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Farmers' Perception of Integrated Watershed Management as a Climate Solution in Northern Ethiopia

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Abstract
Since 1997, the concept of using Integrated Watershed Management (IWM) to mitigate the negative impacts of climate change has been recognized in the Ethiopian development strategies. While IWM has proven effective in reducing land degradation and enhancing socio-economic benefits, there is limited scientific evidence on local farmers' perception of its role in adapting and mitigating climate change. This study, therefore, examines four micro-watersheds, two of which have implemented various IWM practices. Data were collected from 84 individuals using semi-structured questionnaires, focusing on climate change indicators such as temperature and precipitation fluctuations, desertification, drought, unexpected floods, land degradation and productivity. The data were stratified, grouped, and tabulated numerically. Results revealed that 83% of the respondents perceive areas near to the treated watersheds as more productive, resilient and less affected by the climate change variables compared to the untreated areas, even though both groups showed high awareness of climate change impacts. Respondents attributed the positive impact of the treated watersheds to increased community awareness of environmental management and the effectiveness of IWM practices in mitigating climate change. Overall, farmers believed that IWM practices have reduced the impacts of climate change and recommended scaling up the approach in areas that have not yet adopted the approach.

Keywords: Soil and Water Conservation, Climate change indicators, Vulnerability, Resilience, Small-scale farmers

1. Introduction
Climate change is a critical issue (Yan *et al*., 2018; Yong-Jian *et al.*, 2021; Abbass *et al.*, 2022) particularly in the low-income countries such as Ethiopia (Cutter and Christophe, 2009). A very high dependence on rain-fed agriculture, under-developed water management systems, low economic development resulting in low adaptive capacity, weak institutions and lack of awareness are common features (Stern, 2006; Zegeye, 2013).

To minimize the adverse effects of climate change and increase land productivity, and improve resilience, governmental and non-governmental organizations struggle to develop adaptation measures such as the integrated watershed management (IWM) approach (Teka *et al.,* 2020; Gebrehiwot *et al.,* 2022). The IWM approach, in Tigray (northern Ethiopia), was initiated in 1997 in collaboration with the Irish development co-operation program (Irish Aid) (Gebremeskel et al., 2019; Teka *et al.,* 2020; Gebrehiwot *et al.,* 2022). The IWM program had six major objectives (GIZ, 2015; Gebremeskel *et al.,* 2019; Teka *et al.,* 2020): i) improve crop production for food security; ii) improve soil and water conservation (SWC) and soil fertility using appropriate biological and physical measures as well as agricultural inputs; iii) improving multiple water supplies; iv) increase household incomes by diversifying agricultural and nonagricultural activities; v) empower communities' sustainable development of local resources; vi) integrate community priorities by community-based health education, hygiene and sanitation, and savings, as well as increasing the status of women and girls in the target communities.

Several studies such as Teka *et al.* (2020) and Gebrehiwot *et al.* (2022) have examined the extent to which community-based watershed management interventions have resulted in the desired effects. However, to our knowledge, studies on the perception of farming households related to IWM interventions as climate solution are scarce. Understanding farmers' perception helps in sustaining projects interventions (Scherfranz *et al.,* 2024). Therefore, our study attempted to assess perceptions of farming households regarding IWM as adapting remedy to climate change. The study aimed at: i) analyzing local farmers understanding about climate change and its environmental impacts; ii) identifying the perception of local farmers on IWM practices; iii) evaluating the impacts of IWM as climate change adaptation strategies.

2. Materials and Methods

2.1. The Study Area

The study was conducted at Tsigea Watershed in Raya Azebo Wereda, Tigray region, Northern Ethiopia (12°46'27" - 12°51'8" N and 39°34'6" - 39°55'19"E) at an elevation range between 930 and 2934 m above sea level (masl) (Figure 1).

