Groundwater utilization practices for irrigation systems in east Hararghe zone, Ethiopia

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Abstract: Groundwater irrigation plays a critical role to improve food security and livelihoods of rural communities. However, proper utilization of groundwater remains a major constraint for farmers involved in irrigated agriculture. Therefore, this study has explored groundwater utilization practices for irrigation systems among farmers of east Hararghe zone, Ethiopia. Six kebeles from two districts were randomly selected for the study. Quantitative data was collected using an interview schedule from 300 households. Qualitative data was collected using key informant interviews and focus group discussions. Descriptive statistics were used to characterize demographic, socio-economic, and institutional characteristics of sample households. Chi-square and F-tests were used to see the association between independent variables and irrigation systems. Survey results revealed that about 1.67, 5, 9.33, 30.67, 53.33% of households practiced irrigation systems using small streams, ponds, shallow wells, borehole, and a combination of two or more of the above water sources, respectively. Moreover, the high cost of geo-membrane, shortage of motor pumps, and lack of farm tools to construct wells and boreholes

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PUBLIC INTEREST STATEMENT
Increases in food demand and climate variability have resulted in a chronic food shortage in Ethiopia. With increasing food demands of the population and small farm size owned in Ethiopia, it is useful to transform the rain-fed agricultural systems to the combined rain-fed and irrigated agriculture. Groundwater is a significant source of water for human consumption and irrigation. Groundwater is also relevant to sustaining ecosystems and ecosystem services. Thus, this study emphasized on groundwater utilization practices for irrigation systems. Improving the growth of food production and income of smallholder farmers require effective utilization of groundwater resource. Therefore, proper utilization and management of available water is a better solution for rain fed agriculture to cope up with rainfall variability.
are the major problems households faced to store and utilize water. Therefore, the supports of various stakeholders to the development of small scale irrigation are essential to transform smallholder farmers from rain-fed dependent to irrigated agriculture.

**Subjects:** Development Studies; Gender & Development; Regional Development; Research Methods in Development Studies; Sustainable Development; Development Policy; Rural Development

**Keywords:** groundwater; irrigation systems; perceptions; utilization; water storage

1. **Introduction**

Agricultural water is the primary resources for agricultural production to improve food security, incomes, and livelihoods of rural communities (Meshesha & Khare, 2019). Groundwater irrigation plays a critical role to promote poverty alleviation, food security, and farmers’ coping strategies to dry seasons and rainfall variability (FAO (Food and Agricultural Organization), 2014; Cobbing & Hiller, 2019). Eighty percent of groundwater is used for irrigation purpose (Hira et al., 2020). Groundwater also used for drinking and domestic purposes. However, reliable access to water remains a major constraint for millions of poor farmers involved in both rain-fed and irrigated crop production (IFAD (International Fund for Agricultural Development), 2015). Moreover, groundwater is not readily available for use, and vulnerable to prolonged drought (Ayala et al., 2018; Dou, 2016; Makombe et al., 2011). Multiple factors like groundwater overdraw, rapid depletion, rainfall shortage, and deforestation are causing stress on groundwater resources (Famiglietti et al., 2011; Fan et al., 2013). The level of groundwater table is not constant in fact it fluctuates due to recurrent drought, the way peoples watering their crops and weather-related process (Shiri et al., 2013). Thus, properly managed and utilized groundwater can increase water security for crop production (McCartney et al., 2013).

The rainfall variability particularly during the dry season has been the bottleneck for food crop production in Ethiopia (Meshesha et al., 2016). Rain-fed agriculture will be negatively shocked by rainfall variability and reduction in the number of rainy days in a year. Management and proper utilization of available water is a better solution for rain-fed agriculture to cope up with rainfall and climate variability. The wise use and management of water resources for the development of crop production is one of the crucial parts of water resources planning and management, and the economic and social development of smallholder farmers (Meshesha & Khare, 2019). Despite groundwater resources are recognized as crucial for sustainable agricultural growth and poverty reduction, increase in food demand and climate variability have resulted in a chronic food shortage in Ethiopia. Farmers’ perceptions towards irrigation water saving and utilization practices result in overexploitation of groundwater. Besides, the inappropriate planning and management of groundwater utilization is one of the most important factors (Dou, 2016). Furthermore, farm size per household is 0.5 ha, and the irrigated land per household ranges from 0.25–0.5 ha in Ethiopian (MoA (Ministry of Agriculture) Natural Resources Management Directorates, 2011). As a result, individual land holdings per household are too small to feed the household. With this limited farm size owned and increasing food demands of the population, it is useful to transform the rain-fed agricultural systems to the combined rain-fed and irrigation agricultural systems to produce two to three crops per year. Thus, improving the growth of food production and income of smallholder farmers require effective and optimal water resource development and utilization practices.

East Hararghe zone is one of the zones affected by the disappearance and shortage of water sources, climate variability, and recurrent weather-induced shocks such as drought (Setegn et al., 2011; Tesfaye & Seifu, 2016). In this area where the amount and distribution of rainfall are not sufficient to sustain crop growth and development, an alternative approach is to make use of groundwater for irrigation. Makombe et al. (2011) noted that irrigation development is a key for sustainable and reliable agricultural development which leads to overall development in Ethiopia. Groundwater is the key source of water for survival in the east Hararghe zone. Therefore,
knowledge and literature regarding groundwater utilization practices for various irrigation systems could enable the development of the irrigation sector and designing irrigation projects. Specific research has not yet been conducted to address problems related to groundwater utilization for irrigation systems. Therefore, this study has explored groundwater irrigation systems practiced by smallholder farmers; and aimed to assess farmers’ perceptions towards utilization of groundwater for irrigation purposes in east Hararghe zone, the eastern part of Ethiopia.

