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Highlights

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

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- 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).

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

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

Afar is also a site of protracted ethnic conflict. The conflict has often been viewed as a land dispute along the Afar/Somali Region border (OCHA, 2021). However, the causes of the continuation of the century-long violence can more readily be tied to cultural identity than substantive issues (Alemu, 2017). This self-perpetuating conflict substantially affects water security, as 29,000 people were recently displaced and fighting often forces people to move their settlements to areas with sub-optimal water access (OCHA, 2021).

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

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

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

With an improved understanding of the drivers of household water insecurity and water-related emotional well-being or distress, water supply installations for pastoralist populations may be designed around an improved understanding of water users' needs and wants (Whitley et al., 2019). Instead of the traditional infrastructure-first approach, we advocate for water security as a dynamic state where water users can "engage with and benefit from the sustained hydro-social processes that support water flows, water quality, and water services in support of human capabilities and well-being" (Jepson et al., 2017).

2. Materials and Methods

2.1. Study Setting

The study site is Mile Woreda in Afar Region, Ethiopia. Mile Woreda was estimated to contain 117,960 people in 2017, with an average household size of eight (Ethiopia, 2012). Mile Woreda is located 64 km from the regional capital of Semera and 530 km from Addis Ababa. The Woreda is divided into ten rural kebeles (78% of the population) and two small towns (22% of the population). Communities are semi-mobile and male pastoralists follow seasonal nomadic migration routes for water and pasture for their herds, but often congregate at permanent water sources during the dry season, if they exist (Whitley et al., 2019).

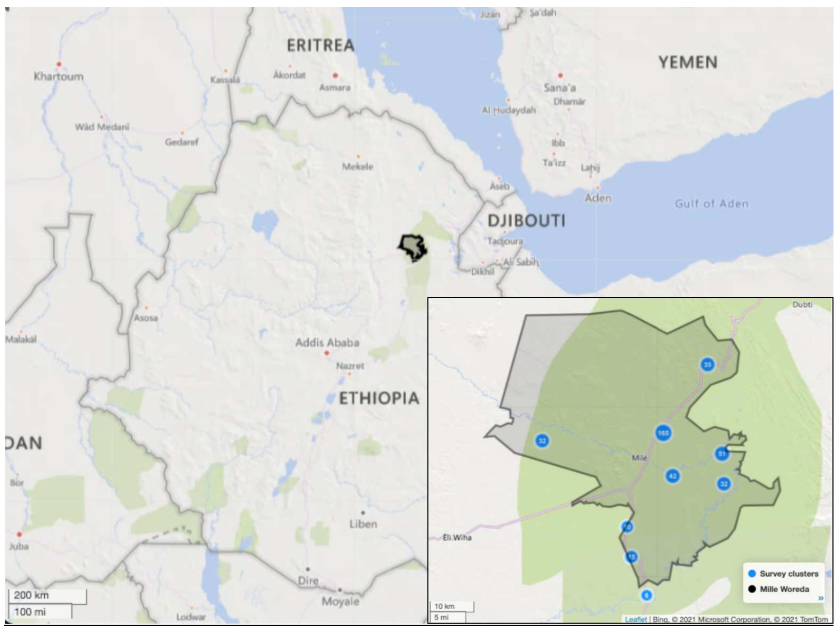

Figure 1: Map of Ethiopia with inset of Mille Woreda boundary and sampling clusters (Ethiopia woreda boundaries are slightly inaccurate in this map from mWater.co).

2.2. Survey Objective

This research uses a mixed qualitative and quantitative approach toward evaluating water supply interventions designed to improve the effectiveness and long-term sustainability of investments in rural water infrastructure in the resource-constrained context of Mile woreda, Ethiopia. This cross-sectional household survey is designed to characterize the multi-dimensional relationships between measured groundwater borehole functionality and usage, household water insecurity, and emotional distress in rural pastoralist communities.

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

This study examines differences in the proportion of households experiencing water insecurity and WRED according to demographic and infrastructure predictors of water service levels. Development interventions assume water security and well-being improvements are associated with high-quality services that guarantee adequate water quantity and reliability, but this has not been proven empirically. The presence of an improved water source is not useful for a community if it is not functional when needed.

There are three main survey hypotheses examined:

1. We hypothesize a positive correlation between household water insecurity experiences and the respondent's WRED;
2. We hypothesize higher scores for water insecurity and WRED are associated with lower measured water service levels and more vulnerable/less resilient household demographics;
3. We hypothesize that high reported household water security correlates to high sensor-measured use of nearby electrical water pumps (>6 hours per day).

