed, they were
 231 also asked the HWISE and WRED questions to gather more responses from
 232 women. Additionally, several informal interviews with the Mille town water

233 utility and village water committees were conducted to gather preliminary
234 data to inform sampling design and question suitability.

235 *2.6. Analysis Methods*

236 **Outcome variables correlation testing:** Testing the correlation be-
237 tween the HWISE and the WRED scores demonstrates whether these accu-
238 rately represent the pastoralist water context in Afar and are valid measures
239 of household-level water insecurity cross-comparable globally. Correlation
240 sample estimates >0.5 and a p-value of <0.01 are considered “moderately
241 correlated” with high statistical significance. Pearson’s correlation coeffi-
242 cient was chosen as the best method for calculating the correlation for this
243 sample size.

244 **Regression modeling:** Linear regression is used to describe the ex-
245 tent, direction, and strength of the relationship of the predictor variables
246 to HWISE and WRED scores. Predictor variables include household demo-
247 graphics and water service levels. A variety of regression models were tested,
248 including linear, logistic, and mixed linear and logistic models with different
249 combinations of fixed and random effects using the lme4 R package (Bates
250 et al., 2021). Data were pre-processed to scale/code variables for model con-
251 vergence. All numerical predictors are center mean-scaled, and categorical
252 variables are either treatment coded when 2-level (gender, urban or rural)
253 or deviation coded when multiple levels (JMP category, life satisfaction, or
254 experience of conflict). Model goodness-of-fit testing and dropping of su-

255 perfluous variables using likelihood ratio testing was used to pick the best
256 models for HWISE and WRED outcome variables.

257 **Runtime cutoffs for water security:** Because of the availability of
258 sensor data for five out of the ten clusters, measured pump runtime is com-
259 pared to the HWISE and WRED scores of the households located in each of
260 the sensor-equipped borehole clusters whether they reported using borehole
261 water or not. One-sided hypothesis testing was used to test for a differ-
262 ence in HWISE and WRED scores for households associated with low versus
263 high-runtime boreholes with a cutoff point of >6 hours of pumping per day
264 on average over the previous 30 days. This cutoff point was pre-selected to
265 match the definition of high groundwater use from Fankhauser et al. (2022)
266 using the same model of sensors reporting borehole usage in Northern Kenya
267 (Fankhauser et al., 2022).

268 **3. Results**

269 The results are presented in four sections. First, we present a description
270 of the demographics and water access situation in the study woreda, with
271 rural/urban and gendered differences where available. The second section
272 compares the HWISE and WRED scores and their correlation. The third
273 section explores the relationships between the HWISE and WRED scores
274 and their social and technological predictors. The fourth section pulls in
275 measured borehole runtime to compare HWISE and WRED scores to water
276 usage.

277 *3.1. Participant Demographics and Service Levels*

278 Table 1 presents the results for respondent demographics and JMP water
279 service levels as mean values with standard deviations in parentheses or as
280 percentages for categorical variables. The units are per household for all but
281 the last two rows, which incorporate responses from male and female adults.

282 A seasonal component was also assessed for the reliability of the primary
283 drinking water source, seen in Figure 3. Participants rated the water point
284 on reliability and predictability for the dry (current) season, and recalling the
285 last rainy season. Sources used in the dry season were most likely to be rated
286 as reliable year round. When recalling the rainy season, there was a tie be-
287 tween reliable year-round sources and unreliable/unpredictable sources. Few
288 rated their source as unreliable but predictable, suggesting an all-or-nothing
289 split between functional and non-functional services in the rural clusters.

290 *3.2. Water Security and Emotional Distress*

291 The HWISE scores range from 0 to 36, where a score ≥ 12 is considered
292 water insecure. The mean HWISE score in this survey was 13.7, meaning
293 the average household experienced water insecurity over the previous month.
294 The means are significantly different when grouped by urban/rural ($p < 0.01$).
295 The rural mean HWISE score was 11.9, and the town mean HWISE score was
296 20.0. There are 284 total responses ≥ 12 ; therefore, 61% of all individuals
297 experienced water insecurity.