2. Literature review

2.1. Agricultural water scarcity

Water scarcity is an excess of water demand over available supply. It occurs when the demand for fresh water exceeds supply in a specified domain (FAO, 2012). In the study of Descheemaeker et al. (2010), water scarcity can be defined as economic or physical. Economic water scarcity is defined as a situation of water scarcity caused by insufficient human capacity or unequal distribution of water or financial resources to develop adequate water resources even though sufficient water in nature is available to meet human needs. For example, water scarcity in most parts of the countries like Ethiopia falls under this economic scarcity situation since Ethiopia is considered as having enough water resources. Physical water scarcity is present where water supply cannot meet the demands of a country’s population. Mostly dry or arid regions are associated with physical water scarcity. In the study of Mukheibir (2010), noted that hydrologists typically assess water scarcity by looking at the population-water equation. From the water stress index, when a country falls below 1000 m³ of fresh water per person per year, it is considered a water-scarce country; and if it is below 500 m³, the country is considered to be in absolute water scarcity. Water scarcity impacts billions of people globally (Mekonnen & Hoekstra, 2016). Economic water scarcity in Sub Saharan Africa manifests in 315 million people endemic food insecurity and low levels of irrigated agriculture (Pavelic et al., 2012; Siebert et al., 2010) and recurrent drought events (Besada & Werner, 2015), all of which can contribute to environmental migration and civil instability.

| Level of water stress                        | Annual renewable freshwater(m³/person/year) |
|---------------------------------------------|--------------------------------------------|
| Absolute water scarcity                     | <500                                       |
| Chronic water shortage                      | 500-1 000                                  |
| Regular water stress                         | 1 000-1 700                                |
| Occasional or local water stress             | > 1 700                                    |

Source: (Food and Agriculture Organization (FAO), 2012)

2.2. Groundwater depletion and shrinking of surface water

Groundwater is a significant source of water for human consumption and irrigation (Siebert et al., 2010). Groundwater is also relevant to sustaining ecosystems and ecosystems services. Globally, the area equipped for irrigation is about 301 million ha of which 38% are equipped for irrigation with groundwater. Total consumptive groundwater use for irrigation is estimated at about 545 km³ per year, or 43% of the total consumptive irrigation water use of 1277 km³ per year (Siebert et al., 2010). Availability of groundwater storage could insulate the people and their livelihood in areas exposed to drought although prolonged drought could compromise groundwater quantity and quality and exacerbate already ongoing degradation. For instance, groundwater supports over 50 percent of irrigation and 85 percent of rural drinking water in India (Das & Burke, 2013; Giordano, 2009).
However, global and local groundwater resources threatened by human activities (Cook et al., 2018; Pfahl et al., 2017). Increasing population numbers and expansion of irrigated agricultural areas are drivers for an ever-increasing demand for water worldwide. The resulting lowering of groundwater levels can have devastating effects on natural stream flow, groundwater-fed wetlands and related ecosystems. As of 2015, 11% of the global lake area has been lost mainly due to increased water consumption in support of irrigated agriculture within water-limited regions (Wine & Laronne, 2020). If groundwater abstraction exceeds the natural groundwater recharge for extensive areas and long times, overexploitation or persistent groundwater depletion can occur (Gleeson et al., 2010). According to Wada et al. (2010), global groundwater depletion increased from time to time, particularly in sub-humid and arid areas. Overuse of water resources at the local level provokes the thought that all usable water can be accessed (Molden, 2009). Furthermore, there could be various push-and-pull factors for accessing groundwater, which will ultimately determine the practical utility of groundwater to deal with water scarcity (Shivakoti, 2016). Ubiquitous availability, ease in access, vast storage potential, and reliable supply and quality are the pull factors attracting people towards groundwater. The pull factors make groundwater an ideal resource for drought mitigation. Push factors are unfavorable conditions when people have no other option than to resort to groundwater supply under constrained situations such as when extracting and assessing groundwater is expensive.

### 2.3. Water management and governance: environmental and equitability issues

There are some research priorities that will enable better integration of the planetary boundaries framework with existing water management and governance approaches. Given the complexities inherent in Earth System dynamics, numerous epistemic uncertainties are embedded in the planetary boundaries framework (Steffen et al., 2018; Westerberg et al., 2017). Zipper et al. (2020) describe how to integrate the water planetary boundary with water management from local to global scales. They clearly articulate a cross-scale approach to use the water planetary boundary in sub-global settings defined by physical features, political borders, or commercial entities. The planetary boundaries are a global environmental sustainability framework for identifying critical transitions points in the complex Earth System. The current freshwater use planetary boundary has been set at 4,000 km$^3$/year blue water consumption, the lower limit of a 4,000--6,000 km$^3$/year range that is considered a danger zone, and lead to poisonous or even catastrophic impacts on the Earth System (Gleeson et al., 2020). The revised freshwater use boundary has retained the consumptive use of blue water from rivers, lakes, reservoirs, and renewable groundwater stores (Steffen et al., 2015).