2.3. Sample Size and Randomization

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

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

The woreda population is divided into clusters located near each suitable motorized borehole to identify households using the water schemes of interest. The survey team selected nine rural clusters and one urban cluster for their proximity to one or more working boreholes, ease of access (there was conflict in the Eastern half of the woreda), and community size. Nine of the chosen boreholes are located in rural kebeles, and three are in Mille town. To avoid over-representing the urban population, we divide the population into urban and rural strata for probability proportional one-stage cluster sampling with 84 samples in town and 32 samples per rural borehole for a minimum sampling requirement of 375 households.

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

2.4. Ethics Review

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

2.5. *Measurement Methods*

The household survey questions were broken into sections on material conditions and demographics, livestock ownership, water service levels (JMP), household water (in)security experiences (HWISE), and water-related emotional distress (WRED). Respondents were asked about the current dry season and the previous rainy season in the rural areas only, with respondents providing their own interpretation of what constitutes the rainy/dry seasons. The complete list of survey questions are available in the Supplementary Materials.

2.5.1. *Water Service Level*

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

2.5.2. *Household Water Security*

The HWISE section includes questions with a four-week recall on experiences that respondents have around their daily tasks, household needs, and water usage. The 12 HWISE questions ask how often respondents experience feeling worry, water supply interruptions, inability to wash clothes, interruptions to plans, challenges with food preparation, hand washing, body washing, feeling thirst, feeling anger, sleeping thirsty, being completely out of water, or feeling shame or stigma due to their water situation. All questions, guidance for enumerators, and suggested avenues of probing are available in the HWISE manual (Network, 2019).

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

2.5.3. Water-related Emotional Distress

Water-related emotional distress (WRED) is a proxy for water insecurity due to the relationships between mental health, stress, and other emotions to water insecurity (Cooper et al., 2019). Rather than observing water use, these questions are designed to capture how people respond to their water situation emotionally in the present day and when they recall the last season (dry or rainy). First, respondents assess their life, water, and security situation satisfaction levels using a Likert scale. Respondents were then asked to pick three emotional words from a list of 12 to describe their feelings about for each of eight questions on aspects of their water situation, including their ability to cope in times of drought, having sufficient quantities of water for domestic needs, and for livestock in the dry and rainy seasons, and the distance traveled to collect water in the dry and rainy seasons. These questions were only asked in the rural clusters because of the lack of livestock ownership or seasonal differences in water supply in the town.

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

The frequency of responses determines the analytical outcome for WRED measurement as a proportion. Here we compare emotional categories (quadrants of the circumplex in Figure 2) to capture emotional experiences of a person's water situation. Twelve emotion words representing strong or weak (active/passive) and positive or negative emotional states, were chosen from the 19 most frequently used emotion words in focus group discussions and interviews in nearby Dulessa Woreda, Afar Region (Cooper et al., 2019). Previous studies have scored the questions individually (Hutchings et al., 2022), but the contribution we present here is an aggregated score for higher-level monitoring of an intervention. In this study, the responses to each question are scored from one to four based on the emotional circumplex quadrants, summed, and divided by 24. A final score of four is the maximum emotional distress (100% negative active responses), and one is the minimum emotional distress (100% positive active responses). The weighted WRED score = $(4*negative-active+3*negative-passive+2*positive-passive+positive-active)/24$.