298 The aggregated and weighted WRED scores range from 1 to 4. A WRED

Table 1: Demographics, water service levels, and life satisfaction. Numerical values are mean and standard deviation. Time to collect water was not collected for the town responses, making us unable to differentiate between limited and basic or safely managed JMP water service levels.

Household	Rural N=313	Town N=96
Respondent age	35 (12)	37 (10)
Household size	7 (10)	5 (3)
Household primary income	68.9% Sales of animals & animal products 22.6% Employment wages 3.9% Daily labor 3.9% Sales of firewood & charcoal 0.9% Other	65.1% Employment wages 17.9% Daily labor 4.7% Rent income 3.8% Sales of animals & animal products 8.5% Other
Est. household spending (ETB/month)	3148 (1718)	4706 (3464)
Camels	2 (5)	0 (0)
Cattle	2 (5)	0 (1)
Goats	19 (17)	2 (3)
Sheep	4 (6)	0 (2)
Water consumption, liters/capita/day	37 (259)	75 (249)
JMP water service levels	0% unimproved 37.5% limited 43.5% basic 18.7% safely managed	1.1% unimproved 18.2% basic or limited 80.7% safely managed or limited
Individual	Rural N=363	Town N=106
Life satisfaction	77% neutral or satisfied (female) 81% neutral or satisfied (male)	71% neutral or satisfied (female) 76% neutral or satisfied (male)
Personal experience of conflict or lack of security over water in the last six months	12% in the household 21% in the village 9.0% another village 6.0% another clan 17% another tribe	33% in the household 22% in the town 15% another village 14% another clan 16% another tribe

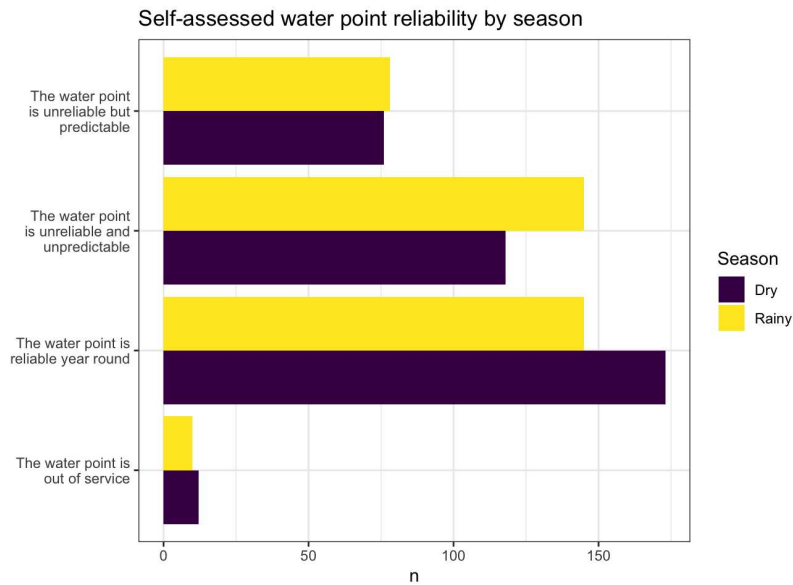


Figure 3: Categorical assessment of primary water source reliability by season among rural respondents

299 score ≥ 1.84 is in the 50th percentile for emotional distress, corresponding
 300 to 150 households or 32% of respondents.

301 Both score distributions are strongly right-skewed, with many scores of
 302 one or zero. Despite the different scale ranges and weights, the HWISE and
 303 WRED scores are not independent and are moderately correlated with high
 304 statistical significance ($p < 0.01$).

305 We did not find a difference between genders for the HWISE or WRED
 306 scores ($p > 0.5$).

307 3.3. Linear Regression

308 The logistic regressions with no random effects are not appropriate as the
 309 WRED one did not converge, and the HWISE one has only significant effects

Table 2: HWISE and WRED scale score means, standard deviations, and correlations with confidence intervals. Values in square brackets indicate the 95% confidence interval. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (Cumming, 2014). ** indicates $p < 0.01$.