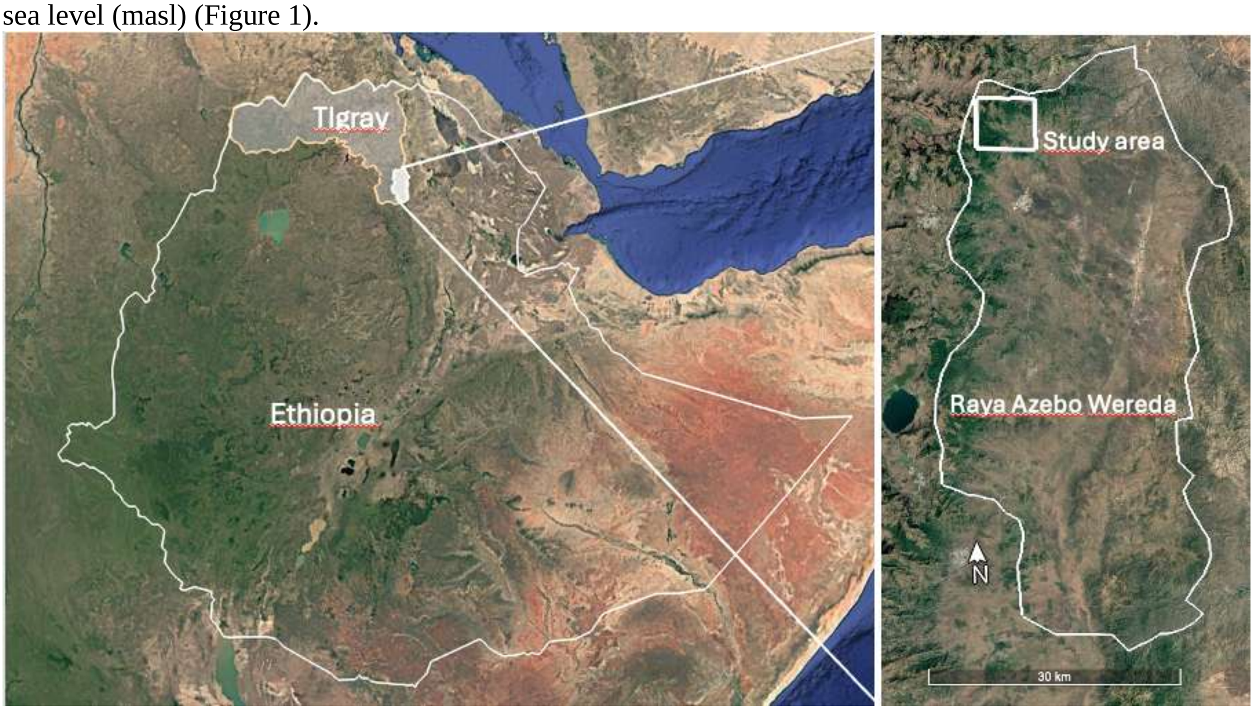

Figure 1: Map of Raya Azebo in Ethiopia and Tigray (the specific watershed highlighted with a square)

The area is characterized by having a bimodal rainfall pattern with small rainy season (February – April) and long rain season (July to September). The mean annual rainfall is 724 mm. The mean daily temperature ranges from 14 °C to 23 °C (Tesfay *et al.*, 2019; CASCAPE, 2020; Kahsay *et al.*, 2021; Abebe *et al.*, 2022). Ninety percent of the Wereda is described as "midland" (1500-2300 masl) and 10% is "lowland" (< 1500 masl) (Tesfay *et al.*, 2019). Mixed farming system is a commonly practiced agricultural system in the area. The major crops produced are sorghum (*Sorghum bicolor*), teff (*Eragrostis tef*), maize (*Zea mays*), chickpea (*Cicer arietinum*), vegetables, and coffee. Livestock production is also a common means of livelihood (Welderufael *et al*., 2023).

Ethiopia's climatic condition is determined by altitude (Abebe, 2017; Gashaw *et al.*, 2023) and so is our case watershed where large part of it is characterized by rugged topography with very high mountains deeply incised canyons, gorges, valley, plain and plateaus (Tesfay *et al.*, 2019; CASCAPE, 2020). The highest point is at 2300 masl and the lowest point at 930 masl (Tesfay *et al.*, 2019). The geology is categorized as the Alaje formation with a Leptosols/Lithosols soil reference group dominating (CASCAPE, 2020).

2.2. Study Method

The study was conducted in 2023. The specific watershed was selected based on the following conditions: i) the existence of two micro-watershed management types (treated and untreated) within the major watershed as shown in Figure 2; ii) accessibility of the areas taking the existing war situation into account. Four micro-watersheds (Hawerwo, Golojema, Cobasha and Kiuhaly) were selected (Table 1).