Water poses a serious challenge to sustainable development. Its scarcity threatens natural resources sustainability (Adeba et al., 2015). Humanity has faced environmental constraints at local and regional levels, with some societies dealing with these challenges more effectively than others (Costanza et al., 2006). Industrial societies often used local waterways and air sheds as dumping grounds for their waste and effluent from industrial processes. This eroded local and regional environmental quality and stability, threatening to undermine the progress made through industrialization by damaging human health and degrading ecosystems. Eventually, this led to the introduction of local or regional boundaries or constraints on what could be emitted to and extracted from the environment (e.g., chemicals that pollute air sheds or waterways) and on how much the environment could be changed by direct human modification (land-use /cover change in natural ecosystems) (Steffen et al., 2015).

Water resource development is essential to bring about sustainable growth of agriculture, rural development, and overall economic progress. Equitable access and rational use of water resources are important to cope with water scarcity. The optimal allocation of limited water resources for various purposes is required for sustainable development. Further, misuse and overuse of water in all the other sectors such as industrial, domestic, and the public should be avoided, because water is a finite resource and its future supply is uncertain (Adeba et al., 2015). Therefore, the equitable and wise use of water is important to guarantee water security and address the conflict arising among communities.
3. Research methodology

3.1. Description of the study areas

The study was conducted in Haramaya and Kersa districts, east Hararghe zone, Ethiopia. Haramaya district is located at 508 km to the east of Addis Ababa, the capital city of Ethiopia. It has an altitude range of 1600–2100 meters above sea level and its average annual rainfall is 790 mm. The mean annual temperature ranges from 17 to 24°C. The estimated population of the district is 271,394 persons; 138,376 male and 133,018 female (CSA, 2007). Out of the total area coverage of 52,163 hectares of the district, 38,183 ha are cultivable, 1,304 ha used for grazing, 52 ha covered by forest, 835 ha for bush and shrub, 5,582 ha for social service, and 6,207 ha for other purposes (Haramaya District Agricultural Office, 2019). Kersa district is located 482 km to the east direction from the capital city of the country. The altitude of the district ranges from 1400 to 3200 meters above sea level. The annual rainfall of the area ranged from 800 to 1500 mm and the minimum and maximum temperature are 18 and 26 °C, respectively. The total area of land of the district is 54,494 ha out of which 38% is cultivated, 2.3% pastures, 6.2% forest, and the remaining 53.5% are considered built-up degraded. According to CSA (2007), the district has a total population of 223,425 persons, of which 112,607 are males and 110,896 are females (Kersa District Administration Office, 2019). The farming system of the two districts characterized by mixed crop-livestock farming. The major crops grown are maize, sorghum, potato, beetroots, and sweet potato, and khat while the major livestock reared include cattle, sheep, goat, and donkey.

3.2. Sample size and sampling techniques

Smallholder farmers of irrigation user households were the target population for the study. Haramaya and Kersa districts were selected purposively due to their potentiality in irrigation practices in the east Hararghe zone. Two-stage random sampling procedures were used for the selection of representative sample households. In the first stage, six potential kebeles in irrigation use, three kebeles from each district, were selected from all 37 irrigation user kebeles using random sampling. In the second stage, 300 sample households were selected randomly from the sampling frame (a total of 8,919 irrigation user households) using the probability proportion sampling method. This was determined by using Yamane formula (Yamane, 1967):

\[ n = \frac{N}{1 + Ne^2} \]

Where: \( n \) = sample size of irrigation user households; \( N \) = irrigation user household heads (target population of sample kebeles, 8919) and \( e \) = level of precision at 5.68% (0.0568).

3.3. Methods of data collection

This study was based on a cross-sectional household survey. Both primary and secondary data were collected using qualitative and quantitative approaches. Quantitative data was collected using an interview schedule from rural households. Qualitative data was collected using key informant interviews and focus group discussions. Semi-structured questions were used to conduct FGDs and KIIIs. Focus group discussions were carried out with a group comprises six to eight members at each kebele on groundwater utilization, management and sustainability of irrigation systems practiced in the study area. Key informant interviews were conducted with Agricultural Extension Officers, and irrigation experts, local leaders and elders to gather technical information on mechanisms of irrigation utilization and development practiced by farmers.

Secondary Sources

Secondary information and literature on the knowledge of irrigation systems and farmers perceptions towards water utilization for the agricultural purpose was collected from different published articles, thesis, dissertation, books, proceedings and conferences.
3.4. Methods of data analysis
Data were analyzed both qualitatively and quantitatively. Quantitative categorical/dummy types of variables were analyzed using percentage, frequency, and chi-square test to see the association between categorical or dummy variables and irrigation systems. Quantitative continuous types of variables were analyzed using F-test to see the relationship between continuous variables and irrigation systems. Moreover, a narrative type of analysis was used to analyze the qualitative type of data collected using focus group discussions and key informant interviews. The data analysis was conducted using Statistical Package for Social Sciences (SPSS) version 22.

3.5. Operational definition of research variables and working hypothesis
4. Dependent variable
Irrigation systems practiced by farmers is the dependent variable of the study. Six irrigation systems were identified. The dependent variables of the study are specified as:

\[ Y_k = \begin{cases} 
1, & \text{if the household uses } K\text{th irrigation system} \\
0, & \text{otherwise} 
\end{cases} \quad (K = 1, 2, 3, 4, 5, 6) \]

Where \( k \) is the irrigation systems practiced by farmers from ground water source.