Variable	Range, cut-off point	Mean	Median	Standard Deviation	Correlation
HWISE (urban)	0-36, >12	20.0	18	9.14	
HWISE (rural)	0-36, >12	11.9	12	10.39	0.57**
WRED (rural)	1-4, >1.84	1.84	1.42	0.71	[0.49, 0.64]

310 from the cluster variable - which does not provide helpful information. The
 311 best-fitting models were the linear mixed-effects models with cluster ran-
 312 dom intercept effects where the outcome variables are treated as continuous
 313 variables.

314 In the HWISE model in Table 3, the JMP water service level, specifically
 315 whether the service was classified as limited or safely managed, and the
 316 household income source, specifically whether households said their primary
 317 source of income was sales of firewood and charcoal, had significant effects.

318 JMP water service levels or safely managed but also unimproved were
 319 associated with lower water insecurity. Household income from employment
 320 wages, pensions, rent, the government safety net, and sales of animals were
 321 associated with lower water insecurity, while income from relatives (remit-
 322 tances), crops, handicrafts, firewood, and charcoal were all associated with
 323 higher water insecurity.

324 A limited JMP level, where time to collect took longer than 30 minutes
 325 was the strongest predictor of HWISE scores, which makes sense given the

Table 3: HWISE Linear Mixed Effects Model

Term	Beta	95% CI	t	df	p
Intercept	11.09	[5.86, 16.31]	4.16	21.92	<0.001
JMP level limited	7.43	[5.57, 9.29]	7.81	430.61	<0.001
JMP level safely managed	-3.51	[-6.07, -0.95]	-2.69	431.27	0.007
JMP level unimproved	-6.53	[-21.87, 8.80]	-0.84	428.22	0.404
Primary source of household income:					
Employment wages	-0.54	[-3.65, 2.56]	-0.34	427.85	0.733
Financial support from government	-1.77	[-17.52, 13.98]	-0.22	429.05	0.826
Financial support from relatives	0.68	[-10.43, 11.79]	0.12	427.65	0.905
Other	7.17	[-8.56, 22.90]	0.89	429.59	0.372
Pension allowance	-1.82	[-12.93, 9.29]	-0.32	427.65	0.748
Rent	-2.07	[-11.29, 7.15]	-0.44	427.6	0.66
Sales of animals & animal products	-0.41	[-3.82, 3.01]	-0.23	434.48	0.815
Sales of crops	6.78	[-4.27, 17.83]	1.2	427.23	0.23
Sales of firewood & charcoal	5.93	[0.79, 11.07]	2.26	429.15	0.024
Sales of handicraft	3.44	[-11.95, 18.82]	0.44	427.29	0.662

326 frequency scoring method. Despite the researchers' assumptions that fire-
 327 wood sellers would have lower HWISE scores because of access to equines
 328 and carts to transport water as well as firewood, only one owned an equine.
 329 This relationship can be better explained by the location of the firewood
 330 sellers where business can be found, along main roads at the most crowded
 331 waterpoints, earning most of them a limited JMP service level.

Table 4: WRED Linear Mixed Effects Model (rural only)

Term	Beta	95% CI	t	df	p
Intercept	31.64	[21.37, 41.92]	6.04	104.06	<.001
JMP level limited	7.75	[3.94, 11.57]	3.98	340.56	<.001
JMP level safely managed	-12.79	[-19.09, -6.49]	-3.98	271.35	<.001
Gender: Female	-5.59	[-9.07, -2.12]	-3.15	340.42	0.002
Household spending	0	[0.00, 0.00]	-1.65	341.19	0.099
Conflict Yes	3.45	[-0.50, 7.40]	1.71	342.15	0.088
Primary source of house- hold income:					
Employment wages	3.79	[-5.14, 12.71]	0.83	337.35	0.406
Financial support from government	-3.91	[-36.02, 28.20]	-0.24	339.09	0.812
Other	11.35	[-20.82, 43.51]	0.69	340.54	0.49
Sales of animals & animal products	9.09	[0.12, 18.06]	1.99	342.74	0.048
Sales of crops	4.16	[-27.24, 35.56]	0.26	335.35	0.795
Sales of firewood & char- coal	8.23	[-3.67, 20.13]	1.35	338.29	0.176