Figure 2: Two of the study micro-watersheds: untreated (left) and treated (right) **(**Photo: Freweyni Mahari)

Stratified random sampling technique was deemed appropriate because the study area included both treated and untreated watershed management types, which are confined to a small area located next to each other. Respondents were selected randomly considering gender (42% females and 58% males), family size (< 5 members is small and > 5 members is big) (ILO, 2021) and age (19 - 35 & 36 - 72 years old) (AUC, 2006). The total population in 2023 was 870 (510 males and 360 female). Out of which, 84 individuals (49 males and 35 female) were selected as a sample for the research following equation 1 suggested in Yamane (1967).

$$n= \frac{N}{1+N}(e)2 \ldots \ldots \ldots \ldots \text{ Equation 1}$$

Where, n = sample size, N = total population, e = level of precision (0.1)

Table 1: Total population, household and study group in the micro-watersheds

Micro-Watershed	Total population	Sample size	Status /Type
Hawerwo	254	22	Treated
Golojema	230	21	Treated
Cobasha	185	19	Untreated
Kiuhaly	201	22	Untreated
Total	**870**	**84**	

For each interview, personal characteristic and demographics were gathered. Studies have shown that sample individual's personal background has a direct impact on the result of the study, dealing with the characteristics of respondents from all categories (Chen *et al.*, 2024). Data were collected onsite through a semi-structured interview in 2023 for three months (March to May). The semi-structured interview is a widely used data collection technique in qualitative research (Pin, 2023). After the available data were collected, grouping and categorizing were followed as suggested in Kaliyadan and Kulkarni (2019). Finally, data were analyzed following descriptive statistical analysis method. Measure of frequency (frequency, %), a type of descriptive statistics, was employed. Frequency analysis deals with the number of occurrences and percentage (Mishra *et al*., 2019).

3. Results and Discussion

3.1. Sample Households' Characteristics

Sample households' characteristics, expressed in terms of educational status, age category, land possession and family size are shown in Table 2. The analysis of the results indicated that majority of the sampled households were illiterate, unable to read and write fully. This implies that the introduction of new agricultural technologies and mechanisms such as IWM appears to be a challenge in these communities if they are delivered in writing. Similarly, Bucciarelli *et al.* (2010), Steel *et al.* (2015), Liu *et al.* (2018) and Asfew *et al.* (2023) argued that communities with high educational background have better performance in introducing new agricultural practices and technologies conducting effective trainings, using time and other resources efficiently, cooperatively working with the tasks and accomplishing projects better than the illiterate group. Societies having awareness about the importance of IWM measures are 9.6 times more likely to adopt them than those who do not have awareness (Asfew *et al.*, 2023). Education is believed to enhance the ability of farmers in receiving, analyzing, and using information and increases understanding of adaptation measures to climate change (Cutter *et al.*, 2009; Wolka *et al.*, 2023).

Table 2: Demographic data of respondents

Category	Untreated (%)	Treated (%)	Mean (%)
Educational status			
Literate	33	58	45.5
Illiterate	67	42	54.5
Age category			
18-35	40	36	38
>35	60	64	62
Land Ownership			
Owning land	81	86	83.5
Landless	19	14	16.5
Family size			
Big family	53	56	54.5
Small family	47	44	45.5

Respondent's age is positively correlated with the adoption of IWM technologies (e.g., Asfew *et al.*, 2023). An increase in IWM technologies adoption with age implies having households with ample experience and knowledge to share about the implementation and practices of IWM. This group was also being keen in taking responsibilities and getting societal acceptance in managing all the tasks in relation with the IWM interventions.

The land ownership status was slightly higher on treated watersheds, 5% higher than the untreated ones. This can also be related to the low number of young people, since low age is strongly related with landlessness (Dagnew et al., 2007; Wolka *et al.*, 2023). This is in par with Jara-Rojas *et al.* (2012) that explain the ownership of land is positively associated with the adoption of soil and water conservation measures.