- \( Y_{k1} \) is irrigation system with irrigation ponds
- \( Y_{k2} \) is irrigation system with water supplied from irrigation wells
- \( Y_{k3} \) is irrigation system practiced using boreholes
- \( Y_{k4} \) is irrigation system using hand dug
- \( Y_{k5} \) is irrigation system directly diverting water from small streams
- \( Y_{k6} \) is irrigation system with two or more of the above water sources.

5. Results and discussion
5.1. Demographic characteristics of sample households
The survey results revealed that the proportion of male headed households practiced irrigation systems using wells, borehole, ponds, small streams diversion, and a combination of two or more systems was 96.4, 89.1, 86.7, 80.0 and 85.6%, respectively. The proportion of female headed households using wells, borehole, ponds, small streams, and a combination of two or more systems was 3.6, 10.9, 13.3, 20.0 and 14.4%, respectively. This indicates that in all irrigation systems, the proportion of male headed households exceed that of female headed households (Table 1 and 2).

The results showed that the mean age of the households practiced irrigation systems using wells, borehole, ponds, small streams and a combination of two or more systems was 37.96, 37.61, 37.87, 42.60 and 36.98 respectively. This indicates that households practiced a combination of irrigation systems was younger than other categories while households practiced small streams for irrigation systems were older than others. The mean household size for the households practiced wells, borehole, ponds, small streams, and a combination of two or more systems was 6.32, 5.79, 5.53, 5.20, and 5.47 respectively. Households practiced irrigation systems using wells have the highest mean household size while households using small streams have the lowest mean household size. Results showed that the mean years of schooling completed by household heads practiced wells, borehole, ponds, small streams and a combination of two or more systems was 3.79, 3.36, 3.13, 1.20 and 2.95, respectively. This indicates that household heads practiced irrigation systems using wells achieved a relatively better level of education than households practiced the remaining systems (Table 3).
Table 1. Definitions of independent variables for the study

| N  | Variables                          | Variable type | Description and measurement                                                                                                                                 | Expected sign |
|----|-----------------------------------|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| 1  | Sex of household head             | Dummy         | 1 if the household head is male and 0, if it is female.                                                                                                   | ±             |
| 2  | Age of household head             | Continuous    | Number in years                                                                                                                                           | -             |
| 3  | Education status                  | Continuous    | Number of years of schooling (grade).                                                                                                                   | +             |
| 4  | Household size                    | Continuous    | Number of people in the household                                                                                                                                 | +             |
| 5  | Experience in water harvesting    | Continuous    | Households’ experience in water harvesting in years                                                                                                                                                             | +             |
| 6  | Perception on water utilization   | Categorical   | measured as 1: Strongly disagree, 2: disagree, 3: Neutral/undecided, 4: Agree, 5: Strongly agree                                                                 | +             |
| 7  | Extension contact                 | Categorical   | Frequency of annual extension contact                                                                                                                  | +             |
| 8  | Use of improved seed              | Dummy         | 1, if the household used improved seeds; 0 otherwise.                                                                                                   | +             |
| 9  | Training                          | Dummy         | 1, if household head has access to water storage related training; 0 otherwise.                                                                          | +             |
| 10 | Experience in irrigation use      | Continuous    | number of years since households started irrigated farming                                                                                             | -             |
| 11 | Crops grown by household head     | Continuous    | Number and frequency of crops cultivated by the household in a year                                                                                     | +             |
| 12 | External support                  | Dummy         | 1, if the household head supported by GO/NGOs; 0 otherwise.                                                                                               | +             |
| 13 | Market distance                   | Continuous    | Distance from household residence to nearest market in walking hours                                                                                     | +             |
| 14 | Weather information               | Dummy         | 1, if household head has access to climate information; 0 otherwise                                                                                     | +             |
| 15 | Farm size                         | Continuous    | Size of cultivated land in hectares                                                                                                                     | -             |
| 16 | Livestock holding                 | Continuous    | Total livestock holding in TLU                                                                                                                          | -/±            |
| 17 | Off-farm/non-farm income          | Dummy         | 1, if any member of the household is involved in off-farm/non-farm income sources; 0 otherwise                                                             | -             |

5.2. Economic characteristics of sample households
The mean livestock owned in TLU was 2.47. The mean livestock owned in tropical livestock unit for households practiced irrigation systems using wells, borehole, ponds, small streams and a combination of two or more systems was 3.07, 2.17, 1.72, 1.78 and 2.63, respectively. This shows that households utilize deep or shallow wells for irrigation owned greater livestock than those using other choices of irrigation systems. The mean farm size owned by sample household heads was 0.49 hectares with a standard deviation of 0.48. The mean farm size holding for households practiced irrigation systems using wells, borehole, ponds, small streams and a combination of two or more systems was 0.38, 0.52, 0.65, 0.78 and 0.47 respectively (Table 3).
### Table 2. Summary of dummy or categorical variables across irrigation systems

