# The Contribution of Water Spreading Weirs in Alleviating Water and Feed Shortages in Ewa and Yalo Districts, Afar Region, Ethiopia

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## ABSTRACT

**Introduction:** Water-spreading weirs (WSWs), introduced in Chad in the 1990s with Swiss support, effectively mitigate water scarcity and forage shortages. By harvesting seasonal floodwaters, WSWs improve water and forage availability, enhance household food security, restore ecosystems, and strengthen the climate resilience of pastoral communities.

**Objective:** This study assesses the contribution of WSWs to water availability, livestock feed, food security, and climate resilience in Ethiopia's drought-prone Afar Region (Ewa and Yalo districts).

**Methodology:** A comparative cross-sectional design was employed using data from 176 households, comprising 106 beneficiaries (treated) and 70 non-beneficiaries (control) households. Quantitative analyses compared water availability, livestock feed, and food security outcomes between groups.

**Results:** WSW interventions produced significant positive effects among beneficiaries. Overall, 70.8% of treated households reported improved water and feed availability ($\chi^2 = 18.264$, $p < 0.05$). Frequent livestock water shortages declined from 78.3% before the intervention to 14.2% afterward, while acute fodder shortages decreased from 80.2% to 1.9% ($\chi^2 = 27.237$, $p < 0.05$; $V = 0.507$). Compared with controls, beneficiaries reported greater improvements in surface water availability (93.4% vs. 74.3% worsening; $\chi^2 = 154.960$, $p < 0.05$; $V = 0.938$), feed availability (83.0% improved vs. 84.3% declining; $\chi^2 = 147.497$, $p < 0.05$; $V = 0.915$), and household food security (72.6% vs. 17.2%; $\chi^2 = 55.635$, $p < 0.05$; $V = 0.562$).

**Conclusion:** WSWs improve water retention, pasture recovery, and household food security, demonstrating their effectiveness as a nature-based solution for strengthening resilience in arid and semi-arid pastoral areas such as Afar.

**Keywords:** Climate adaptation, feed shortage, pastoral resilience, floodwater harvesting, livestock health, water and forage availability, Water Spreading Weirs.

## INTRODUCTION

### Background

Dryland regions are increasingly experiencing recurrent droughts, erratic rainfall, land degradation, and declining agricultural productivity as a result of climate variability and climate change. These challenges have intensified water scarcity, reduced livestock feed availability, and threatened household food security, particularly in arid and semi-arid regions where livelihoods depend predominantly on rain-fed agriculture and pastoralism [1]. Consequently, the strategic deployments of sustainable land and water management interventions have become an indispensable precondition for improving the adaptive capacity and the resilience of vulnerable communities.

Water-spreading weirs (WSWs) have emerged as an effective and cost-efficient approach for restoring degraded landscapes and enhancing water availability in dryland environments. The technology was first introduced in Chad during the 1990s with support from Swiss development cooperation [1]. It was subsequently adopted in Niger in 1997, particularly in the Tahoua region, where WSWs complemented existing soil and water conservation measures implemented under the Projet de Développement Rural de Tahoua (PDRT). The combined interventions stabilized degraded watersheds, restored valley ecosystems, and significantly improved agricultural production [2]. The initial generations of water-spreading weirs were constructed using gabions—stone-filled wire baskets. Although relatively easy and inexpensive to construct, these structures were vulnerable to erosion and structural failure during high flood events. Recognizing these limitations, substantial technical improvements were introduced from around 2000 onwards. Gabions were progressively replaced by reinforced natural stone masonry with cement mortar, resulting in more durable structures capable of withstanding greater hydraulic pressure while reducing maintenance requirements [3].

In parallel with these physical upgrades, the planning and implementation processes also became more systematic and technically sound. Engineering and construction firms received targeted training in designing structures adapted to local topography and hydrology. In addition, community involvement was prioritized: local populations were engaged in both the construction and ongoing maintenance of the weirs [4]. This participatory approach not only extended the lifespan of the infrastructure but also fostered a sense of ownership among users [3; 4].

The effectiveness of WSWs has been demonstrated across several Sahelian countries. By 2010, more than 200 WSWs had been constructed in the Tahoua region of Niger, rehabilitating approximately 10,000 hectares of degraded land and benefiting nearly 5,000 farmers and pastoralists through improved water availability, increased agricultural production, and enhanced food security [5]. Similar successes were achieved in Burkina Faso, where the HIMO/FICOD program constructed 65 WSWs across 23 valleys between 2003 and 2010, contributing significantly to land restoration and livelihood improvement [2]. Building on these achievements, the technology was expanded to Chad through the DETA and PDRD programs, which constructed more than 100 WSWs by 2010 to support sustainable natural resource management and rural development [2].

The demonstrated success of WSWs has led to their widespread adoption by international development agencies, including German, Swiss, and French development cooperation, as well as the World Bank, as part of integrated strategies for climate change adaptation, sustainable land management, and food security in the Sahel [6]. Beyond their environmental benefits, WSWs have strengthened institutional capacity, promoted community participation, and enhanced resilience to climate-related shocks in vulnerable dryland regions.

Recognizing these successes, Ethiopia has recently adopted WSW technology as part of its climate-resilient agricultural development and watershed management initiatives. In the Afar Region, where recurrent drought, water scarcity, and degradation of grazing lands continue to undermine pastoral and agro-pastoral livelihoods, WSWs have been introduced to improve water distribution, rehabilitate degraded rangelands, increase fodder availability, and strengthen household food security. However, empirical evidence on their effectiveness under Ethiopian conditions remains limited, necessitating rigorous impact assessment.

**Statement of the Problem**

The Afar Region is among the most drought-prone areas of Ethiopia, characterized by highly variable rainfall, recurrent droughts, severe water shortages, land degradation, and declining pasture resources [7-8]. The livelihoods of pastoral and agro-pastoral communities depend heavily on the availability of water and natural grazing lands, making them particularly vulnerable to climate variability and environmental degradation. These challenges have resulted in reduced livestock productivity, declining agricultural production, frequent food shortages, and increasing household poverty [9-10].

To address these challenges, the Government of Ethiopia, through the Ministry of Agriculture and its development partners, has introduced Water Spreading Weirs (WSWs) as an innovative intervention to improve water harvesting, restore degraded landscapes, enhance livestock feed production, and strengthen climate resilience in dryland areas. Studies further indicate that these interventions can increase soil water availability by approximately 10–22%, leading to improvements in forage production, crop performance, and ecosystem restoration in dryland environments [11-12]. The technology has shown considerable success in several Sahelian countries, including Niger, Burkina Faso, and Chad, where WSWs have contributed to increased agricultural productivity, improved water availability, land rehabilitation, and enhanced household food security [2; 5-6].

