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Impact of Hydropower Dam on Household Water Security: Evidence from Amerti-Neshe Reservoir in Northwestern Ethiopia

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Abstract

Understanding the impact of hydropower dam construction on adjacent local community water security is critical for identifying factors that influence water security as well as improving water supplies in rural areas. This study analyzes the impact of hydropower dam construction on the water security of households around the Amerti and Neshe dams in Northwestern Ethiopia. A multistage sampling procedure was followed to select 485 households (268 affected and 217 non-affected) for our analysis. A principal component analysis was applied to five dimensions of water security (access, utilization, affordability, quality, and quantity) and then the households water security index (HWSI) was constructed. An endogenous switching regression model was applied to analyze the impact of dam construction on the water security status at the household level in the study area. Our findings revealed that there is a significant mean difference in HWSI between affected and non-affected households regarding water access and quality. The average treatment effect indicates that the construction of the two dams has had a negative impact on household water security, reducing it by 12%. As a result, government and other stakeholders should consider relocating affected households to better areas in order to mitigate such negative effects on household water security.

Key words: Dam, Displacement, Household, Hydro-power, Security, Water

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Introduction

Water is an imperative human need as it is inextricably connected to agriculture, energy, industry, education, gender equality, the environment and, ultimately to the overall economic development. Globally, this is an essential component to achieve not only the SDG 6, which focuses on water and sanitation but nearly all of the SDGs (World Bank, 2020). Water security refers to the adaptive capacity to maintain the long-term availability, access to, and safe use of an acceptable and dependable quantity and quality of water for health, livelihoods, ecosystems, and productive activities in the face of risks and conflicts (USAID, 2020). Even though access to clean water is very essential for life, still 80 percent of the world's population lives in areas threatened by water insecurity (UN-Water and

UNESCO, 2019). Globally, 2 billion people have no access to safely managed drinking water and 3.6 billion people also lacked safely managed sanitation (WHO/UNICEF/JMP, 2020). In the least developed countries, 74 % of rural people do not have access to safe drinking water, putting them at risk of waterborne diseases and malnutrition (Agapitova et al., 2017) and 90% of countries in Africa are still water-insecure (Nkiaka, 2022).

Water security plays an indispensable role for achieving sustainable and inclusive growth. A water-secure world maximizes water productive power and minimizes its destructive force. Water security enhances environmental protection as well as social justice because it addresses the consequences of poor water

management. Over the past two decades, researchers and practitioners have tried to comprehend the socio-economic and environmental implications of increasing water security and its meaning in practice ([Global Water Partnership, 2014](#))

In Africa, nearly 29% of the continent's population has no access to basic drinking water while 40% of it has no access to sanitation ([Oluwasanya et al., 2022](#)). Specific to the Horn of Africa, the situation of water security is much pressing because of high population growth (urbanization), extreme poverty and income inequality in the area ([Olet et al., 2020](#)). Ethiopia has a relatively huge endowment of water, with a mean total surface water flow of roughly 122 billion m³/year, and renewable groundwater resources estimated at 2.6 billion (Ludi E., n.d.). Despite these water resource potentials, Ethiopia faces a number of water-security risks, many of which are exacerbated by climate change (erratic rainfall variability and drought), deteriorating small-scale subsistence agricultural activity and exacerbating household poverty and food insecurity ([Murgatroyd et al., 2021](#)). Hydrological variability and lack of access to water and sanitation are the major manifestations of water insecurity which is a challenge to achieve the country's development goals ([IMF, 2015](#)). This demonstrates that water security extends far beyond a country's water resource endowment, as there are water-scarce countries with better water security, while some of the world's most water-rich countries (such as Ethiopia) are still struggling to access improved drinking water ([Global Water Partnership, 2014](#)).

Since the time of the Imperial regime, Ethiopian governments have made a number of efforts to address the issue of water security, including the construction of various hydroelectric dams throughout the country ([Association, 2021](#)). The construction of dams can alleviate the serious impacts of climate change by mitigating the uncertainty associated with rain-fed agriculture and food insecurity and extreme poverty in the country. However, dam construction can have also negative consequences especially on the rural mass population that lives around the dam project sites. Dam constructions can result in deprivation of riverbank gardens and total switch-off the water security and these may lead to reduction of income of affected farm households (CGIAR Research Program on Water Land and Ecosystems ([WLE, 2017](#))). In this regard, ([Work & Cave, 2014](#)), for example, pointed out that reservoir filling of the Gibe III dam has endangered the water security of adjacent households. [Pradhan & Srinivasan \(2022\)](#) also revealed that, in spite of huge investments, dam construction has not improved households water security.

Reservoir dam constructions usually result in drowning of significant land which is originally covered by water. It can force many households to lose their home and their

agricultural land (both cultivated and grazing land). In most of the Sub-Sahara Africa countries including Ethiopia, development projects including dams are planned following a carrot-and-stick approach which often results in a displacement of people against their will with insufficient and unrecognized compensation ([Kraljevic et al., 2013](#); [Olana, 2006](#)). Further to its benefits, the construction of dams might facilitate for water insecurity as evidenced by a series of threats from Egypt and Sudan on the construction of the Great Ethiopian Renaissance Dam ([Association, 2021](#)).