| Independent variables | Response          | Irrigation systems practiced by households (%) | Total (N = 300) | χ² |
|-----------------------|-------------------|-----------------------------------------------|----------------|----|
|                       |                   | Wells (N = 28) | Borehole (N = 92) | Ponds (N = 15) | Natural stream (N = 5) | Combination (N = 160) |
| Sex of household heads | Male              | 96.4           | 89.1             | 86.7           | 80.0               | 85.6               | 87.7 | 3.07 |
|                       | Female            | 3.6            | 10.9             | 13.3           | 20.0               | 15.0               | 12.7 |
| Non/off-farm income   | Yes               | 21.4           | 5.4              | 20.0           | 0.0                | 15.0               | 12.7 | 1.36 |
|                       | No                | 78.6           | 94.6             | 80.0           | 100.0              | 85.0               | 87.3 | 8.54* |
| Use of improved crop seed | Yes         | 64.3           | 62.0             | 66.7           | 40.0               | 60.0               | 61.0 |
|                       | No                | 35.7           | 38.0             | 33.3           | 0.0                | 40.0               | 70.0 | 1.36 |
| Access to water storage related training | Yes | 35.7           | 9.8              | 13.3           | 0.0                | 13.7               | 14.3 |
|                       | No                | 64.3           | 90.2             | 86.7           | 100.0              | 86.3               | 85.7 | 12.87** |
| Received support on water storage practices | Yes | 14.3           | 1.1              | 0.0            | 0.0                | 4.4                | 4.0  |
|                       | No                | 85.7           | 98.9             | 100.0          | 100.0              | 95.6               | 96.0 | 10.64** |
| Access to weather information | Yes | 53.6           | 26.1             | 46.7           | 40.0               | 50.6               | 43.0 |
|                       | No                | 46.4           | 73.9             | 53.3           | 60.0               | 49.4               | 57.0 | 15.91*** |
| Frequency of extension contacts per year | Once in a year | 43.8           | 26.9             | 57.1           | 100.0              | 16.4               | 25.2 |
|                       | Once in six months | 0         | 26.9             | 14.3           | 0.0                | 17.8               | 17.1 |
|                       | Every quarter     | 0             | 36.7             | 14.3           | 0.0                | 19.2               | 19.5 |
|                       | Every month       | 18.6          | 7.7              | 14.3           | 0.0                | 32.9               | 24.4 |
|                       | Twice in a month  | 12.5          | 3.8              | 0.0            | 0.0                | 9.6                | 8.1  |
|                       | Every week        | 6.3           | 0.0              | 0.0            | 0.0                | 4.1                | 3.3  |
|                       | Everyday          | 18.8          | 0.0              | 0.0            | 0.0                | 0.0                | 2.4  | 49.84*** |

***, **, * indicate statistical significance at less than 1, 5 and 10% probability level, respectively. Source: field survey, 2019
Table 3. Summary of continuous variables across irrigation systems

| Independent variables | Irrigation systems practiced by households (mean and standard deviation) | Total (N = 300) |
|-----------------------|--------------------------------------------------------------------------|-----------------|
|                       | Wells (N = 28) | Borehole (N = 92) | Ponds (N = 15) | Small streams (N = 5) | Combination (N = 160) | Mean (SD) | F—test |
| Age of household heads (years) | 37.96(11.54) | 37.61(11.14) | 37.87(13.01) | 42.60(14.47) | 36.98(12.16) | 37.40(11.82) | 0.32 |
| Household size (number) | 6.32(2.99) | 5.79(2.11) | 5.53(3.64) | 5.20(2.17) | 5.47(2.89) | 5.65(2.71) | 0.71 |
| Education level of households (years) | 3.79(3.51) | 3.36(3.74) | 3.13(3.81) | 1.20(2.68) | 2.95(3.59) | 3.13(3.62) | 0.77 |
| Experience in using irrigation (years) | 10.96(8.89) | 6.25(5.95) | 8.20(7.44) | 11.20(7.79) | 7.42(5.99) | 7.49(6.50) | 3.39*** |
| Distance to the nearest market (hours) | 0.79(0.39) | 1.05(0.35) | 1.00(0.17) | 0.73(0.51) | 0.98(0.45) | 0.98(0.41) | 2.64** |
| Frequency of crops produced (number) | 1.30(0.55) | 1.61(0.53) | 1.53(0.52) | 1.60(0.89) | 1.74(0.57) | 1.65(0.57) | 3.79*** |

***, ** indicate statistical significance at less than 1 and 5 % probability level, respectively. Source: field survey, 2019
The results revealed that the proportion of households engaged in non/off-farm income generating activities and practiced irrigation systems using wells, borehole, ponds, small streams, and a combination of two or more systems were 21.4, 5.4, 20, 0 and 15%, respectively. Similarly, the proportion of households not engaged in non/off-farm income activities, but practiced irrigation systems using wells, borehole, ponds, small streams and a combination of two or more systems was 78.6, 94.6, 80, 100 and 85%, respectively (Table 2).

5.3. Institutional characteristics of sample households
Survey results showed that the percentage of households utilized improved crop seed and practiced irrigation systems using wells, borehole, ponds, small streams, and a combination of two or more systems were 64.3, 62.0, 66.7, 40 and 60% respectively, whereas the proportion of households not used improved crop seed but practiced irrigation systems using wells, borehole, ponds, small streams, and a combination of two or more systems were 35.7, 38.0, 33.3, 60 and 40%, respectively. About 14.33% of the sample households took training on water resources management, the importance of groundwater for irrigation systems, rainwater management, and on how to access and utilize groundwater. The training was delivered by development agents, district agricultural office, local universities, and the private sector. The remaining (85.67%) of households did not receive training related to groundwater utilization practices mainly due to inaccessibility of the training and lack of opportunity to attend the training (Table 2).