Despite increasing investment in WSW construction in Ethiopia, particularly in the Afar Region, there remains limited empirical evidence regarding their actual contribution to improving water availability, livestock feed resources, household food security, and climate resilience. Existing studies have largely focused on the technical performance of water harvesting structures or watershed management interventions, with relatively little attention given to their socio-economic impacts at the household level [13-14]. Consequently, policymakers and development practitioners have limited evidence to guide decisions regarding the expansion, improvement, and long-term sustainability of WSW interventions.

Furthermore, few studies have employed comparative approaches that examine differences between households benefiting from WSW interventions and comparable households without access to the technology. Such comparative evidence is essential for understanding whether observed improvements can be attributed to WSWs and for identifying the mechanisms through which these interventions enhance rural livelihoods.

This study addresses these knowledge gaps by assessing the contribution of Water Spreading Weirs to improving water availability, livestock feed resources, household food security, and climate resilience among households in the Ewa and Yalo districts of the Afar Region. By comparing intervention and non-intervention households, the study provides empirical evidence to support policy formulation, improve implementation strategies, and inform future investments in climate-resilient land and water management interventions in Ethiopia.

### Objectives of the Study

#### General Objective

To assess the contribution of Water Spreading Weirs (WSWs) to improving water availability, livestock feed resources, household food security, and climate resilience in the drought-prone Ewa and Yalo districts of the Afar Region, Ethiopia.

#### Specific Objectives

The study specifically aims to:

- assess the effect of Water Spreading Weirs (WSWs) on water availability for agricultural and livestock production;
- evaluate the contribution of WSWs to improving the availability of livestock feed resources;
- examine the impact of WSWs on household food security among beneficiary and non-beneficiary households;
- assess the role of WSWs in enhancing household climate resilience and adaptive capacity to recurrent drought; and
- compare key socio-economic, agricultural, and food security outcomes between households in WSW intervention areas and comparable non-intervention areas.

## RESEARCH METHODOLOGY

### Description of the Study Areas

The Afar Region, located in northeastern Ethiopia, spans about 270,000 km² and is divided into six administrative zones. It lies between latitudes 8°49'–14°30' N and longitudes 39°34'–42°28' E (Figure 1). The region borders Tigray (NW), Amhara (SW), Oromiya (S), and Somali (SE), as well as Djibouti (E) and Eritrea

(NE). Elevation ranges from 1500m to 120m below sea level. The climate is arid with bimodal rainfall (150–500 mm annually) and temperatures between 20°C and 48°C. As of the report of CSA [15], the population was estimated at 1.67 million, predominantly pastoral and agro-pastoral communities. The study was conducted in Ewa and Yalo districts in Zone Four (Fente Rasu). **Ewa District** lies near the eastern escarpment of the Ethiopian highlands, bordered by Chifra (South), Amhara (West), Gulina (North), and Awra (East). It covers 1,463.89 km² and is located about 650 km from Addis Ababa and 188 km from Semera. The district has an elevation of 550–1080m, with a population of approximately 57,252 [15], 97.4% of whom are rural pastoralists. Rainfall ranges from 500–850 mm annually [16], and temperatures vary from 22.5°C to 37.5°C [17]. **Yalo District**, located 732 km from Addis Ababa, borders Megale (N), Gulina (S), Teru (E), and Alamata (W). It covers 822.75 km² with elevations ranging from flat plains to low hills. The district has a lowland (kola) climate, with temperatures between 21°C and 38°C and average annual rainfall of 500 mm [18]. As of the 2007 census, the population was 47,459, with 95% engaged in pastoralism [18].