332 In the WRED model in Table 4, which only covered the rural kebele
 333 clusters, a limited or safely managed JMP service level, the respondent's
 334 gender, and a primary source of household income from sales of animals
 335 and animal products were the most significant predictors. The technical

336 predictors have effects as expected, where a JMP level of “limited” led to
337 higher emotional distress than baseline (basic), while safely managed services
338 significantly lowered emotional distress.

339 The WRED score picked up on social predictors of water insecurity better
340 than HWISE, such as how a female-headed household was a strong predictor
341 of higher emotional distress. Employment wages, sales of animals, crops,
342 firewood, and charcoal increased emotional distress, while household income
343 from the government safety net lowered WRED scores. Experiencing water-
344 related conflict in the last six months, whether in the household, village, clan
345 or with another clan or tribe/region, increased WRED scores.

346 *3.4. Borehole Runtime Cutoffs for Water Security*

347 Only one cluster has an average of greater than 6 hours a day of pump
348 runtime: rural cluster 5. There is a difference in HWISE ($p < 0.01$) and
349 WRED ($p < 0.5$) scores between households in this cluster and the four low-
350 runtime rural borehole clusters using a one-sided t-test. The difference is
351 significant for HWISE, where the high-runtime group had a mean of 8.7, or
352 not water-insecure, while the low-runtime group had a mean of 12.3, making
353 that group water-insecure on average. The difference between high and low-
354 runtime groups’ WRED scores was insignificant, although WRED decreased
355 on average from the low to the high runtime groups. The average daily
356 borehole usage over the past month prior to survey data collection for each
357 cluster with a working sensor is presented below in Table 5.

Table 5: Borehole runtime in clusters with sensors and water security scores (highlighted HWISE and WRED scores are considered water insecure/distressed)

Cluster	Sample Size	Mean Runtime (hours)	HWISE	WRED
Rural 1	36	0.00	21.6	2.41
Rural 2	45	0.785	11.0	1.48
Rural 3	40	1.26	13.8	1.84
Rural 4	29	3.40	1.03	1.40
Urban 1	29	4.52	21.7	-
Rural 5	43	7.43	8.77	1.73

358 Rural cluster 1 had a non-functional generator and the system was not
359 providing water, as reflected in the lack of runtime over the prior month. As
360 the site is close to the conflict between the Afar and the Issa and there was no
361 functional WASHCO, minimal attention was given to repairing the system,
362 and it is still non-functional. Accordingly, HWISE and WRED scores were
363 the highest of the rural clusters as respondents indicated that their daily
364 water experiences were highly impacted by the broken water system and the
365 security situation. As a response, many households had to make difficult
366 decisions to relocate for better water and pasture while avoiding areas with
367 conflict.

368 Rural cluster 2 had an infrequently used but functional water system with
369 an average runtime of 47 minutes a day. Several challenges to reliable oper-
370 ation and service provision were identified by a WASHCO member. Many
371 households access the water via backyard connections, but the leakage rate
372 is very high, and many pipes are corroded due to high salinity. Respondents
373 complained about the taste and worried about the health effects of the poor

374 water quality. A shortage of funds to buy diesel for the generator, and a bro-
375 ken fiberglass storage tank were other reasons for the low utilization. The
376 HWISE and WRED scores for this cluster were close to but underneath the
377 cut-off points.

378 Rural cluster 3's borehole was used only 75 minutes per day over the
379 prior month, but the sensor was offline the day the community was sampled,
380 making the runtime data less reliable. HWISE and WRED scores were both
381 over the thresholds for water insecurity/emotional distress.