Regarding receiving external support related to using irrigation, only 4% of sample households received support such as geo-membrane, money, technical advises, improved seed and farm tools from public universities, CARE Ethiopia, district agricultural office, and safety net providers. The remaining 96% of the household heads did not receive any support related to irrigation activities. About 43% of household heads access to weather related information whiles the remaining 57% of them not access to weather information. Out of the total sample household heads, 123(41%) of them had contact with extension workers in relation to practices of irrigation systems and groundwater utilization practices while 59% have no contact with extension workers related to water storage for an irrigation system. Accordingly, the statistical analysis result of the survey showed that 25.2, 17.1, 19.5, 24.4, 8.1, 3.3, and 2.4% of the households get extension contact once in a year, every month, every quarter, once in six months, twice in a month, every week, and everyday respectively (Table 2).

The minimum and maximum distance of household heads to the nearest market in walking hours was 0.17 and 2 hours respectively. The mean distance in walking hours for households practiced wells, borehole, ponds, small streams, and a combination of two or more irrigation systems were 0.79, 1.05, 1, 0.73 and 0.98 respectively. In relative term, households practiced irrigation systems of small streams have better access to the nearby market place (Table 3).

5.4. Psychological characteristics of sample households
Farmers’ perceptions on groundwater utilization practices are categorical variables measured as 5: Strongly agree, 4: Agree, 3: Neutral/undecided, 2: Disagree, 1: Strongly disagree based on 11 statements which indicate households perceive towards agricultural water utilization strategies. For example, regarding the statement on wise use of irrigation water consumes time and energy, 35.30% of households strongly disagree while 5.3% of them agreed. Moreover, 63% of households strongly agree with the statement storing water for small scale irrigation increases crop yield and important to secure food (Table 4).

5.5. Typology of groundwater utilization practices in the study areas
Smallholder farmers of the study area utilize groundwater resources using few technologies and traditional methods such as dig out open shallow wells (less than 5 meters), deep boreholes (less than 30 meters), hand dug wells, ponds, and small streams for small scale irrigation (Table 5). The major mechanisms of water application to crops from water sources were using motor pump. Based on the survey result carried out in the study areas, about 84.67, 12.67, and 2.66% of
Table 4. Farmers’ perception towards groundwater utilization practices (N = 300)

| Statement/items                                                                 | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|--------------------------------------------------------------------------------|----------------|-------|---------|----------|-------------------|
| Wise use of irrigation water consumes time and energy                          | 23.7           | 5.3   | 3.7     | 32       | 35.30             |
| Utilize surface irrigation water is better than groundwater                     | 13             | 7.7   | 4       | 41       | 34.3              |
| Effective utilization of irrigation water is not needed                          | 7              | 1.7   | 0.3     | 29.7     | 61.3              |
| It is difficult to harvest rainwater since it requires resources                | 46.7           | 38.3  | 4.7     | 6.3      | 4                 |
| Open wells and boreholes are essential for irrigation systems                   | 34             | 39    | 13.7    | 11       | 2.3               |
| Rainfall alone is sufficient to increase agricultural production                | 9              | 9.3   | 7.3     | 22       | 52.3              |
| Storing water for irrigation increases crop yield and secure food crops         | 63             | 31.7  | 2.3     | 1.7      | 1.3               |
| Irrigation water storage practices result in human diseases like malaria        | 25.3           | 18.3  | 13      | 25       | 18.3              |
| Water storage practices cause animal health problems                           | 24.7           | 13    | 17.7    | 31.7     | 13                |
| Scientific knowledge is superior than indigenous to store irrigation water     | 27             | 9.7   | 21      | 32.7     | 9.7               |
| Geo-membrane used to store irrigation water for the dry period is expensive     | 72.3           | 16.7  | 9.3     | 0.3      | 1.3               |

Source: Field Survey, 2019
Table 5. Types of irrigation systems practiced by households

| Irrigation systems                                      | Frequency | Percent |
|---------------------------------------------------------|-----------|---------|
| Irrigation system directly diverting water from small streams | 5         | 1.67    |
| Irrigation system practiced using ponds                  | 15        | 5.00    |
| Irrigation system with water supplied from open shallow wells | 28        | 9.33    |
| Irrigation system with water supplied from boreholes     | 92        | 30.67   |
| Irrigation system with two or more of the above water sources | 160       | 53.33   |
| **Total**                                                | **300**   | **100** |

Source: Field Survey, 2019

Households in the study areas apply water to their crops using a motor pump, watering cans or bucket and traditional diversion of water from small streams, respectively. However, the high cost of fuel is the major problem of households used a motor pump. About 146 (48.67%) of households faced a challenge of the high cost of motor pump fuel to apply water to their crops. The remaining 31.67, 10.33 and 9.33% of households influenced by long distance of farm land from water sources, inadequate labour, and scarcity of groundwater, respectively. According to FAO (2014), fuel costs and access to fuel constitutes a constraint for small-scale farmers.

5.6. Irrigation water and crop production
According to survey results, about 55, 40, and 5% of households produce crops twice, once and three times per year using irrigation, respectively. The first three major crops cultivated in the study area include khat, potato, and maize (Table 6). However, households faced a problem of crop failure while using irrigation. The causes of crop failure during 2018 cropping season include the shortage of irrigation water, diseases, unsuitable weather condition, inadequate credit services, poor water management, and poor adaptation of crop varieties.