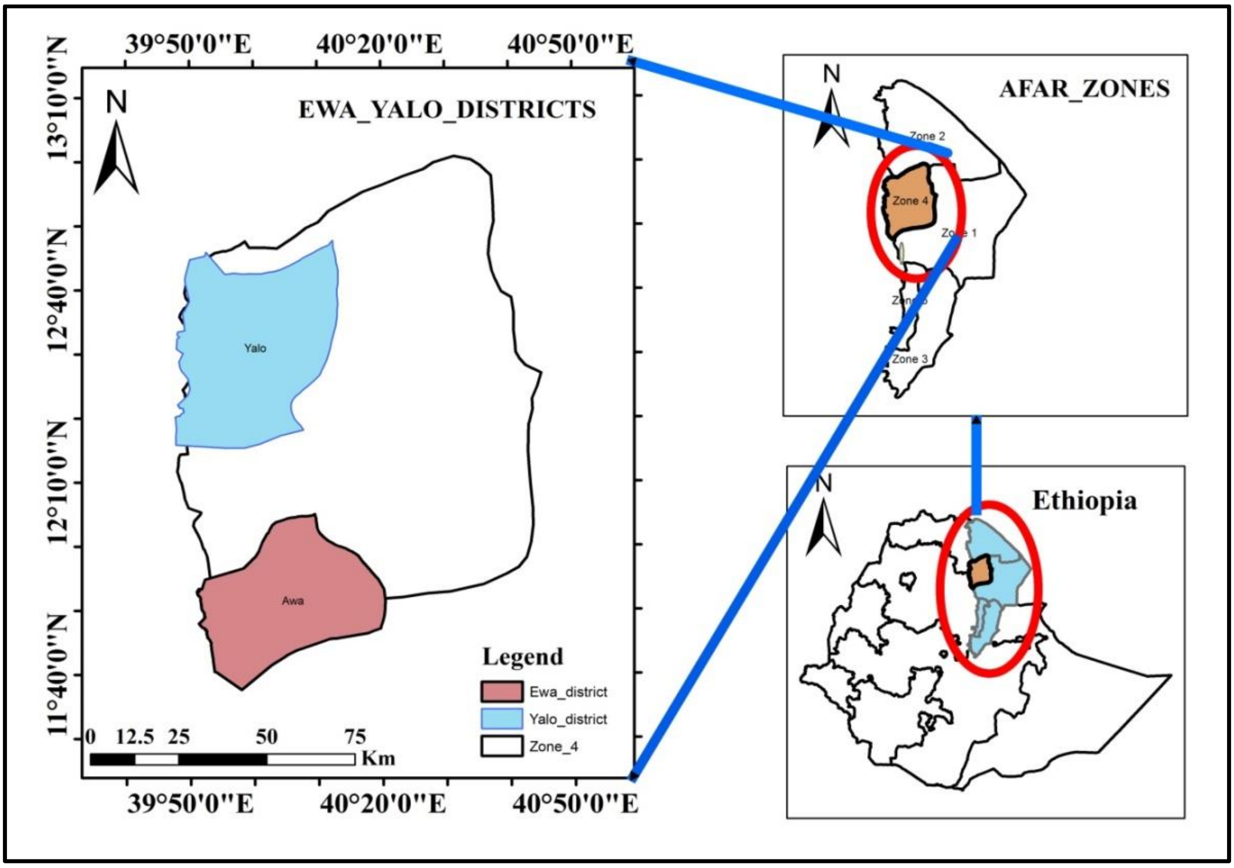



Figure 1: Map of study area

## Research design

This study evaluates the impact of WSWs —an intervention promoted by the Ethiopian Ministry of Agriculture [3]—on mitigating water and feed shortages and improving household food security in the Ewa and Yalo districts of the Afar Region, Ethiopia. A comparative cross-sectional research design was employed, incorporating both intervention (treated) and control (non-treated) groups. The intervention group comprised households located in areas where WSWs had been implemented, while the control group included households from comparable ecological and socio-economic settings without WSW interventions. By comparing outcomes between these two groups, the study assesses to generate evidence on the effectiveness of WSWs in enhancing climate resilience, agricultural productivity, and overall food security at the household level.

## Sampling and Household Selection

A stratified random sampling technique was employed to ensure the representativeness of the sample and comparability between intervention and non-intervention areas. A total of 176 households were selected and stratified based on intervention status, with further consideration given to comparable agro-ecological and socio-economic characteristics.

The sample comprised two groups. The intervention (treated) group included 106 households from communities where WSWs, promoted by the Ethiopian Ministry of Agriculture [3], had been implemented. These households represented beneficiaries of the WSW intervention. The control (non-treated) group consisted of 70 households from comparable agro-ecological settings where no WSW interventions had been implemented. This group served as the counterfactual for assessing the impacts of the intervention.

Within each stratum, households were selected through simple random sampling to minimize selection bias and improve the reliability of the results. Stratification considered key characteristics, including geographical location, agro-ecological conditions, land-use patterns, and livelihood dependence on agriculture and livestock. Selecting households from ecologically and socio-economically comparable settings strengthened the validity of the comparative analysis and enhanced the forcefulness of the impact assessment.

### Data Collection

Primary data were gathered through a combination of quantitative and qualitative methods. Quantitative data were obtained through structured household questionnaires administered via face-to-face interviews. The survey collected information on household socio-economic characteristics, water availability, livestock feed resources, agricultural production, and household food security indicators.

Qualitative data were collected through Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) involving community leaders, agricultural extension workers, and local project personnel. These methods provided contextual information on the implementation of WSWs, community perceptions of their effectiveness, and the challenges and opportunities associated with the intervention. The integration of quantitative and qualitative data enhanced the comprehensiveness and credibility of the study findings through methodological triangulation.

### Data Analysis

The collected data were coded, entered, cleaned, and analyzed using appropriate statistical software. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize the socio-economic characteristics of the sampled households and the key study variables. To evaluate the impact of WSWs, a comparative analysis was conducted between intervention (treated) and non-intervention (control) households. Differences in continuous variables were assessed using independent-samples *t*-tests, while categorical variables were compared using chi-square tests where appropriate. In addition, regression analysis was employed to estimate the effect of WSW interventions on water availability, livestock feed resources, and household food security while controlling for relevant household and socio-economic characteristics. Statistical significance was assessed at the 5% level ($p < 0.05$).

## RESULTS AND DISCUSSION

### Demographic Characteristics of Households

In the study area, household heads play a key role in coordinating farming activities. The water spearing weir adoption is significantly shaped by the head's gender, education, and age, whereas family size exerts no meaningful influence [19-20]. A socio-demographic analysis of 176 households showed that 78.4% were male-headed. Gender was found to significantly affect farming decisions—68.1% of male-headed households used a WSW, compared to 31.6% of female-headed households (Table 2). Conversely, 68.4% of non-users were female-headed [21-22]. This association is statistically significant ($\chi^2 = 16.605$, df=1, $p <0.05$) though the strength of this relationship is weak ($\Phi = 0.31$). This finding aligns with earlier studies suggesting that gender disparities in access to productive resources and extension services often shape technology adoption in agriculture [23-24]. Regarding marital status, the majority of household heads were married (93.2%), and marital status showed no statistically significant difference between users and non-users (Table 2). This indicates that marital status was not a key determinant of adoption decisions in the study area, consistent with evidence that its influence on technology uptake is often indirect or context-dependent [23].

Education constitutes a cornerstone of human capital, enhancing individuals' capacity to improves the ability to generate and apply new knowledge, and supports economic development—a mechanism consistently linked to greater technological engagement in agriculture [25-27]. The majority of respondents had no formal education 71.6% (with 56.6% of treated households and 94.3% of non-treated households). Among all respondents, 8.5% had primary education (grades 1–4), 17.6% had junior secondary education (grades 5–8), 1.7% had senior secondary or technical education (grades 9–12), and 0.6% had education beyond grade 12.

**Table 2:** Demographic characteristics of households

| Variable Definition | | Treated | | Non-treated | | Total | | $\chi^2$ cal | df | P-Value |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Freq. | % | Freq. | % | Freq. | % | | | |
| Gender | Female | 12 | 11.3 | 26 | 37.1 | 38 | 21.6 | 16.6 | 1 | 0 |
| | Male | 94 | 88.7 | 44 | 62.9 | 138 | 78.4 | | | |
| | **Total** | **106** | **100** | **70** | **100** | **176** | **100** | | | |
| Marital Status | Single | 4 | 3.80 | 0 | 0 | 4 | 2.3 | 7.52 | 3 | 0.057 |
| | Married | 100 | 94.4 | 64 | 91.4 | 164 | 93.2 | | | |
| | Divorced | 1 | 0.9 | 1 | 1.4 | 2 | 1.1 | | | |
| | Widowed/Widower | 1 | 0.9 | 5 | 7.2 | 6 | 3.4 | | | |
| | **Total** | **106** | **100** | **70** | **100** | **176** | **100** | | | |
| Educational Status | Illiterate | 60 | 56.6 | 66 | 94.3 | 126 | 71.6 | 30.25 | 4 | 0 |
| | 1- 4 grade | 15 | 14.2 | 0 | 0 | 15 | 8.5 | | | |
| | 5- 8 grade | 27 | 25.5 | 4 | 5.7 | 31 | 17.6 | | | |
| | 9- 12 grade | 3 | 2.8 | 0 | 0 | 3 | 1.7 | | | |
| | Above 12 grade | 1 | 0.9 | 0 | 0 | 1 | 0.6 | | | |
| | **Total** | **106** | **100** | **70** | **100** | **176** | **100** | | | |

Source: Field Survey (2020)

The difference in educational attainment between users and non-users was highly significant ($\chi^2 = 30.252$, df = 4, $p < 0.05$) and moderately strong (Cramer's V = 0.415). The difference attainment between users and non-users was a highly significant association ($\chi^2 = 30.252$, df = 4, $p<0.05$) and moderately strong effect size (Cramer's V = 0.415) (Table 2). This reinforces the argument that education plays a foundational role in building human capital and facilitates the comprehension and operational skills necessary for technology adoption, with user households systematically outperforming non-user households in educational achievement [28-29].