Respondents with big family size (Table 2) with higher numbers of labor, were also observed actively participating in all the tasks of the watershed programs much more than those with small sized family members. These results correspond with the findings of Gedefaw *et al.* (2018) and Wolka *et al.* (2023) that stated the only labor readily available for agricultural and soil conservation tasks comes from household labor and the adoption of IWM is positively correlated with the agricultural labor force.

3.2. Perception on Climate Change and its Effects

3.2.1. Climate Change Status and Indicators

According to the field survey, awareness of climate change seems high in both communities, with over 80% indicating sufficient level of knowledge. Figure 3 describes farmers' perception on climate change occurrences in their surroundings.

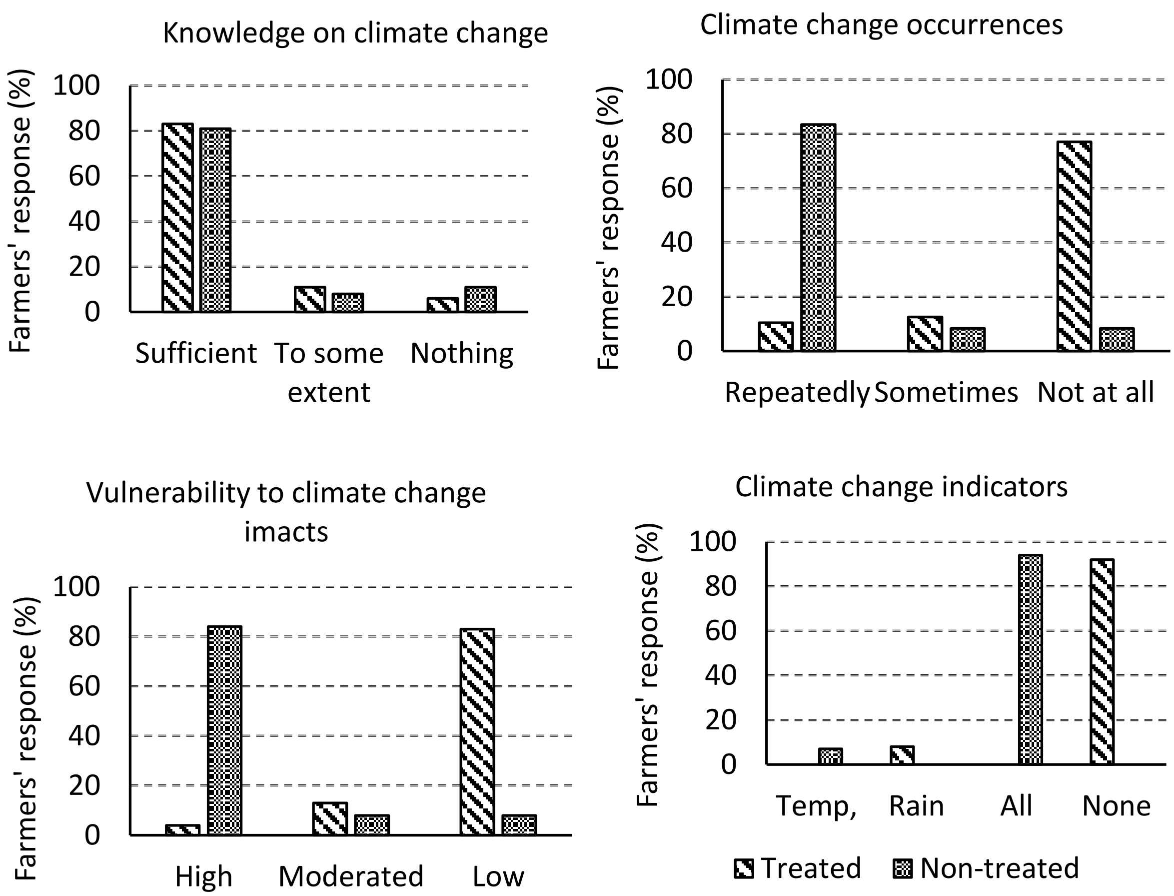

Figure 3: Farmers' Perception on Climate Change Status and Indicators

Little differences were found in the knowledge of climate change between the two groups (Figure 3) and has to be considered high in both (83% and 81%, from treated and non-treated Watersheds, respectively).