In Ethiopia, limited studies have been conducted to understand the impact of hydropower dam conservation on adjacent household water security. A study by ([Hailu et al., 2020](#)) developed households' water security index using principal component analysis in the case of the Awash basin of Ethiopia. [Assefa et al. \(2018a\)](#) also undertook a study in which they tried to develop generic domestic water security index in the case of Addis Ababa, Ethiopia. These studies were limited to the construction of household's water security index and they didn't address the displacement-impact of dam construction on household's water security. In addition to this, studies by ([Kansara et al., 2021](#); [Murgatroyd et al., 2021](#); [Olana, 2006](#)) also tried to identify socio-economic and environmental challenges of dam construction on adjacent households.

In this study, we have investigated the impact of the Amerti-Neshe reservoir dams on the water security of the surrounding rural households. A study like this has paramount significance in expanding our understanding of the effect of multi-purpose dam construction on poor communities who mostly depend on land and agricultural produce thereof as the primary source of their livelihood. In this respect, we first conceptualize and develop households' water security index using five dimensions in the study area. Secondly, we have examined the impact of development-induced impact of dam construction on rural households' water security. Thirdly, our study provides robust results using an appropriate impact assessment econometric method known as Endogenous Switching Regression model to identify the impact of development-induced displacement (either from home or from cultivated land) due to the two reservoir dams on adjacent households' water security. Finally, this study has come up with supplemental policy options which can help to address problems of water security in the study area and beyond.

2. Conceptual framework

We have developed a conceptual framework ([see Figure 1](#)) that captures the overall the analysis of data in this paper. The framework indicates that the construction of hydroelectric dams can have several negative consequences on adjacent households' quality, quantity, affordability and utilization of water. It also

indicates that hydropower dam construction might have also a positive effect on households' water security through increasing access to water, access to small scale irrigation and through raising water utilization. In

this study, water security of households is demonstrated using five water dimensions – access, affordability, quality, quantity, and utilization.

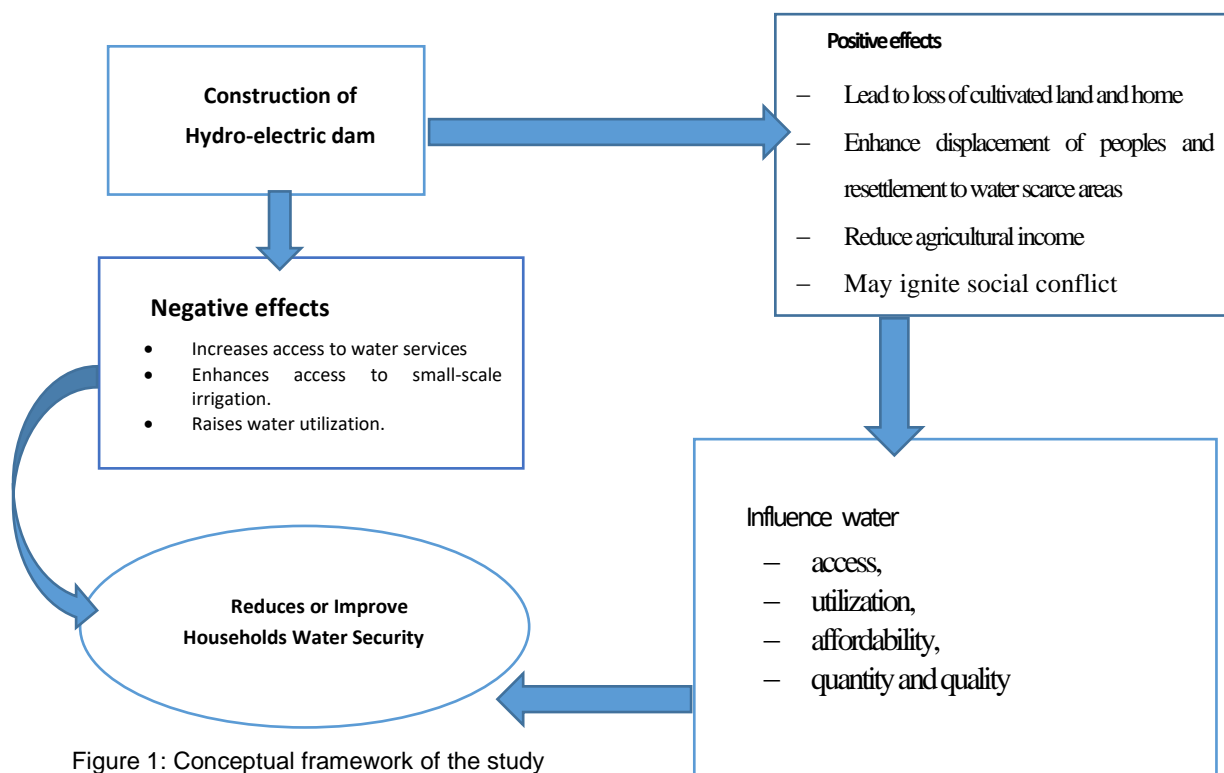
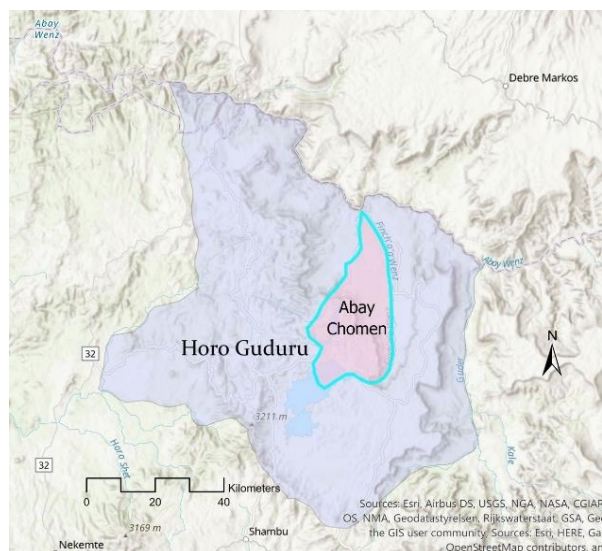
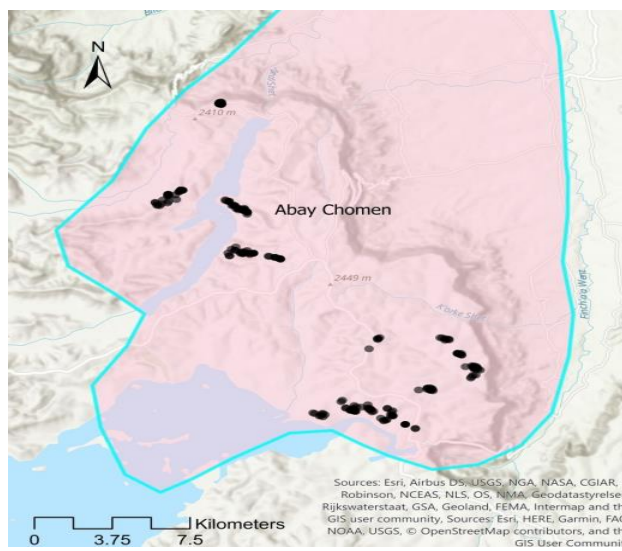