Furthermore, age is frequently conceptualized in agricultural adoption literature as a proxy for farming experience, risk tolerance, and the household life-cycle stage, all of which can shape investment decisions [30-31]. In this study, the average age of household heads was 38 years (ranging from 20 to 56 years). Notably, users were significantly younger (mean = 36.21, SD = 6.41) than non- users (mean = 40.59, SD = 7.40), with the t-test confirming a statistically meaningful gap at the 5% level (Table 3). This aligns with findings that younger farmers often exhibit greater openness to novel practices and possess longer planning horizons, which may encourage investment in yield-enhancing technologies [32-33].

In contrast, family size—commonly theorized to influence adoption through household labor availability, particularly for practices that are labor-intensive [34-35]—did not show a statistically significant difference between users and non-users. The average family size across the sample was 7.06 members (range: 2–13; SD = 2.465), yet this variable did not independently drive adoption decisions in this context. Overall, while gender, education, and age emerge as robust and significant determinants of water spearing weirs (WSWs) use, family size remains a non-factor, suggesting that labor endowment alone does not guarantee technological engagement where other capital or informational constraints may be binding (Table 3).

**Table 3**: Demographic characteristics of households

| Variable Definition | **Treated** | | | **Non-treated** | | | df | T-Value | P-Value |
|---|---|---|---|---|---|---|---|---|---|
| | N | Mean | St.dev | N | Mean | St.dev | | | |
| Age | 106 | 36.21 | 6.412 | 70 | 40.59 | 7.401 | 174 | -4.17 | 0 |
| Family Size | 106 | 6.84 | 2.462 | 70 | 7.39 | 2.451 | 174 | 1.44 | 0.151 |
| Year of Experience | 106 | 2.72 | 0.453 | 70 | 3.53 | 2.608 | 174 | -2.58 | 0.012 |

Source: Field Survey (2020)

**Availability of Water and Feed**

With regards to availability of surface water and feed, 75(70.8%) and 31(29.2%) of treated households stated that WSWs contributed for alleviation of water and feed shortage problems significantly and slightly, respectively. This was statistically significance difference for contribution of WSWs in alleviating water and feed shortage problems between significantly and slightly at 5% probability level ($\chi^2_{cal}$ = 18.264, df = 1, P <0.05) (Table 4).

**Table 4:** Contribution of water spearing weirs in alleviating water and feed shortages

| | | Frequent | % | **$\chi^2$ cal** | **df** | **P-value** |
|---|---|---|---|---|---|---|
| | Significant | 75 | 70.8 | 18.264 | 1 | 0.000 |
| | Slight | 31 | 29.2 | | | |
| | Total | **106** | **100** | | | |

(Source: Field Survey, 2020)

**Water Availability**

***Water Shortage Problems (Before and After WSWs)***

Water scarcity constitutes a fundamental constraint to smallholder agricultural and livestock systems, particularly in semi-arid and rainfed environments where seasonal droughts frequently undermine household food security and animal productivity [36-37]. In response, water-harvesting structures such as spreading weirs have been promoted as effective interventions to enhance on-farm water availability, reduce livestock water stress, and buffer production systems against intra-seasonal dry spells [38-39]. To assess the effectiveness of water spreading weirs (WSWs) in alleviating such constraints, a before-and-after comparison of perceived livestock water shortage was conducted among treated households. Prior to WSW construction, 78.3% households reported that their animals faced water shortage "often," while the remaining 21.7% indicated "sometimes" experiencing such deficits (Figure 2). This distribution underscores the acute water stress characterizing the pre-intervention period, reflecting broader patterns documented across similar dryland contexts [40-41]. Following the construction of WSWs, however, the situation improved markedly: 85.8% households reported that their animals now face water shortage "rarely," with only 14.2% still reporting "sometimes" shortages (Figure 2). This positive shift was statistically significant at the 5% probability level ($\chi^2$ = 4.842, df = 1, $p < 0.05$), confirming that WSWs have contributed meaningfully to reducing livestock water scarcity—a finding that aligns with earlier impact evaluations of water-harvesting technologies on pastoral and mixed crop-livestock systems [42-43].

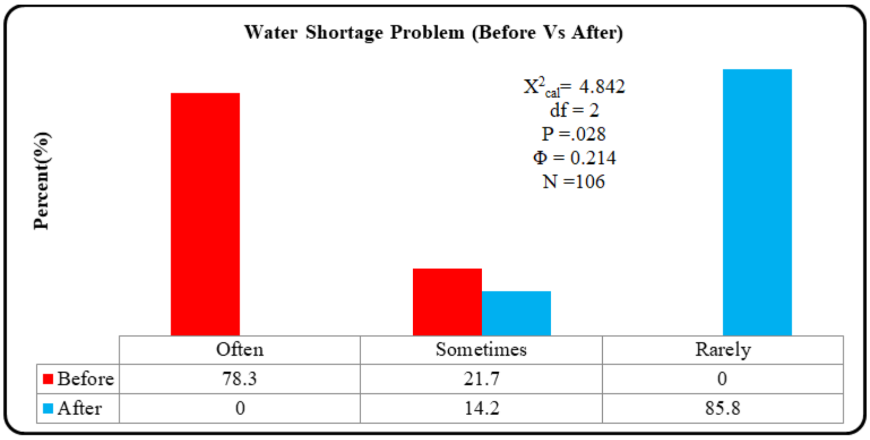



**Figure 2:** Frequency Water Shortage Problem (Before Vs After**)** (Source: Field Survey, 2020)

Nonetheless, inspection of the Phi coefficient (Φ = 0.214, N = 106) suggests that the strength of this association is weak. This modest effect size may be attributable to the binary nature of the pre/post comparison, inter-annual rainfall variability, or the fact that WSWs, while effective in mitigating dry-spell impacts, do not entirely eliminate water deficits during severe drought episodes, as external climatic and hydrological factors continue to shape overall water availability [44-45]. Nevertheless, the significant reduction in reported water shortage frequency provides empirically grounded evidence that WSW adoption contributes to enhanced household resilience, particularly in terms of securing water resources for critical livelihood assets such as livestock [46].