A study in Southern Ethiopia (Belay et al., 2022; Wolka *et al.,* 2023) also reported that most farmers (82% and 83%, respectively) perceived changing in local climate.

Increased temperature, increased flooding, and shortage of rain in both amount and duration where the climate change indicators that most often got mentioned. More than 94% of the respondents from the untreated watersheds reported experiencing all these three indicators. More than 83% of the farmers from the untreated watersheds perceive high vulnerability of the area to the effects of climate change, again indicating good knowledge about the impact of climate change. Similarly, Robinson (2021), Belay *et al.* (2022) and Wolka *et al.* (2023) revealed that the common phenomena of climate changes are temperature rises and heat waves, heavy rainfall and flooding, drought, strong winds and others. A study in south-west Ethiopia also reported that more than 80% of the farmers perceived climate variability such as increasing temperature and rainfall fluctuations (Wolka *et al.*, 2023).

Nevertheless, the occurrence of such climate change indicators is minimal in the treated watersheds. Only rainfall shortage is reported as their concern. Regardless of the concern on repeated rainfall shortage, treated watershed seems resilient to the effects of climate change as reported by more than 83% of the respondents. This could be related to the power of increased vegetation cover, which leads to balancing the micro-climate. Earlier studies (e.g., Gebremeskel *et al.*, 2019; Teka *et al.*, 2020) also reported positive climate adaptation impacts from IWM activities through reduced surface runoff, and improved moisture.

The major drivers of climate change were meager use of natural resources, deforestation, over grazing and high population as reported by all the respondents. This corresponds with the findings of Wolka *et al.* (2023) that reported that most households, about 91%, assume that climate change is caused by high population pressure, deforestation, and overexploitation. Furthermore, farmers in northern Ethiopia perceived that cutting trees in search of farmland and firewood contributes to climate variability and adversely affects land productivity and, ultimately, food security (Tofu *et al.,* 2022). Berhanu *et al.* (2024) identified several key factors contributing to Ethiopia's vulnerability to climate variability and change. These factors include a heavy reliance on rain-fed agriculture, which is highly sensitive to climate fluctuations, underdeveloped water resources, rapid population growth, low levels of economic development, limited adaptive capacity, insufficient road infrastructure in drought-prone regions, weak institutional frameworks, and a general lack of awareness.

3.2.2. Effects of Climate Change

Majority of the respondents from the untreated watersheds perceived that land degradation, repeated droughts, high and shortage and unexpected rain and floods are some of the common natural hazards occurring because of climatic changes (Figure 3). The respondents (83%) rated the severity of land degradation in the untreated watersheds as high. This finding aligns with the conclusions of the World Bank (2008) and Zegeye (2013), who reported that climate change has increased the frequency and intensity of extreme weather events (e.g., droughts, floods, heat waves), altered global precipitation patterns, expanded desertification, intensified wildfires, reduced biodiversity, increased environmental pollution, decreased agricultural productivity, exacerbated water scarcity, and heightened the incidence of pests and diseases.

The impact of climate change extends beyond bio-physical aspects to also include socio-economic conditions of smallholder households. All households, regardless of their location, recognized that climate change can have socio-economic effects. This observation aligns with the findings of Abbass *et al.* (2022), who argued climate change is the most challenging natural phenomenon to manage due to its direct and indirect effects on the socio-economic and political structures of human life. Despite advancements in wealth and technology in modern industrial societies, our daily lives, income, and recreational activities still largely depend on favorable climatic conditions (World Bank, 2008).

3.2.3. Adaptation Mechanisms to the Effects of Climate Change

Seventy-nine percent of the respondents from the treated micro-watersheds practiced some adaptation strategies to protect their land from the impacts of climate change (Figure 4). In contrast, 94% of the respondents from the untreated watersheds did not use any mitigation mechanisms or adaptation strategies to protect their lands from climate change impacts. This implies that people living near or in IWM treated areas have better opportunity to protect their environment from the impacts of climate change most likely due to the IWM structures.