Figure 1: Conceptual framework of the study



Source: survey data

Figure 1: Distribution of sampled households



3. Materials and methods

3.1 Study area

This study is undertaken Abay-Chomen District in Horo Guduru Wollega zone of the Oromia Regional State (see

Figure 2) by focusing on the surrounding communities of the Amerti-Neshe reservoir dams. The Amerti-Neshe

watershed has a predominantly Woina Dega climate with an average annual rainfall of 1,823 mm between 1970 and 2006 with eighty percent of the rain occurring between May and September (Asefa, 2016). The mean monthly temperature varies between 14.9 and 17.5 degrees Celsius and has annual evapotranspiration of 1320 mm (Bellete, 2014). The watershed is predominantly composed of clay and haplic luvisol soil types (Bellete, 2014). The luvisol soil type is well-suited for agriculture due to its mineral and nutrient contents. Grasslands, wetlands, and forests are the common types of vegetation covers. Cultivated land makes up a significant share of the vegetation cover of the Amerti-Neshe watershed. While the cultivated land cover has continually increased over the years, the grasslands and wetlands have dwindled (Senbeta, 2018). The cultivated land is covered by various crops cultivated by smallholder households including teff, wheat, barley, sorghum, maize, millet, oats, lentils, beans, peas, sesame, vegetables, and fruits (Geleta & Deressa, 2021). The topography of the Amerti-Neshe catchment varies considerably from lowlands as low as 902 m a.s.l. in the downstream areas to highlands as high as 2448.5 m a.s.l. on the plateaus. This big difference in elevation has made the catchment prone to soil erosion and land degradation (Amdihun, 2006).

3.2 Sample size and sampling methods

We followed a multi-stage sampling procedure to select the study and the study respondents. The total population of the study area was 48,316. In the first stage, Abay-Chomen district was selected because it was the most affected district by the construction of the hydropower dams (three hydropower reservoirs in the district). In the second stage, 10 villages (both affected and non-affected) were randomly selected from the district following simple random sampling. After allocating the required sample size proportionally to each village, sample households were selected using a simple random sampling procedure. The authors followed (Yamane, 1967) sample size determination formula, which suggests minimum required sample size for any population size at a 5% level. After adjusting for a 75% response rate, the initial sample size (400) was

Table 1: Dimensions and indicators for determining Households' Water Security Index

Water Security dimensions	Indicators	Measure of indicators
Access	Distance to the drinking water source in minutes(one trip)	1 for access and 0 otherwise
	Stability of water service (scale)	

increased to 533 of which 485 households' respondents were used for actual data collection. The response rate was about 91%.

3.3 Data analysis

Data were analyzed in two steps: first we estimated household water security index using PCA, and second, we used Endogenous Switching Regression (ESR) model to assess the impacts of dam construction on affected and non-affected households as presented below.