***Water Shortage Problem (Treated and Untreated)***

Beyond examining temporal changes within adopters, comparing treated and non-treated households offers a crucial counterfactual perspective for isolating the net effect of water-harvesting interventions—a standard evaluative approach in impact assessment studies [47; 43]. The survey revealed starkly contrasting water scarcity profiles between the two groups. Among the 106 treated households, 85.8% reported that their livestock experienced water shortage "rarely," while the remaining 14.2% indicated "sometimes"—with no treated household reporting frequent scarcity. In contrast, among the 70 non-treated households, the majority (78.6%) stated their animals faced shortages "often," while 21.4% reported "sometimes," and notably, no non-treated household reported a "rare" occurrence. This near-dichotomous distribution underscores the transformative potential of WSWs in substantially altering dry-season water availability, a finding echoed in similar evaluations of rainwater-harvesting structures in sub-Saharan Africa, where adopters consistently exhibit superior livestock water security compared to their non-adopting neighbors [48; 40].

The observed divergence was statistically highly significant at the 5% probability level ($\chi^2 = 144.690$, df = 2, $p < 0.05$) (Figure 3). Critically, the magnitude of this association was exceptionally strong, as indicated by Cramer's V = 0.907 (N = 176).

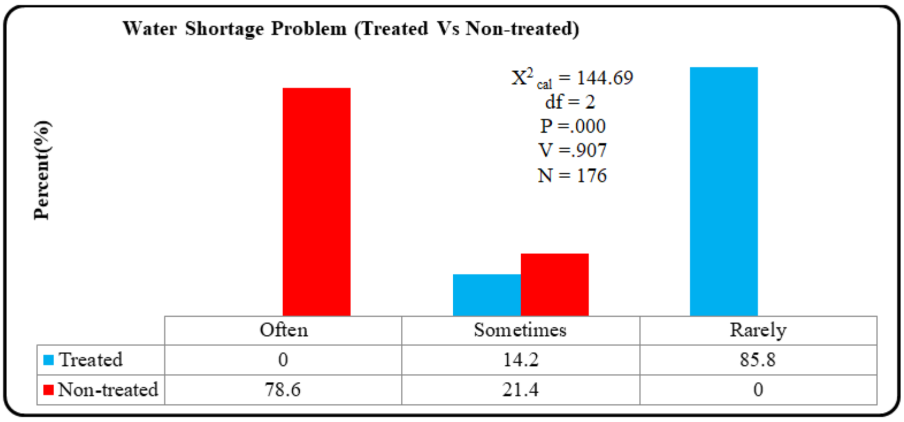
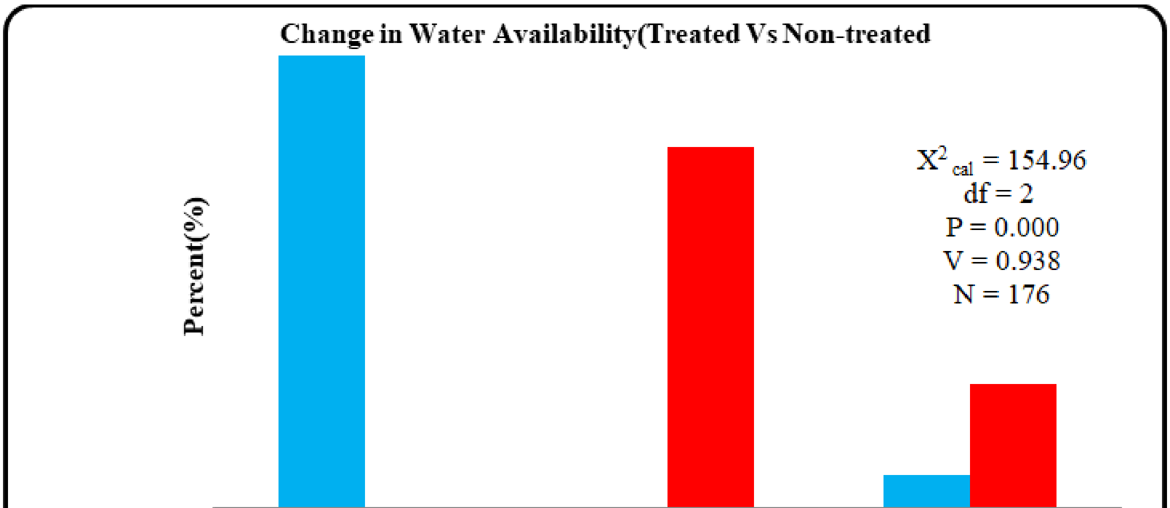



**Figure 3:** Frequency Water Shortage Problem (Treated Vs Non-treated) (Source: Field Survey, 2020)

According to Cohen's [49] widely cited benchmarks for effect size interpretation in chi-square analyses, a Cramer's V exceeding 0.5 denotes a large effect; consequently, a value of 0.907 indicates a remarkably powerful relationship between WSW adoption and reduced livestock water stress—far surpassing conventional thresholds for practical significance [49-50]. Such a high effect size implies that the intervention explains the overwhelming majority of the variance in reported water shortage outcomes across the sample. This striking disparity—where "rare" shortages are almost exclusively reported by treated households and "often" shortages predominantly by non-treated ones—provides compelling ex-post evidence that WSWs significantly enhance household resilience to hydrologic variability [44; 51]. In effect, the construction of WSWs appears to have redefined the water access landscape for adopting communities, shifting them from a state of chronic deficit to one of relative abundance, while non-adopters remain trapped in acute water insecurity—a pattern that affirms the critical role of such technologies in building adaptive capacity against climate-induced water shocks in mixed crop-livestock systems [52-53].