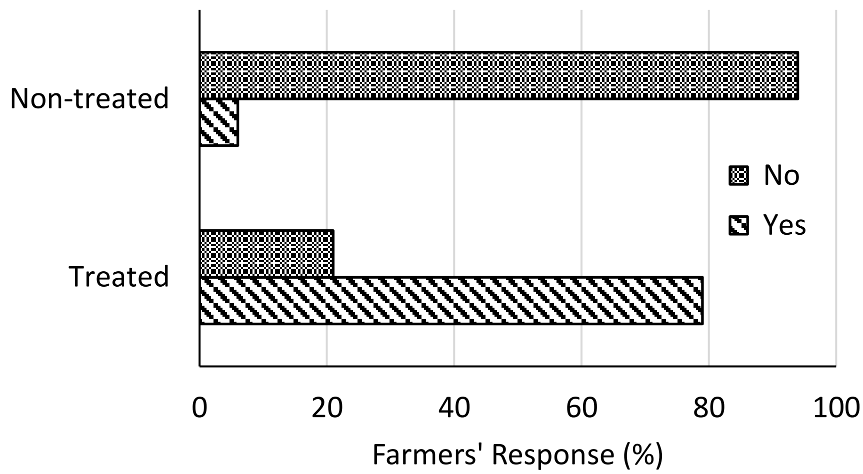

Figure 4: Use of adaptation mechanisms to the impacts of climate change

All households who adopted coping strategies introduced small ponds, use shifting cultivation, built soil bunds, and planted trees to overcome the impacts of climate change. These are in agreement with the findings of Dagnew *et al.* (2015), Amjath-Babu *et al.* (2016) and Getie *et al.* (2020) who reported IWM measures such as soil bund, stone bund, stone faced soil bund and terraces integrated water harvesting structure and biological measures as effective in improving hydrological response and reduction of continued soil erosion.

3.3. Implemented IWM Interventions and their impact

3.3.1. Implemented IWM Interventions

The major types of IWM interventions implemented in the treated watersheds are listed in Figure 5. Majority of the respondents (77%) revealed that trenches, afforestation programs, exclosures to keep animals away from crops, and water harvesting structures were the major IWM interventions, aligned with the objectives of IWM (GIZ, 2015; Gebremeskel *et al.*, 2019; Teka *et al.*, 2020). Similarly, Dagnew *et al.* (2015) and Wolka *et al.* (2023) described that soil bund, stone-bund, stone faced soil bund, terrace integrated with in situ water harvesting structure and biological measures were the dominant measures implemented in many watersheds.