5.7. Farmers’ perception towards agricultural water utilization
The result in Table 7 indicates that the opinion of sample households towards proper use of water, motivation to use groundwater, impacts of storing water on human and animal health, indigenous and scientific knowledge of water storing, and cost of using geo-membrane to harvest water across water storage practices for irrigation systems was statistically significant at less than 1% probability level (Table 7). The mean score of farmers’ perceptions and views about the wise use of groundwater for irrigation consumes time and energy was 3.5 with a standard deviation of 1.58, whereas the mean score of their perception towards the motivation to use groundwater compared to surface water for irrigation systems were 3.76 with a standard deviation of 1.34. Furthermore, the mean scores of the farmer’s perceptions towards effective utilization of groundwater for irrigation systems was rated 4.37 (Table 7).

5.8. Problems hindering groundwater storage and utilization practices
Households of the study area faced various problems while practicing water storage strategies for irrigation systems. For instance, lack of plastic sheet or geo-membrane (41.34%) stood first as one of the challenges farmers faced to store water for irrigation systems (Table 8). Plastic sheets are often used in constructing ponds for water harvesting. However, plastic sheets are not always available because they are not constantly imported. As a result, there is often a shortage of plastic sheets at local and central markets. Furthermore, the following problems are ranked by the sample households during the interview schedule.
Table 6. Types and amount of crops produced using groundwater irrigation in the study area

| Types of Crops | Frequency | Percent | Amount produced (kg) | Minimum | Maximum | Mean | Std. deviation |
|----------------|-----------|---------|----------------------|---------|---------|------|----------------|
| Khat           | 226       | 22.09   |                      | 10      | 4000    | 170.90 | 426.47         |
| Potato         | 183       | 17.89   |                      | 30      | 10,000  | 2111.79 | 1799.84       |
| Maize          | 122       | 11.94   |                      | 25      | 20,000  | 843.51 | 1717.02       |
| Onion          | 120       | 11.73   |                      | 50      | 10,000  | 1901.65 | 2123.71       |
| Sorghum        | 99        | 9.68    |                      | 100     | 3500    | 594.26 | 467.15        |
| Cabbage        | 83        | 8.11    |                      | 30      | 12,000  | 2613.68 | 2254.75       |
| Beetroot       | 44        | 4.30    |                      | 200     | 9000    | 1936.36 | 1798.72       |
| Tomato         | 33        | 3.23    |                      | 20      | 2000    | 928.97 | 645.44        |
| Carrot         | 33        | 3.23    |                      | 300     | 4000    | 1431.58 | 938.11        |
| Lettuce        | 25        | 2.44    |                      | 600     | 6000    | 2268.42 | 1542.02       |
| Garlic         | 18        | 1.76    |                      | 100     | 3500    | 772.77 | 931.76        |
| Spinach        | 18        | 1.76    |                      | 200     | 3500    | 1335   | 917.82        |
| Pepper         | 16        | 1.56    |                      | 50      | 1200    | 616.67 | 369.12        |
| Leek           | 3         | 0.28    |                      | 600     | 4300    | 2300   | 1868.15       |

Source: Own computation from survey data, 2019

5.9. Causes and proposed solutions for irrigation water scarcity in the study areas

According to survey results, about 95.67% of households responded that they faced a shortage of agricultural water during the 2018 cropping seasons whereas 4.33% of them did not face a shortage of agricultural water. About 65% of households faced agricultural water shortage in the months of January to March while 25.33 and 5.34% of them influenced by agricultural water scarcity from April to June, and October to December, respectively. The households asked whether or not they know the reasons for the agricultural water shortage. Accordingly, all households those faced agricultural water shortage for irrigation purpose (95.67%), responded that they know the reasons of water shortage in the study areas. Information regarding causes or reasons for irrigation water shortage in the study areas was gathered using focus group discussions and key informant interviews. Accordingly, many group discussants and key informants in Kersa district narrated the following reasons: the shortage of rainfall, prolonged drought, climate change, the decline of groundwater, shortage of labour to construct shallow wells, high cost of geo-membrane to prevent water loses, lack of modern machines to construct deep boreholes. Group discussants and informants in Haramaya district also mentioned various reasons such as lack of awareness and training on how to use irrigation water properly, an increment of irrigation users from time to time, deforestation, expensiveness of rainwater harvesting materials, and excess loose of water during water application to crops.

To overcome irrigation water scarcity, the participants of the focus group discussions and key informants interview suggested various mechanisms. These include short term training and advisory services on how to use irrigation water, rainwater harvesting, dig out multiple boreholes or wells, construct large water storage in groups, using geo-membrane to prevent water infiltration, use drought resistant and early matured improved seed, use agricultural inputs (pesticides, fertilizer, insecticides), government or nongovernmental support (e.g motor pump, fuel, geo-membrane, long water transferring tube, local farm tools used to dig out boreholes and wells, water detecting and extracting machines or technologies to construct deep wells and boreholes, generator or electric power to reduce the cost of fuel).
### Table 7. Summary of households’ perception towards groundwater storage practices (five rating likert scale)