3.3.1 Estimation of Households water security Index

In this study, households' water security index (HWSI) was developed using a principal component analysis. Major dimensions and indicators which were used to develop households' water security index is presented in Table 1. Once those dimensions and indicators were identified following previous studies (e.g. (Assefa et al., 2018b); (Hailu et al., 2020) and (Oluwasanya et al., 2022), a principal component analysis (PCA) was used. However, since indicators of households' water security are on a different scale of measurements, they should be rescaled between 0 and 1 using the following method (Chaves, 2014).

$$New_i = \frac{Actual_i - Minimum}{Maximum - Minimum}$$

Where New_i is the value of the newly rescaled variable for the i^{th} household, $Actual_i$ is the value of the original variable for the i^{th} household, minimum and maximum are the minimum and the maximum value of the original variables before rescaling.

In the first stage PCA was applied to indicators of water security in each dimension and then components was retained based on Kaiser's greater than 1 Eigen value criterion for each household. The retained (principal) component accounts for much of the variance among the set of original variables (Krishnan, 2010; Noko and Nwuzor, 2021). Then based on the retained components, indices were developed for each dimension, following (Chao & Wu, 2017) as follow

$$D_k = \pi * \lambda_k \dots \dots \dots (1)$$

Where D_k is the index of the K^{th} water security dimension π is the eigenvalue of the retained component and λ_k is the principal score of the component?

	The convenience of the water service (scale)	4 = good, 3 = acceptable, 2 = not-good, 1= not-applicable
Affordability	The monthly payment for drinking water Water point expense per month Number of days of interruption from the main source per month Who fetches the water (scale between 1 and 4)	USD USD Number of days 1 = women, 2 = Girl, 3 = Boy, 4 = men
Quality	Color of the water (scale) The smell of the water (scale) Test of the water (scale) Clarity of the water (scale)	4 = good, 3 = acceptable, 2 = not-good, 1= not-applicable 4 = good, 3 = acceptable, 2 = not-good, 1= not-applicable 4 = good, 3 = acceptable, 2 = not-good, 1= not-applicable 4 = good, 3 = acceptable, 2 = not-good, 1= not-applicable
Quantity	Per day water consumption in liters. Water collection container size. Frequency of water availability.	liters Jerican 1. Daily 24 hours a day 2. Daily at certain hours 3. Three – five days a week 4. One-two days a week 5. Less frequent than once a week
Utilization	Water for drinking (scale) Water for cooking(scale) Water for bathing(scale)	3 = Piped water/standpipe, 2 = Protected spring/well, 1 = Others 3 = Piped water/standpipe, 2 = Protected spring/well, 1 = Others 3 = Piped water/standpipe, 2 = Protected spring/well, 1 = Others

Source: Previous studies (Assefa et al., 2018b), (Hailu et al., 2020) and (Oluwasanya et al., 2022)

Once the indices for each dimension was developed, in the second stage PCA was applied to those indices of the water security dimension. In the first stage, one component was retained following Kaiser’s rule of greater than 1 eigenvalue criterion. Finally, households’ water security index was determined as the product of the eigenvalue of the retained component and the component score of the retained component for each household. The Households’ Water Security Index (HWSI) was constructed as above, and it has both negative and positive values. Thus, for better understanding, it was rescaled between 1 and 100, using the following formula:

$$NWSI_i = \left(\frac{OWSI_i - Minimum}{Maximum - Minimum} \right) * 100\%$$

Where $NWSI_i$ is the newly adjusted water security index of the i^{th} household, $OWSI_i$ is the original water security index of the i^{th} household, minimum and maximum is the minimum and maximum value of the original households water security index respectively.

3.3.2 Endogenous Switching Regression

The primary challenge in studying the impact of something using non-experimental cross-sectional data is obtaining appropriate counterfactuals, correcting self-

selection bias, and controlling for non-observable farm and household characteristics e.g OLS (Abdulai & Huffman, 2014; Becerril & Abdulai, 2010; Shiferaw et al., 2014).

If all assumptions of Ordinary Least Square (OLS) estimation are fulfilled, the impact of dam construction on households’ water security can be estimated as

$$Y_{ki} = \beta X_{ki} + \theta A_{ki} + U_{ki} \dots \dots \dots (2)$$

Where Y_{ki} Households water security index, X_{ki} is a vector of variables that affect households water security index and θ captures the impact of dam construction on households’ water security.

But, under violations of assumptions of OLS (like self-selection problem) θ might be biased so that the impact on water security will be biased. To correct the bias, Heckman selection or instrumental variable approach could be used (Wooldridge, 2002). Yet, these two approaches still assume that the water security function would differ only by a constant term between displaced and non-displaced households due to dam construction. In a real sense, the difference between the two is more systematic due to the potential interaction between the dam construction and water security determinants. Several studies used propensity score matching (PSM)

to deal with structural differences (Becerril & Abdulai, 2010; Asfaw et al., 2012). However, these differences were basically based on observed variables and PSM does not help much when there are unobservable factors affecting households' water security. In addition, when two groups of households have the same mean of covariates, it does not necessarily mean they have the same level of impact as their covariates can have different returns regarding water security function. The PSM and other approaches are therefore quantity-based impact assessment methods that ignore the returns to covariates that can influence outcome variable.