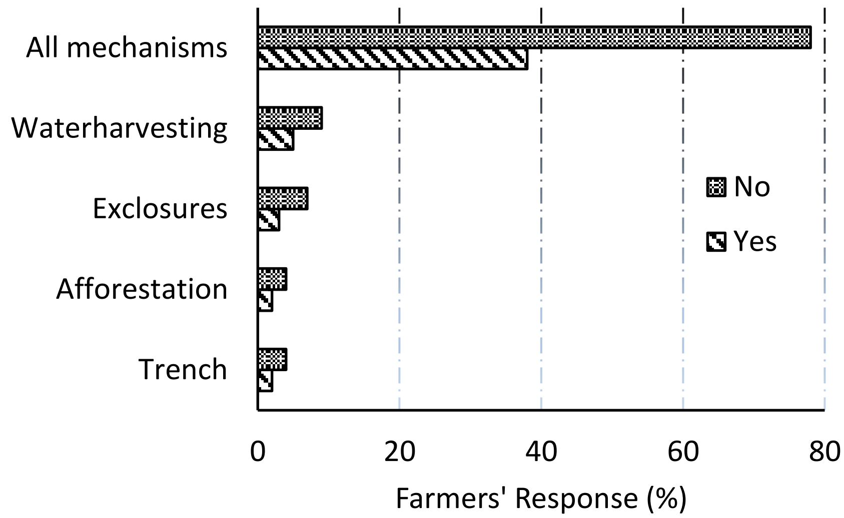

Figure 5: IWM practices implemented in the treated watersheds

3.3.2. IWM Impacts

Majority of the IWM beneficiary farmers reported positive impacts from the interventions (Table 3). The impacts mentioned were reduced soil erosion, improved vegetation cover, increased land productivity, and improved access to water (domestic and irrigation). Majority (83%) of the respondents from the treated watersheds and only 4% from the non-treated watersheds believe that the quality of their surrounding grazing land has shown an improvement in the last five years. Majority of the interviewees in the treated watersheds (85%) and untreated watersheds (14%) also reported an increase access to irrigation water sources. These results are in par with the findings of Wolka *et al.* (2023) that stated 70% of farmers perceived positive effects of watershed management in climate change adaptation. Our findings are also in conformity with Tofu *et al.* (2022) that reported watershed management activities have improved soil fertility, rehabilitated degraded lands, replenished dried ponds, and increased water discharge. This corresponds with the findings of Teka *et al.* (2020), Gebregergs *et al.* (2021) and Gebrehiwot *et al.* (2022) who witnessed IWM practices improved vegetation cover, improved water potential, increased soil carbon sequestration and reduce soil erosion in the northern highlands of Ethiopia.

Table 3: Farmers' perception on the role of IWM

Indicators	Treated		Non-treated	
	Yes (%)	No (%)	Yes (%)	No (%)
Increased land productivity	100	---	---	100
Reduced soil erosion	100	---	---	100
Improved domestic water sources	100	---	---	100
Better animal feed (grazing land)	83	17	4	**96**
Improved vegetation cover	100	---	---	100
Improved access to irrigation water sources	85	15	14	86

The dominant water sources in the studied watersheds are listed in Figure 6. Use of potable water from springs and wells was a new phenomenon in areas near or in the treated watersheds because of the increased ground water potential. However, 25% of the sample population still depend on river for domestic uses.

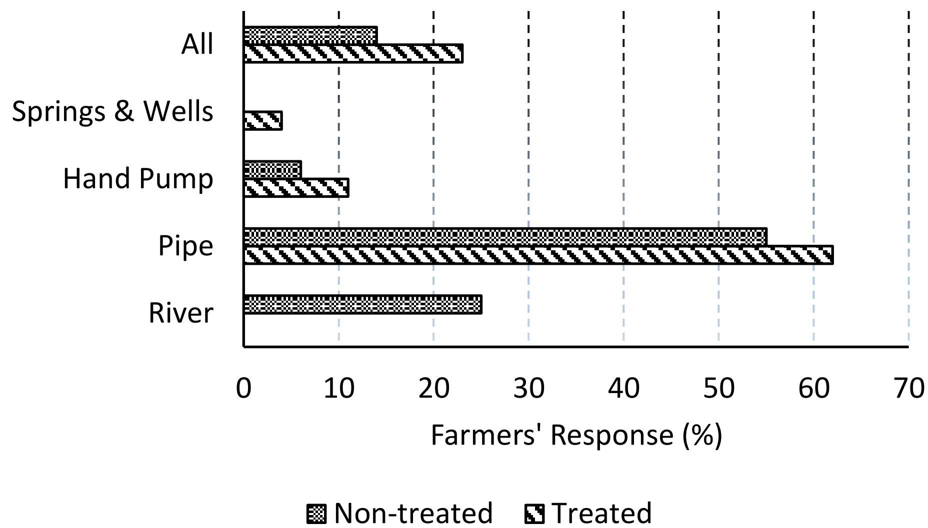

Figure 6: Households' Perception (%) on the role of IWM to water sources improvement

4. Conclusions and Recommendations

Communities living in both areas, had sufficient knowledge and awareness about the concept, the causes and impacts of climate changes. In the treaded watershed, they are also well aware on how to effectively use mechanisms to mitigating the impacts. The farming community understood the results of the implemented IWM practices in reducing unexpected floods, soil erosion, land degradation, as well as increasing vegetation cover, surrounding hydrology and land productivity.

To sustainably enhance the effectiveness of IWM as a strategy for climate change adaptation and mitigation, the farming community has proposed the following measures: i) Conduct training sessions, workshops, and experience-sharing events to educate the community about how to mitigate the impacts of climate change through different IWM methods; ii) Supply the community with necessary materials or resources to support the ongoing tasks; iii) Reward model farmers to motivate others and highlight the benefits of the operational tasks and let them realize the gap or difference created after the intervention; iv) Create favorable conditions for both governmental and non-governmental stakeholders to participate in and support environmental protection activities; v) Organize special social groups with their own bylaws to enhance the effectiveness of ongoing IWM interventions.

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Conflict of Interest

The authors declare that they have no conflicting interest.

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