Consistent with the positive biophysical outcomes of water-harvesting interventions documented by Gebreegziabher and Tadesse [54], a substantial 93.4% of the 106 treated households reported improved surface water availability since 2018, with only 6.6% observing no inter-annual variation. On the other hand, mirroring the degradation patterns in unmanaged catchments highlighted by Pandey et al. [55], a majority (74.3%) of the 70 non-treated households reported a “reduction”, while the remaining 25.7% noted no change—with none recording any improvement. To evaluate the statistical independence of these contrasting distributions, a Pearson chi-square test was employed [56], which confirmed a highly significant divergence between the treatment and control groups at the 5% significance level ($\chi^2 = 154.960$, df = 2, $P < 0.05$) (Figure 4). Furthermore, the calculated Cramer’s V coefficient (V = 0.938, N = 176) far exceeds the conventional threshold for a large effect size [49], indicating an exceptionally strong association between intervention participation and perceived changes in surface water availability.




| | Improved | Reduced | No change |
|---|---|---|---|
| Treated | 93.4 | 0 | 6.6 |
| Non-treated | 0 | 74.3 | 25.7 |

**Figure 4:** Change in Water Availability (Treated Vs Non-treated) (Source: Field Survey, 2020)

**Availability of Feed**

***Feed Shortage Problem (Before and After WSWs)***

Feed scarcity constitutes a chronic challenge in mixed crop-livestock systems, particularly in semi-arid environments where primary productivity is tightly constrained by rainfall variability and the resultant water deficits, which in turn limit biomass production for both grazing and fodder [57; 46]. Given that livestock productivity depends directly on forage availability, water-harvesting interventions such as spreading weirs—

by enhancing soil moisture and promoting vegetation regrowth—are theoretically expected to generate significant downstream benefits for feed supply [58; 39]. Before the construction of water spreading weirs, 80.2% reported that their animals faced feed shortage "often," while 19.8% indicated "sometimes"—a distribution reflecting acute and pervasive fodder deficits. On the other hand, after construction of WSWs, 84.9% households experienced shortages "sometimes," and 13.2% "rarely," only 1.9% continued to face them "often." This systematic movement away from the "often" category toward the lower-frequency categories suggests that WSWs have substantially improved dry-season forage availability—likely through enhanced moisture retention that extends the growing period of natural pastures and supports crop residue production, a relationship documented in similar agro-ecological settings [40; 53].

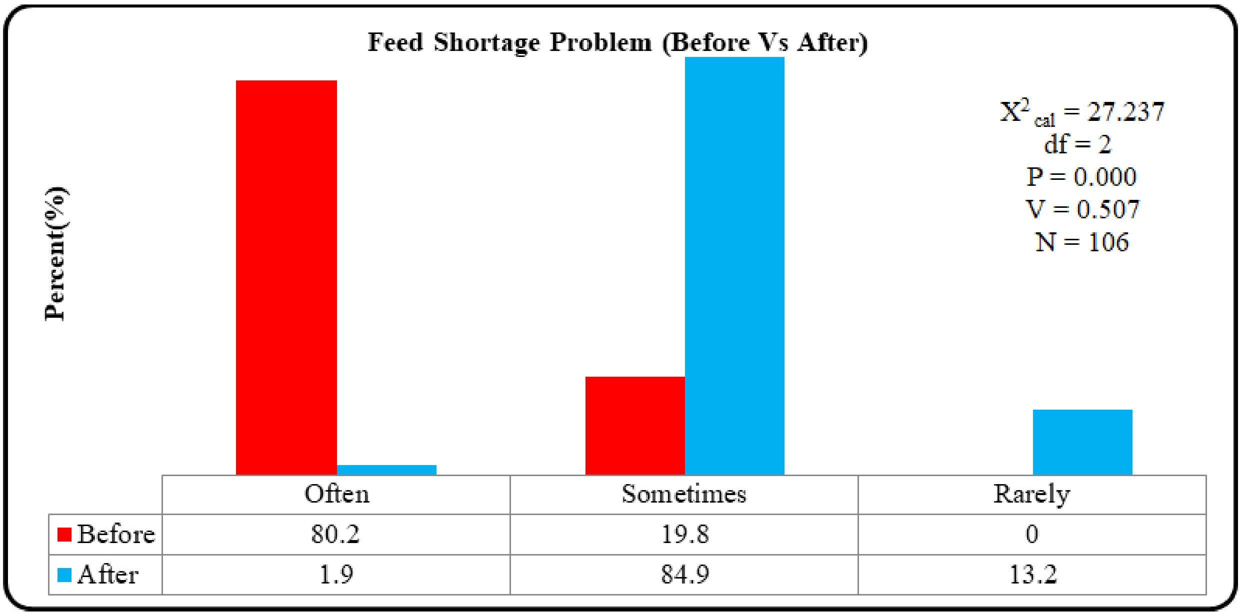



**Figure 5:** Frequency Feed Shortage Problem (Before Vs After**)** (Source: Field Survey, 2020)

The observed shift was statistically significant at the 5% probability level ($\chi^2 = 27.237$, df = 2, $p < 0.05$) (Figure 5). Inspection of Cramer's V (V = 0.507, N = 106) indicates a moderately strong association, which, according to Cohen's [49] widely used benchmarks, approaches the threshold for a large effect. The moderately strong nature of this relationship, rather than a near-perfect one, is plausible given that feed availability is influenced by multiple interacting factors beyond water provision—including soil fertility status, livestock grazing pressure, land management practices, and inter-annual rainfall variability[59-60]. Nevertheless, the substantive reduction in the proportion of households reporting frequent shortages reinforces the argument that WSWs serve as a critical entry point for improving livestock feed security by easing the hydrological bottleneck that constrains plant biomass production [44].

***Feed Shortage Problem (Treated and Untreated)***

The study also revealed that, the frequency of animals faced to feed shortage statistically significant between treated and non-treated households. From 106 treated household respondents, a vast majority reported either "sometimes" (84.9%) of households or "rarely" (13.2%) of households, experiencing feed shortages, with only 1.9% of households still reporting "often." On the other hand, from 70 non-treated households 71.4% faced shortages "often," while the remaining 28.6% reported "sometimes"—and notably, no non-treated household reported a "rare" occurrence. This near-binary distribution—where "rare" shortages are almost exclusively the domain of adopters and "often" shortages overwhelmingly characterize non-adopters—provides compelling evidence that WSWs fundamentally alter the feed security landscape, likely by facilitating year-round access to green forage and crop residues that would otherwise be unavailable during prolonged dry spells [48; 51].

The difference was statistically highly significant ($\chi^2 = 99.659$, df = 2, $p < 0.05$) (Figure 6), with Cramer's V = 0.752 (N = 176) denoting a very strong association. Such a large effect size underscores that WSW adoption is a dominant determinant of household feed security status, effectively insulating adopters from the acute fodder crises that persistently afflict their non-adopting neighbors—a pattern consistent with the broader literature on water-harvesting impacts on agro-pastoral resilience [52; 38].