The Endogenous switching regression (ESR) model, which is a two-step estimation, in a counterfactual framework, disregards the assumptions imposed by PSM and other methods mentioned above (Lokshin & Sajaia, 2004; Wooldridge, 2002). Following Lokshin and Sajaia households were sorted into two regimes: those affected by dam construction and those not affected. In the first step of the application, one estimates the probability of a given household being affected by the construction of the dam using a probit regression model as follows:

$$A_{ki}^* = \alpha Z_{ki} + \mu_{ki} \dots \dots \dots (3)$$

Where A_{ki}^* is a binary variable equal to 1 if a farmer is affected by the construction of the dam and 0 if not; Z_{ki} is a vector of household characteristics that affect households water security, and μ is an error term normally and independently distributed with mean 0 and constant variance.

In the second stage, independent water security regressions are estimated for both affected and non-affected households. These regression functions can be given as follows.

$$\text{For affected: } WSI_{1i} = \beta_{1i}X_{1i} + \delta_1\hat{\lambda}_{1i} + \varepsilon_{1i} \text{ if } A_{ki} = 1 \dots \dots \dots (4)$$

$$\text{For non-affected: } WSI_{2i} = \beta_{2i}X_{2i} + \delta_1\hat{\lambda}_{2i} + \varepsilon_{2i} \text{ if } A_{ki} = 0 \dots \dots \dots (5)$$

Where WSI_{ki} are households water security index, $\hat{\lambda}_{ki}$ is the inverse Mill's ratios (IMRs) computed from the selection equation(first-stage) to correct for endogeneity and selection bias in the second-stage estimation (outcome equations), X_{ki} are different households characteristics, β and δ are parameters to be estimated, and ε_{ki} is an independently and identically distributed error term with mean zero and constant variance. The standard errors are bootstrapped to account for the hetero-skedasticity arising from the generated regressors(λ^*).

The endogenous switching regression model relies on trivariate joint normality of the stochastic terms ε_{1i} , ε_{2i} , and μ_i . This is given as follows.

$$cov(\varepsilon_{1i}, \varepsilon_{2i}, \mu_i) = \begin{bmatrix} \sigma_{\mu}^2 & \sigma_{\varepsilon_1\mu} & \sigma_{\varepsilon_2\mu} \\ \sigma_{\varepsilon_1\mu} & \sigma_{\varepsilon_1}^2 & \sigma_{\varepsilon_1\varepsilon_2} \\ \sigma_{\varepsilon_2\mu} & \sigma_{\varepsilon_1\varepsilon_2} & \sigma_{\varepsilon_2}^2 \end{bmatrix}$$

Where σ_{μ}^2 is the variance of the error term of the selection equation in the first step of the estimation; $\sigma_{\varepsilon_1}^2$ and $\sigma_{\varepsilon_2}^2$ are the variance of the error terms of the two outcome equations in the second step of the regression; $\sigma_{\varepsilon_1\varepsilon_2}$ are the covariance between the error terms of the two outcome equations. Because the two outcomes – being affected and non-affected– cannot be simultaneously observed for any given household, these variances cannot be defined. $\sigma_{\varepsilon_1\mu}$ and $\sigma_{\varepsilon_2\mu}$ measure the covariance between the selection equation and the outcome equations in each of the two regimes. If these covariances or, more accurately, the correlation coefficients ($\rho_1 = \frac{\sigma_{\varepsilon_1\mu}}{\sigma_{\varepsilon_1}\sigma_{\mu}}$ and $\rho_2 = \frac{\sigma_{\varepsilon_2\mu}}{\sigma_{\varepsilon_2}\sigma_{\mu}}$) calculated thereof, are statistically different from zero, endogenous switching is suspect. The endogenous switching regression is estimated and identified by the construction of non-linearity by getting proper exclusive restriction. To meet this requirement, at least one variable included in the selection equation should be excluded from the outcome equation, so that family size is used as an exclusive restriction in this study.

To examine and quantify the impact that dam construction had on households' water security, the average treatment effects on the treated (ATT, affected) and average treatment effect on the untreated (ATU, non-affected) should be calculated after the second-stage endogenous switching regression (Lokshin & Sajaia, 2004). To this end, the expected values of households' water security index for both affected and non-affected households were computed considering both actual and counterfactual scenarios. Following the studies of (Abdulai & Huffman, 2014), (Teklewold et al., 2013) and (Manda, 2016), the actual expected value of the water security index for affected households was calculated using the following formula:

$$E(WSI_{1i} | A_{ki} = 1) = E(\beta_{1i}X_{1i} | A_{ki} = 1) \dots \dots \dots (6)$$

By the same logic, the actual expected value of the water security index for non-affected households was estimated using the following formula:

$$E(WSI_{2i} | A_{ki} = 0) = E(\beta_{2i}X_{2i} | A_{ki} = 0) \dots \dots \dots (7)$$

Due to the reason that this study was only depend on one-time cross-sectional data, to finally estimate ATT and ATU, the expected value of households' water security index in counterfactual scenarios should be predicted. Counterfactual measures the average values of the water security index of affected households if they weren't affected by the dam construction and the expected values of the water security index of non-

affected households if they were affected by the dam construction.