| Statement/items                                                                 | Wells (N = 28) | Borehole (N = 92) | Ponds (N = 15) | Small streams (N = 5) | Combination (N = 160) | Total (N = 300) | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) | Mean (SD) | F—test |
|--------------------------------------------------------------------------------|----------------|-------------------|----------------|-----------------------|-----------------------|----------------|-----------|-----------|-----------|-----------|-----------|--------|
| Wise use of irrigation water consumes time and energy                          | 3.25 (1.51)    | 3.13 (1.78)       | 3.00 (1.77)    | 4.40 (0.55)           | 3.78 (1.41)           | 3.50 (1.58)     | 3.55***   |           |           |           |           | 3.55*** |
| Utilize surface irrigation water is better than groundwater                     | 2.93 (1.39)    | 4.37 (1.11)       | 4.07 (1.22)    | 3.00 (1.00)           | 3.55 (1.34)           | 3.76 (1.34)     | 10.06***  |           |           |           |           |         |
| Effective utilization of irrigation water is not needed                         | 4.18 (1.39)    | 4.41 (1.23)       | 4.60 (0.83)    | 4.00 (1.73)           | 4.36 (0.93)           | 4.37 (1.09)     | 0.56      |           |           |           |           |         |
| It is difficult to harvest rainwater since it requires labour, money, and materials | 1.71 (0.89)    | 1.84 (1.13)       | 1.80 (1.37)    | 2.80 (0.84)           | 1.81 (0.99)           | 1.83 (1.05)     | 1.17      |           |           |           |           |         |
| Farm ponds, open shallow wells and boreholes are essential for small scale irrigation systems | 2.25 (1.21)    | 2.07 (1.15)       | 2.00 (1.31)    | 2.20 (0.45)           | 2.08 (0.97)           | 2.09 (1.06)     | 0.22      |           |           |           |           |         |
| Rainfall alone is sufficient to increase agricultural production and productivity | 3.93 (1.25)    | 4.03 (1.39)       | 3.87 (1.46)    | 2.60 (0.55)           | 4.04 (1.31)           | 3.99 (1.34)     | 1.48      |           |           |           |           |         |
| Storing water for irrigation increases crop yield and important to secure food   | 1.29 (0.46)    | 1.49 (0.81)       | 1.67 (1.05)    | 1.00 (0.00)           | 1.48 (0.73)           | 1.47 (0.75)     | 1.21      |           |           |           |           |         |
| Water storage practices for irrigation systems causes human health problems such as malaria | 2.57 (1.23)    | 2.50 (1.49)       | 3.00 (1.73)    | 5.00 (0.00)           | 3.16 (1.41)           | 2.93 (1.48)     | 6.22***   |           |           |           |           |         |
| Water storage practices cause animal health problem                            | 2.82 (1.31)    | 2.49 (1.42)       | 3.13 (1.68)    | 4.60 (0.55)           | 3.18 (1.31)           | 2.95 (1.39)     | 5.73***   |           |           |           |           |         |
| Scientific knowledge of groundwater storage is better than indigenous knowledge | 2.68 (1.33)    | 2.36 (1.35)       | 2.47 (1.55)    | 3.20 (0.45)           | 3.25 (1.29)           | 2.88 (1.37)     | 7.37***   |           |           |           |           |         |
| Plastic sheet or geo-membrane used to store irrigation water for a long period of time is very expensive | 1.29 (0.46)    | 1.09 (0.29)       | 1.47 (1.06)    | 1.00 (0.00)           | 1.63 (0.92)           | 1.42 (0.78)     | 8.10***   |           |           |           |           |         |

*** indicate statistical significance at less than 1% probability level. Source: field survey, 2019
Table 8. Major problems households faced while storing water for irrigation systems

| Main constraints                                                                 | Frequency | Percent | Rank |
|---------------------------------------------------------------------------------|-----------|---------|------|
| Lack of geo-membrane                                                           | 124       | 41.34   | 1    |
| Shortage of motor pump                                                          | 64        | 21.34   | 2    |
| Lack of materials to construct wells and borehole (especially modern machine)   | 58        | 19.33   | 3    |
| Small irrigable land holding                                                    | 17        | 5.67    |      |
| Distance of farmland from water sources                                         | 16        | 5.33    | 5    |
| High price to purchase fuel for motor pump purposes                             | 8         | 2.67    | 6    |
| Lack of water saving irrigation technologies                                     | 6         | 2.00    | 7    |
| Conflicts between farmers within the same irrigation blocks due to issues related to sharing irrigation water | 3         | 1.00    | 8    |
| Lack of skill or knowledge about water storage practices and management          | 1         | 0.33    | 9    |
| Shortage of skilled labour to construct water storage techniques (well, borehole etc) | 1         | 0.33    | 9    |
| Lack of skilled labour to construct water storage techniques (construction of ferro-cement tanks) | 1         | 0.33    | 9    |
| Lack of water                                                                     | 1         | 0.33    | 9    |
| Total                                                                           | 300       | 100     |      |

Source: Field Survey, 2019

6. Conclusions

Farmers’ perceptions towards groundwater utilization practices result in overexploitation of groundwater. Besides, the inappropriate planning and management of groundwater utilization is one of the most important factors. Farmers’ opinions towards the proper use of water, motivation to use groundwater, and cost of using plastic sheet or geo-membrane were influenced by groundwater storage practices for small scale irrigation. Finally, groundwater resources located at deeper locations largely unutilized in the study area. Water mainly extracted manually by irrigators. Such water resources require greater technologies and finances to access. Therefore, properly managed and utilized groundwater for small scale irrigation can increase water security for crop production, particularly during dry periods.

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Disclosure statement

The authors have not declared any conflict of interests.

Data availability statement

The data used for this study can be obtained from the corresponding author.

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