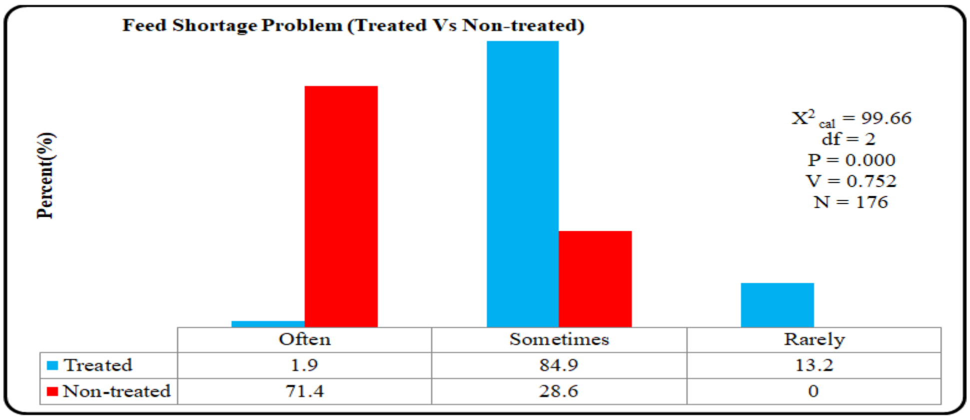



**Figure 6:** Frequency of Feed Shortage Problem (Treated Vs Non-treated) (Source: Field Survey, 2020)

With respect to inter-annual trends in feed availability since 2018, the divergence between the two groups became even more pronounced. Among treated households, 83% respondents reported that feed availability had *improved* relative to previous years, while 17% perceived *no change*; strikingly, not a single treated household reported a decline. On the other hand, from 70 non-treated household respondents (84.3%) stated that feed availability had *reduced* over the same period, while 15.7% perceived *no change*, and no non-treated household experienced an improvement. This asymmetric trajectory—where adopters experience progressive gains while non-adopters undergo progressive losses—points to the dual role of WSWs in not only alleviating current feed deficits but also building longer-term adaptive capacity against climate-induced degradation and recurrent drought [53; 51].

The observed differences were statistically significant at the 5% level ($\chi^2$ = 147.497, df = 2, $p < 0.05$) (Figure 7), with Cramer's V = 0.915 (N = 176) indicating an exceptionally strong relationship. This near-perfect association implies that WSW adoption accounts for the overwhelming majority of the variance in perceived feed trends across households. The sustained improvement reported by adopters likely reflects a positive feedback loop: enhanced water availability supports better biomass production, which in turn improves soil organic matter and moisture retention over time, reinforcing overall pasture productivity—a mechanism increasingly recognized in the sustainable land management literature [58; 36]. Meanwhile, the widespread decline reported by non-adopters aligns with broader regional observations of land degradation and rainfall unpredictability, further underscoring the protective, resilience-enhancing function of water-harvesting infrastructure [45-46].

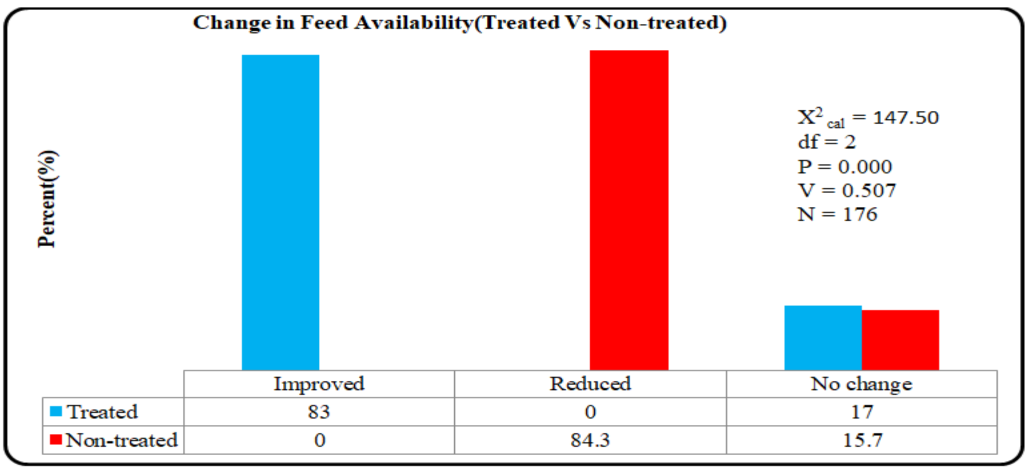


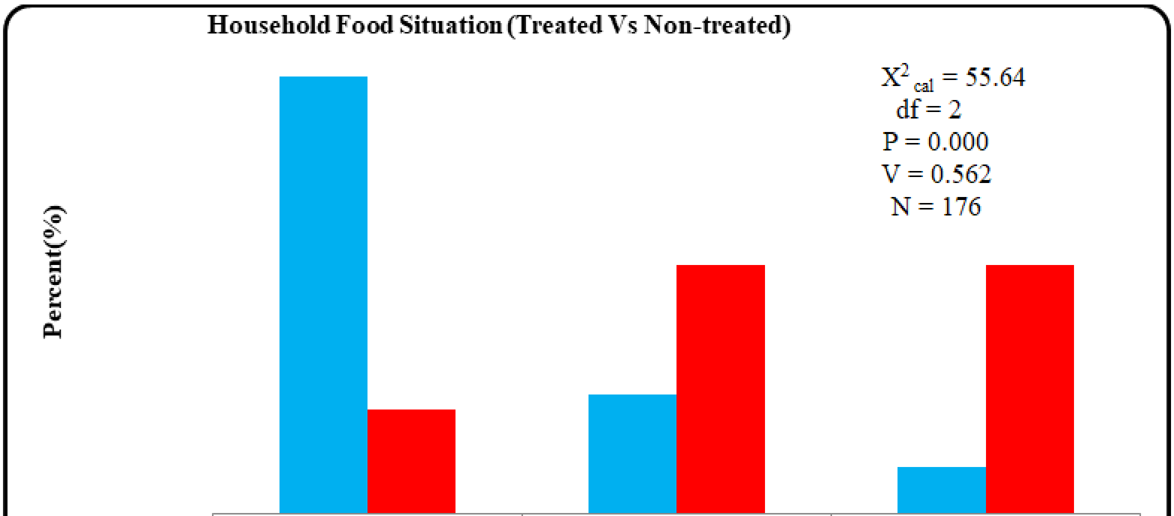

**Figure 7:** Change in Feed Availability (Treated Vs Non-treated) (Source: Field Survey, 2020)

### Household Food Situation

A cross-sectional analysis was conducted to evaluate changes in household food security status among respondents over the preceding twelve-month period [61]. Within the pastoralist communities of the study area, households exhibited different trajectories in their food security conditions, including improvement, stability, or deterioration [62-63]. Among the households that received the intervention, the majority (72.6%) reported an improvement in their food situation, while 19.8% indicated that their status had remained unchanged and only 7.6% experienced a worsening.