Following (Lokshin & Sajaia, 2004), the counterfactual expected value of the water security index for affected households was calculated as

$$E(WSI_{2i} | A_{ki} = 1) = E(\beta_{2i}X_{2i} | A_{ki} = 1) \dots \dots \dots (8)$$

Using the same logic, the counterfactual expected value of the water security index for non-affected households is estimated as

$$E(WSI_{1i} | A_{ki} = 0) = E(\beta_{1i}X_{1i} | A_{ki} = 0) \dots \dots \dots (9)$$

Now the average treatment effect on the treated (ATT) and the average treatment effect on the untreated (ATU) are estimated using the following equations:

$$ATT = E(\beta_{2i}X_{2i} | A_{ki} = 1) - E(\beta_{2i}X_{2i} | A_{ki} = 0) \dots \dots \dots (10)$$

ATU

$$= E(\beta_{2i}X_{2i} | A_{ki} = 0) - E(\beta_{1i}X_{1i} | A_{ki} = 0) \dots \dots \dots (11)$$

years. Affected households were headed by older heads (47 years) as compared to non-affected households (44 years) and the variation is statistically significant at a 1% level of significance. The average family size of sampled households was 6.1 (higher than the country's average of 4.6 (CSA, 2017) with a minimum and maximum of 1 and 14 years, respectively. Affected households' family size (6) is higher than non-affected households' family size (5) and the difference is also statistically significant at a 10% level of significance. The average land holding size of sampled households was 11.5 hectare with a standard deviation of 80.32 which indicates that there is a big variation in in land size distribution among sample households in the study area. The average tropical livestock unit in the study area was 7.86 with a maximum value of 43.14. Moreover, affected households on average have lower tropical livestock unit (7.26) than non-affected households (8.61) and the variation is also statistically significance at 5% level of significance. This suggests that there was a real variation of TLU among affected and non-affected households, as augmented by study discussants; the affected households' tropical livestock unit was lost/reduced owing to the effects of dam construction. Table 2 also indicates that affected households have, on average, higher cost for improved seeds (155.6) than non-affected households (108.46) and the difference is also statistically significant at 5% level of significance.

4. Results and discussion

4.1.1 Socio-economic characteristics of the respondents

Table 2 presents the socio-economic characteristics of sample households in the study area. The average age of sampled household head in the study area was 45.79

Table 2: Characteristics of sample households in the study area: Continuous Variables

Variables	Mean	Std. dev.	Affected	Not-affected	T-test
			households(N=268)	(N=217)	
			Mean	Mean	
Age (Years)	45.79	14.11	47.3	43.9	2.63***
TLU	7.86	6.97	7.26	8.61	-2.12**
Land size(ha)	11.5	80.32	9.32	14.24	-1.41
Cost of fertilizer (Birr)	1474.7	20.62	1338	1643.6	-1.62
Cost of improved seed(Birr)	134.5	240.97	155.6	108.46	2.12**
Cost of pesticide(Birr)	235.1	326.5	227.4	241.4	Add res
Distance to water source(Minute)	15.5	14.5	16.13	14.71	1.06
Family Size	6.1	2.47	6.27	5.88	1.73*

Source: Jima et al. (under review). Note: ***, ** and * indicates statistical significance at 1%, 5% and 10% level of significance respectively.

Table 3: Characteristics of sampled households: Categorical variables

Variables	Affected households(N=268)	Non-affected households(N=217)
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		Total Freq.	Freq.	%	Freq.	%	χ^2 test
Gender	Male	396	219	18.3	177	18.4	0.0018
	Female	89	49	81.7	40	81.6	
Marital status	Married	445	241	89.9	204	94	2.64
	Un-married	40	27	10.1	13	6	
Credit Access	Yes	150	83	31	67	30	0.005
	No	335	185	69	150	70	
Access to Irrigation	Yes	143	76	28.4	67	31	0.36
	No	342	192	71.6	150	69	
Access to training	Yes	231	115	57	116	53.4	5.34**
	No	254	153	43	101	46.6	
Access to Electricity	Yes	323	164	61	159	73.2	7.86***
	No	162	104	39	58	26.8	

Source: Jima et al. (under review). Note: ***, ** and * indicates statistical significance at 1%, 5% and 10% level of significance respectively.

Table 3 demonstrates characteristics of sample households related with categorical variables. It also presents the chi-square test of linear independence between affected and non-affected households related to various categorical variables. The result indicates that 396 (81.65%) of the sample households in the study area were male while the rest were female headed households.

Table 3 also indicates that only 30.93% (150) of the sample households have access to credit services while the rest 69.07% didn't have credit service in the study area. This suggests that access to credit was very low in the study area. Regarding irrigation among sample households, only 29.48% (143) of them have access to irrigation while the rest 70.52% (342) sample households didn't have access to irrigation which indicates that access to irrigation was relatively low in the study area. The result also might suggest that benefit of the dam as a source of irrigation water for households was very low in the study area or households were not that much beneficiary from the dam for irrigation since it is not allowed to use the water for irrigation. Furthermore, affected households' access to electricity (61%) is found to be lower than non-affected households (73.2%) and the result is also statistically significant at 1% level of significance.