382 Rural cluster 4, located close to Mille River, has a motorized borehole
383 with drinking water taps and a livestock drinking trough. Most users have
384 an on-plot tapstand, although there are many broken taps and water points.
385 The solar-powered pump is often left running until the reservoir overflows
386 and few users contribute to maintenance or pay for water.

387 Urban cluster 1 serves the upper part of Mille town. Most residents have
388 unpredictable and unreliable water supply, with many households purchasing
389 water from merchants. None of the 10 public tap stands were working and
390 the utility manager reported many household connections are non-functional,
391 do not reach all areas, or have insufficient pressure to deliver water.

392 Rural cluster 5 is worth expanding on. This water system is solar-powered
393 and leads to a large concrete reservoir, livestock drinking trough, and three
394 fenced tap stand installations open 24 hours/day. Due to heavy rainfall three
395 weeks prior to the survey, many households switched to consuming surface
396 water instead of borehole water. Cloudy days also can affect the performance

397 of the solar pump, but the system was in good condition and had no problems
398 with functionality over the prior month. No e. Coli was detected on the day
399 of sampling and users are happy with the borehole water quality. The reasons
400 cited for using surface water were the convenience and accessibility as many
401 households are located far from the water points. The water tariff is 20 Birr
402 per month but not all users pay. The community has a functional water and
403 sanitation committee (WASHCO) which has successfully arranged for minor
404 repairs to the distribution line, but a major repair of the solar panels after
405 wind damage required intervention from an NGO.

406 **4. Discussion**

407 Conducting a household survey during the global COVID-19 pandemic
408 led to some extra challenges, namely the delays in survey implementation two
409 years after preparatory fieldwork and the lack of sufficient question and trans-
410 lation testing. Some questions were dropped once it became clear that the
411 enumerators could not gather quality data that addressed the intended ob-
412 jective. The lead researcher also could not be physically present in Ethiopia
413 and managed the survey team remotely.

414 The data collection was done in the dry season when daily temperatures
415 ranged from 37-42 degrees C. But in the prior to three to four weeks there
416 was rain in most of the sampled kebeles and in the neighboring highlands,
417 making surface water more accessible. Due to the nature of a one-time cross-
418 sectional survey, assessing any seasonal effects or the established effects of

419 rainfall on borehole usage due to source-switching in this context was difficult
420 (Thomas et al., 2019). Asking respondents about 6+ month recall periods
421 about the last rainy period also introduced some unreliability.

422 The questions on household material wealth were not fully suitable to
423 this context. As the sampling was done during the month of Ramadan, some
424 households reported higher than typical spending due to the holiday. This is
425 also an area with low levels of banking and many transactions are done by
426 bartering or by the male head of household only, and so the monthly house-
427 hold spending we report is less reliable, especially from female respondents.
428 Counting livestock is the typical method to measure pastoralist household
429 wealth, but we asked about spending levels to measure wealth for the 30%
430 and 95% of rural and town households, respectively, that did not earn the
431 majority of their household income from livestock.

432 The way well-being is measured in this study is heavily affected by conflict
433 and a similar population with identical water use patterns might not have
434 the same WRED scores. Conflict was ongoing during sampling to the East
435 towards the Somali border in Adaytu kebele. However, rather than being a
436 drawback of the methodology, we believe the sensitivity to emotional distress
437 caused by conflict is relevant to water in this context.

438 Part of the motivation for this study was to test the HWISE and WRED
439 methods against each other. We expected to see poor performance of the
440 standard 12-question HWISE scale in the context of pastoralist water usage
441 due to source switching and the nomadic context, however the high correla-

442 tion between the scores establishes the validity of the HWISE method in this
443 context and also establishes the WRED scoring method developed for this
444 study as a reliable measurement of water security.

445 **5. Conclusion**

446 Pastoralists in the Afar region of Northern Ethiopia have been poorly
447 served by improved water supplies that operate infrequently and breakdown
448 1-2 times per year, a problem caused by a general lack of maintenance and
449 management in the water sector (Libey et al., 2022). Traditional monitor-
450 ing methods in the water sector frequently label a population covered when
451 there is access to infrastructure, but fail to account for possible long-term
452 effects unique to fragile rangeland ecosystems. Interventions in Afar must
453 consider overcrowding, the preference for surface water when available, and
454 the increasing severity of drought due to climate change. We designed this
455 study to test whether the installation of motorized boreholes for this nomadic
456 population are meeting pastoralists needs and contributing to water security
457 and emotional well-being.