In contrast, merely 17.2% of non-treated households reported improvements. The remaining households were largely split between those whose conditions remained unchanged (41%) and those who experienced deterioration (41.8%). These patterns point to notable differences in resilience and adaptive capacity between the two groups, consistent with evidence from prior studies on rural livelihood interventions [64-65].

A chi-square test of independence revealed a statistically significant difference in household food situation outcomes between the treated and non-treated groups at the 5% probability level ($\chi^2 = 55.635$, df = 2, $p < 0.05$) (Figure 8), with benchmarks for a moderately strong effect size (Cramér's V = 0.562, N = 176) that exceeds conventional moderate-effect thresholds [66; 49]. These findings align with broader empirical evidence that targeted livelihood interventions can meaningfully influence household food security dynamics [67-68].




| | Improved | Stayed | Worsened |
|---|---|---|---|
| Treated | 72.6 | 19.8 | 7.6 |
| Non-treated | 17.2 | 41.4 | 41.4 |

**Figure 8:** HHs Food Situation (Treated Vs Non-treated) (Source: Field Survey, 2020)

## CONCLUSIONS AND RECOMMENDATION

### Conclusions

This study indicates that Water Spreading Weirs (WSWs) have considerable potential as a nature-based intervention for addressing hydrological, ecological, and livelihood challenges in the drought-prone areas of Ewa and Yalo. The comparative findings suggest that WSW beneficiary households generally report better access to water, greater availability of fodder and agricultural opportunities, and improved livelihood and adaptive-capacity outcomes compared with non-beneficiary households.

The findings suggest that WSWs are associated with improved water retention and recharge through the spreading and infiltration of floodwater, potentially enhancing soil moisture and rangeland conditions. These improvements are reflected in increased availability of grasses and fodder species, opportunities for small-scale crop production, improved access to water for domestic and livestock use, and diversification of pastoral and agro-pastoral livelihoods. Overall, WSWs have potential to improve access to natural resources and livelihood opportunities and strengthen household capacity to cope with drought and climate-related stresses, particularly when supported by appropriate rangeland management, institutional support, extension services, and livelihood diversification.

However, because the study employed a comparative cross-sectional design, the observed differences between beneficiary and non-beneficiary households should be interpreted as **associations and comparative differences rather than definitive causal effects** of WSW interventions. Differences between the two groups may partly reflect pre-existing socioeconomic, geographic, institutional, and livelihood characteristics. Therefore, the observed improvements cannot be attributed solely to WSW interventions.

Generally, WSWs represent a promising approach for improving water availability, supporting rangeland and livelihood recovery, and strengthening resilience in drought-prone pastoral and agro-pastoral areas. To establish the magnitude and causal contribution of WSW interventions and assess their long-term environmental and livelihood effects, future research should employ longitudinal or quasi-experimental designs and integrate household-level data with objective measurements of rainfall, groundwater and surface-water availability, vegetation conditions, crop production, and livestock productivity.

## Recommendations

Based on the study's outcomes observed, the following recommendations are proposed to optimize and sustain the benefits of WSW interventions:

- **Strategic scaling of WSW interventions:** WSWs should be considered for replication in other water-stressed pastoral and agro-pastoral areas with suitable hydrological and topographical conditions. Scaling should be guided by site-specific assessments and community priorities rather than assuming uniform impacts across locations.

- **Strengthening community participation and governance:** Community-based institutions should be strengthened to support participatory planning, equitable water use, routine maintenance, conflict management, and sustainable management of WSW structures. Greater community involvement can also promote local ownership and long-term sustainability.

- **Integrated rangeland and livelihood management:** WSW interventions should be complemented by appropriate rangeland management practices, including controlled grazing, area enclosures, reseeding of suitable fodder species, and livelihood diversification. Such complementary measures can help sustain improvements in vegetation and livestock production.

- **Capacity building and technical support:** Pastoral and agro-pastoral communities should receive appropriate training on WSW maintenance, sediment management, water-use practices, and basic monitoring. Local technical capacity should be strengthened to reduce dependence on external support.

- **Long-term environmental and livelihood monitoring:** Future interventions should establish systematic monitoring of groundwater and surface-water levels, rainfall, soil moisture, pasture biomass, crop yields, livestock productivity, and household livelihood outcomes. Integrating these objective measurements with household survey data would provide stronger evidence of environmental and livelihood changes.

- **Longitudinal and quasi-experimental research:** Future studies should collect baseline and follow-up data from beneficiary and comparable non-beneficiary households. Where appropriate, **propensity score matching and difference-in-differences approaches** should be considered to improve comparability, reduce observable selection bias, and provide stronger evidence of the causal effects of WSW interventions.

- **Policy integration:** WSWs should be incorporated, where supported by further evidence and site-specific feasibility assessments, into regional and national climate adaptation, drought-risk management, water-resource development, and livelihood resilience strategies. Continued institutional and financial support should be accompanied by monitoring and evidence-based evaluation.

- **Further impact assessment:** Future research should examine whether observed changes in household livelihoods and adaptive capacity correspond with measurable changes in water availability, vegetation conditions, crop production, and livestock productivity. This would help distinguish intervention-related effects from changes associated with broader socioeconomic, climatic, or institutional factors.

### Ethics approval and consent to participate

This statement is typically included in research studies to indicate that the study has been reviewed and approved by an ethics committee and that participants have given their informed consent to take part in the study.

### Consent for publication

Not applicable

### Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

### Competing interests

The authors have stated that they do not have any competing interests.

### Funding

There is no financial fund directly.

### Author's contributions

**NA**: has made significant contribution in conception and designing of the study, sample collection, data analysis, interpretation of results, manuscript preparation (editing, commenting, and suggesting ideas), and approved the final manuscript. **SY:** has contributed to the study design, sample collection, data analysis, interpretation of results, and manuscript preparation, including editing, commenting, and providing suggestions. All authors read and approved the final version of the manuscript for publication.

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