Regarding the displacement impact of the dams, 55.26% (268) of sample households were affected (either they

lost their land or they lost their original home) while the rest 44.74% (217) households were not-affected (neither they lost their cultivated land nor their home) by the construction of Amerti-Neshe reservoir dam in the study area.

4.1.2 Estimation of Households Water Security Index

The result of the estimation of indices for dimensions of water security is presented in **Table 4**. The component loading of almost all dimensions was greater than 0.5 which indicates that dimensions were well explained by the proposed indicators. Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy for access (0.61), affordability (0.5), quality (0.86), quantity (0.5) and utilization (0.66) were greater than equal to 0.5 suggesting that the sample size was good enough to undertake principal component analysis. The negative component loading (-0.45) of distance to the drinking water source in the access dimension indicates that access to water declines as the distance to water sources gets farther. The negative component loadings in the monthly payment for water (-0.48) and the number of days of interruption (-0.51) also suggest that those variables negatively affect the affordability of water for households. The positive component loadings for the rest of the indicators in each dimension suggest that those indicators positively affect households' water security in their respective dimensions.

Table 4: Component loadings of indicators of households' water security in each dimension

Water Security dimensions	Indicators	Component Loadings
	Distance to the drinking water source in minutes	-0.45

Access	Access to irrigation	0.33
	Stability of the service (scale between 1 and 4)	0.55
	The convenience of the service (scale between 1 and 4)	0.61
Affordability	The monthly payment for water (USD/month)	-0.48
	Water point expense (USD/month)	0.56
	Number of days of interruption from the main source (pre month)	-0.51
	Who fetches the water (scale between 1 and 4)	0.44
Quality	Color of the water (scale between 1 and 4)	0.49
	The smell of the water (scale between 1 and 4)	0.51
	Test of the water (scale between 1 and 4)	0.5
	Clarity of the water (scale between 1 and 4)	0.5
Quantity	Per day water consumption in liters	0.71
	Water collection container size (Jerican)	0.68
	Frequency of water availability (scale between 1 and 5)	0.15
Utilization	Water for drinking (scale between 1 and 3)	0.58
	Water for cooking (scale between 1 and 3)	0.61
	Water for bathing (scale between 1 and 3)	0.54

Table 5: Average component loadings of dimensions of households water security in the study area

Dimensions of households' water security	Component loadings
Access Index	0.63
Affordability Index	0.24
Quality Index	0.65
Quantity Index	0.27
Utilization Index	0.21

Table 5 presents the result of the second-stage principal component analysis in which PCA was applied on indices of major dimensions of households' water security. All of the component loadings were positive. This shows that those dimensions are positively related to households' water security. The result of the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was also 0.52 which indicates that our sample size was good enough to undertake principal component analysis.

Table 6 indicates the mean comparison test of households' water security index between affected and non-affected households. As clearly indicated, there is a significant mean difference in access and quality dimension between affected and non-affected households in which the latter has better access to (67.25) and quality of water (83.98). This might suggest that non-affected households have better overall water security than affected households. However, the result

also indicates that there was no significant mean difference between affected and non-affected households regarding other dimensions of water security. This might be attributed to resettlement of the affected households to areas where there was scarcity of water or low quality and utilization of water. The average household water security index (both affected and non-affected) is 45.8 which is even below the half way line and this suggests that water security in the study area was low. The result is consistent with the findings of (Assefa et al., 2018b) and (Hailu et al., 2020) who identified access, affordability and quality of water as major water security determinants and found that water security was still low in Addis Ababa and Awash basin of Ethiopia. The result is consistent with the finding of (Oluwasanya et al., 2022) who revealed that households' water security for most African countries is relatively meager.

Table 6: Indices of water security dimensions between affected and non-affected households

Households water security dimension	Affected households (N=268)	Non-affected households (N=217)	Mean difference	T-test
	Mean	Mean		
Access Index	59.8	67.25	7.44	3.4***
Affordability Index	47.21	47.00	-0.21	-0.4

Quality Index	73.56	83.98	10.41	4.94***
Quantity Index	10.83	11.69	0.85	1.44
Utilization Index	38.44	41.72	3.28	1.24

Note: ***, ** and * indicates statistical significance at 1%, 5% and 10% level of significance respectively.

Econometric result

This study employed an endogenous switching regression model to establish causal inference between households affected by dam construction and their water security, which controls for both observed and unobserved endogeneity (Khanal et al., 2020). In this case, the sources of endogeneity were the non-random sorting of households based on those affected due to the construction of the dams and those who did not. The first step in endogenous switching regression was to estimate the selection equation which identifies factors that influences the probability of a given household being affected by the construction of the dam.

The second stage endogenous switching regression was estimated by incorporating the inverse mills ratio terms from the first stage and removing the exclusive restriction (family size) from the first-stage estimation

(binomial probit regression (see the annex). Then the expected values of water security, as measured by the households' water security index (HWSI), for affected and non-affected households in both actual and counterfactual scenarios were estimated. Following that, the average treatment effect on the treated (ATT) and average treatment effect on the untreated (ATU) were predicted as the difference between actual and counterfactual scenarios for affected and non-affected households respectively. The result of ATT and ATU estimation is presented in Table 7. The average treatment effect on the treated (-5.9) was statistically significant at a 1% level of significance. Similarly, the average treatment effect on the untreated (4.7) was also statistically significant at a 1% level of significance.