458 A methodological contribution is the validation of the HWISE household
459 water security scale against the Afarigna-specific WRED score. We intro-
460 duce a cut-off point and scoring method for the WRED method to compare
461 to other numerical indicators. The two outcome variables are moderately
462 correlated with high significance (0.57, $p < 0.01$), meaning that emotional
463 distress from a household's water situation is related to the frequency of ac-

464 tivity interruptions from water deprivation experienced - making both scales
465 good choices to survey population water security and well-being efficiently.

466 Although the outcome variables are correlated, the different predictors in
467 the mixed effects models highlight a sensitivity to social factors in the WRED
468 method that HWISE did not pick up. Both scores were likely to increase
469 if a household was classified as limited JMP service level and decreased if
470 the service level was safely managed. Urban water customers, while having
471 access to higher quality services on paper due to the presence of piped water,
472 actually have higher household water insecurity than those in the rural areas
473 of Mille woreda. Town residents earn their income from employment and
474 villagization, making them more reliant on a single source of water, while
475 pastoralists in Afar respond to changing seasons, grazing conditions, and
476 outbreaks of conflict by moving their herds and settlements.

477 Counter intuitively, income from livestock was most likely to improve a
478 household's HWISE score but income from livestock lowered WRED scores.
479 Traditional water and grazing land management techniques are highly sensi-
480 tive to rainfall and water availability (Nassef and Belayhun, 2012). Although
481 higher household wealth in livestock can mean higher water security experi-
482 ences, the negative relationship to emotional distress means that owners of
483 larger herds worry about drought and its effect on their livelihoods more than
484 those who have alternate sources of income. Additionally, gender was not a
485 significant predictor of HWISE scores, although the labor of water collection
486 in Afar is highly gendered and other studies have found significant burdens

487 on women (Hutchings et al., 2022).

488 Although cross-sectional studies of rural water uses and security are nu-
489 merous, none have integrated borehole pump usage over time to definitively
490 declare what level of water source reliability is necessary before improvements
491 are seen in household water security and water-related emotional well-being.
492 More than six hours of motorized borehole usage per day for a community
493 of around 400 people is associated with greater household water security
494 ($p < 0.01$) and emotional well-being ($p < 0.5$) in this study setting.

495 Adding additional water points to the dry lowlands of Afar have led to
496 overcrowding and rangeland degradation in the past. However, we see that
497 there are substantial improvements in water security and emotional well-
498 being among households with access to safely managed and functioning water
499 supplies. Water security and improved well-being have substantial effects on
500 household health and wealth, especially for pastoralists. Our findings suggest
501 that increasing the reliability and daily usage of existing piped systems over
502 the short-sighted expansion of sources is worth the investment in services it
503 will take to reach even the most far-flung communities.

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516 Appendix A. Appendix

Table A.6: Afar emotion words and previous spellings

Spelling Used	Previous Spelling	Emotion Translation
Istiraaca	Estrahina	Extremely fulfilled and satisfied
Farci	Ferhi	Well satisfied
Cayyeh	Haye	Satisfied, but less so
Ruffa	Rufa	Feeling relieved, needs are fulfilled
Affoofiyya	Alfe	Feeling optimistic but cautious
Gadda	Gada	Feeling grateful
Cisabbootiyya	Hisabona	Feeling extreme lack, overwhelmed, and beyond one's ability to cope
Meysi	Meysi	Fear associated with physical danger
Naqabu	Naqubu	Anger
Taqabi	Tabaqi	Disappointed, sadness, helplessness
Gamoomitiyya	Gemoma	Feeling hopeless, head hanging low from hunger or thirst
Nadaama	Nedama	Fatigued

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