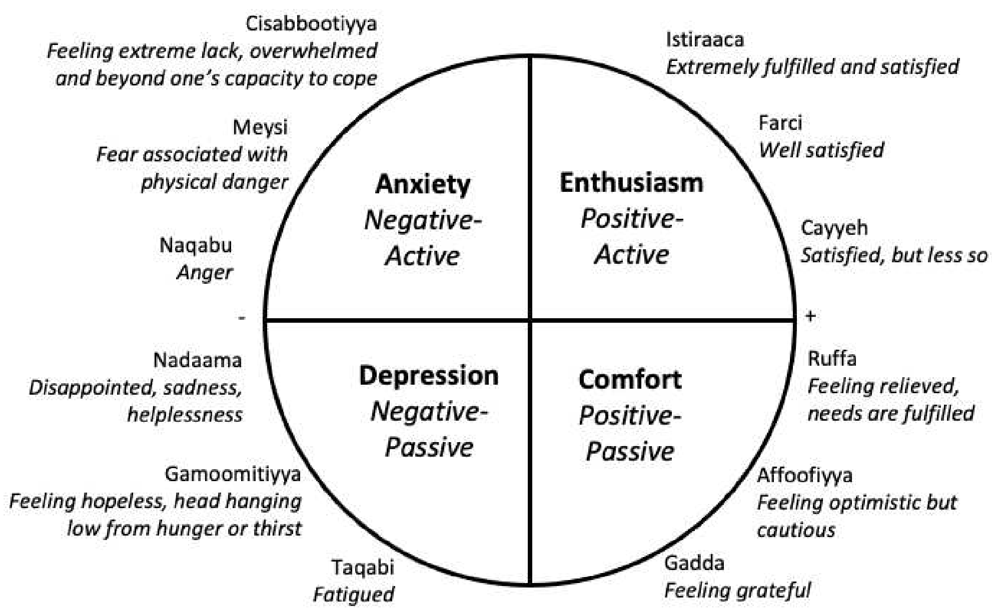

Figure 2: Emotional quadrants in the Afarigna language are divided by enthusiasm, comfort, depression, and anxiety. Originally published by Cooper et al., (2019). Alternate spellings and expanded definitions are available in the supplementary materials Table A.6.

Where spouses were available and consented to be surveyed, they were also asked the HWISE and WRED questions to gather more responses from women. Additionally, several informal interviews with the Mille town water utility and village water committees were conducted to gather preliminary data to inform sampling design and question suitability.

2.6. Analysis Methods

Outcome variables correlation testing: Testing the correlation between the HWISE and the WRED scores demonstrates whether these accurately represent the pastoralist water context in Afar and are valid measures of household-level water insecurity cross-comparable globally. Correlation sample estimates >0.5 and a p-value of <0.01 are considered "moderately correlated" with high statistical significance. Pearson's correlation coefficient was chosen as the best method for calculating the correlation for this sample size.

Regression modeling: Linear regression is used to describe the extent, direction, and strength of the relationship of the predictor variables to HWISE and WRED scores. Predictor variables include household demographics and water service levels. A variety of regression models were tested, including linear, logistic, and mixed linear and logistic models with different combinations of fixed and random effects using the lme4 R package (Bates et al., 2021). Data were pre-processed to scale/code variables for model convergence. All numerical predictors are center mean-scaled, and categorical variables are either treatment coded when 2-level (gender, urban or rural) or deviation coded when multiple levels (JMP category, life satisfaction, or experience of conflict). Model goodness-of-fit testing and dropping of superfluous variables using likelihood ratio testing was used to pick the best models for HWISE and WRED outcome variables.

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

3. Results

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

3.1. Participant Demographics and Service Levels

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

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

3.2. Water Security and Emotional Distress

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

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

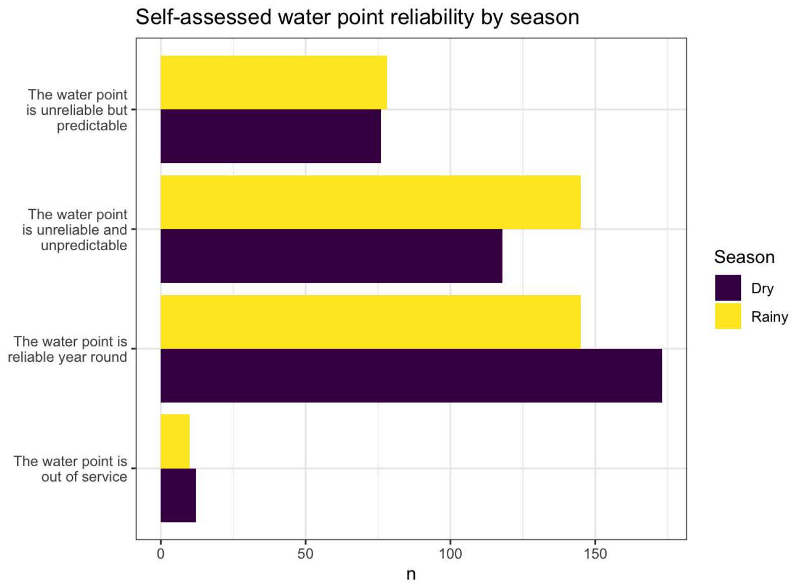

Figure 3: Categorical assessment of primary water source reliability by season among rural respondents