Table 7: Average treatment effect of households' water security index (HWSI) after Endogenous Switching regression

Households Status	Households Water Security Index		
	Actual	Counterfactual	ATT
Affected	43.2	49.13	-5.9****
Non-affected	Actual	Counterfactual	ATU
	49.15	44.44	4.7***

Note: *** indicates statistical significance at 1% level of significance ATT= Average treatment effect on the treated ATU = Average treatment effect on the untreated

The findings suggest that, as a result of dam construction (which causes household displacement or relocation), affected households' water security was reduced on average, while non-affected households' positive average treatment effect was maintained (4.7). This indicates that non-affected households have a higher water security index, indicating better water security. According to these findings, affected households' water security index drops by 12% on average, while non-affected households' water security increases by 10.5 percent. The result implies that non-affected households would have low water security if they were affected while affected households would have better water security if they were not-affected. The findings suggest that the construction of a dam in the study area has reduced households' water security, which could be attributed to the relocation of affected households to remote or inaccessible areas with limited access to water services. It could also be attributed to a decrease in household personal income as a result of reduced agricultural production, which reduces households' ability to obtain significant quality and quantity of water. This study's

findings are consistent with those of (Soukhaphon et al., 2021; Hailu et al., 2020; Oluwasanya et al., 2022).

5. Conclusion and recommendations

As water is a building block for agriculture and food production, problem of water security has been the major focus of scientific literature particularly in developing countries. This study has examined the impact of Amarti and Neshe hydropower dam construction in northwestern Ethiopia. The study employed both descriptive and econometric data analysis methods. The result revealed that there is significant mean difference of water security index (WSI) between affected and non-affected households based on the access and quality of water at the household level. The average treatment effect after endogenous switching regression also indicates that the construction of Amarti and Neshe dams has negatively affected households' water security due to displacement of households from their land and their original home. Therefore, government and other related stakeholders should give utmost care especially to the resettlement of affected households so that the

negative consequence of dam construction on water security is reduced. Furthermore, this study recommends future studies on this topic to focus on the intensity of impact of hydropower dam construction on specific dimensions of households' water security.

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6.2. Funding

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6.3 Competing Interest: Author declare no competing interest

6.4 Data availability

Study data is available on request.

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Appendix 1: Result of first stage endogenous switching regression: Selection equation

Variables	Coef.	z	P>z	Marginal effects
Gender of HH head	.065 (.18)	0.35	0.724	.026
Age of HH head	.012(.004)	2.77	0.006***	.004
Marital status	-.46 (.27)	-1.71	0.088*	-.17
Education	-.34(.128)	-2.71	0.007***	-.13
Number of income sources	-.16(.12)	-1.25	0.213	-.063
TLU	-.026(.009)	-2.70	0.007***	-.01

Land size in hectares	-.0004(.0007)	-0.58	0.564	-.00017
Credit access	.0209(.12)	0.16	0.871	.0082
Access to Training	-.18(.12)	-1.40	0.162	-.071
Family size	.073(.026)	2.79	0.005***	.028
Use of Improved seed	.17(.125)	1.40	0.160	.069
_cons	.069(.38)	0.18	0.858	

Pearson goodness-of-fit test =9.41 LR $\chi^2(11)$ = 35.26
 $P > \chi^2 = 0.31$ $P > \chi^2 = 0.0002$

Source: Own computation (2022) NB: *** and * indicates statistical significance at 1% and 10% level of significance respectively. Numbers in brackets are standard errors.

Appendix 2: Result of Second Stage Endogenous switching regression estimation (Dependent variable: Households water security Index)

Variables	Affected (N = 268)			Non-affected (N = 217)		
	Coef.	Std. Err.	P>t	Coef.	Std.Err.	P>t
Gender(Male)	7.774863	2.956824	0.009***	1.839299	2.764676	0.507
Age	.2561593	.0974341	0.009***	.1413311	.0870475	0.106
Marital status (Married)	-7.0452	4.043326	0.083*	-7.01799	4.83067	0.148
Education(Illiterate)	2.228548	2.755399	0.419	-1.9261	2.734651	0.482
Number of income sources	-6.1696	2.239393	0.783	2.552422	2.189544	0.245
TLU	-4.8924	.1827509	0.008***	-.34772	.1692963	0.041**
Land size in hectare	.0169294	.0142313	0.235	-.00714	.0093881	0.447
Credit access	.8786055	2.002917	0.661	1.012935	2.003914	0.614
Access to Training	-4.95465	2.157239	0.022**	.61202	2.208939	0.782
Use of Improved seed	11.05891	2.036522	0.000***	5.2032	2.251095	0.022**
mills1	35.77717	8.614739	0.000***			
mills2				14.07235	7.377305	0.058*
_cons	7.423183	8.414367	0.378	58.10602	10.30517	0.000
	$Prob > F = 0.0000$			$Prob > F = 0.0197$		

Source: Own

computation (2022) NB: ***, ** and * indicates statistical significance at 1%, 5% and 10% level of significance respectively.