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

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

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

3.3. Linear Regression

The logistic regressions with no random effects are not appropriate as the 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]

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

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

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

A limited JMP level, where time to collect took longer than 30 minutes 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

frequency scoring method. Despite the researchers' assumptions that firewood sellers would have lower HWISE scores because of access to equines and carts to transport water as well as firewood, only one owned an equine. This relationship can be better explained by the location of the firewood sellers where business can be found, along main roads at the most crowded 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 household 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 & charcoal	8.23	[-3.67, 20.13]	1.35	338.29	0.176

In the WRED model in Table 4, which only covered the rural kebele clusters, a limited or safely managed JMP service level, the respondent's gender, and a primary source of household income from sales of animals and animal products were the most significant predictors. The technical predictors have effects as expected, where a JMP level of "limited" led to higher emotional distress than baseline (basic), while safely managed services significantly lowered emotional distress.

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

3.4. Borehole Runtime Cutoffs for Water Security

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

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

Rural cluster 2 had an infrequently used but functional water system with an average runtime of 47 minutes a day. Several challenges to reliable operation and service provision were identified by a WASHCO member. Many households access the water via backyard connections, but the leakage rate is very high, and many pipes are corroded due to high salinity. Respondents complained about the taste and worried about the health effects of the poor water quality. A shortage of funds to buy diesel for the generator, and a broken fiberglass storage tank were other reasons for the low utilization. The HWISE and WRED scores for this cluster were close to but underneath the cut-off points.

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

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

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

Rural cluster 5 is worth expanding on. This water system is solar-powered and leads to a large concrete reservoir, livestock drinking trough, and three fenced tap stand installations open 24 hours/day. Due to heavy rainfall three weeks prior to the survey, many households switched to consuming surface water instead of borehole water. Cloudy days also can affect the performance of the solar pump, but the system was in good condition and had no problems with functionality over the prior month. No e. Coli was detected on the day of sampling and users are happy with the borehole water quality. The reasons cited for using surface water were the convenience and accessibility as many households are located far from the water points. The water tariff is 20 Birr per month but not all users pay. The community has a functional water and sanitation committee (WASHCO) which has successfully arranged for minor repairs to the distribution line, but a major repair of the solar panels after wind damage required intervention from an NGO.

4. Discussion

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

The data collection was done in the dry season when daily temperatures ranged from 37-42 degrees C. But in the prior to three to four weeks there was rain in most of the sampled kebeles and in the neighboring highlands, making surface water more accessible. Due to the nature of a one-time cross-sectional survey, assessing any seasonal effects or the established effects of rainfall on borehole usage due to source-switching in this context was difficult (Thomas et al., 2019). Asking respondents about 6+ month recall periods about the last rainy period also introduced some unreliability.

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

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

Part of the motivation for this study was to test the HWISE and WRED methods against each other. We expected to see poor performance of the standard 12-question HWISE scale in the context of pastoralist water usage due to source switching and the nomadic context, however the high correlation between the scores establishes the validity of the HWISE method in this context and also establishes the WRED scoring method developed for this study as a reliable measurement of water security.

5. Conclusion

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

A methodological contribution is the validation of the HWISE household water security scale against the Afarigna-specific WRED score. We introduce a cut-off point and scoring method for the WRED method to compare to other numerical indicators. The two outcome variables are moderately correlated with high significance (0.57, $p<0.01$), meaning that emotional distress from a household's water situation is related to the frequency of activity interruptions from water deprivation experienced - making both scales good choices to survey population water security and well-being efficiently.

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

Counter intuitively, income from livestock was most likely to improve a household's HWISE score but income from livestock lowered WRED scores. Traditional water and grazing land management techniques are highly sensitive to rainfall and water availability (Nassef and Belayhun, 2012). Although higher household wealth in livestock can mean higher water security experiences, the negative relationship to emotional distress means that owners of larger herds worry about drought and its effect on their livelihoods more than those who have alternate sources of income. Additionally, gender was not a significant predictor of HWISE scores, although the labor of water collection in Afar is highly gendered and other studies have found significant burdens on women (Hutchings et al., 2022).

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

Adding additional water points to the dry lowlands of Afar have led to overcrowding and rangeland degradation in the past. However, we see that there are substantial improvements in water security and emotional well-being among households with access to safely managed and functioning water supplies. Water security and improved well-being have substantial effects on household health and wealth, especially for pastoralists. Our findings suggest that increasing the reliability and daily usage of existing piped 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.

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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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