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Socio-Economic Effects of Flooding and Farmers' Adaptation Strategies in Fogera Flood Plain, Northwest Ethiopia

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Abstract

Flooding is a recurring challenge in Ethiopia, particularly in Fogera Woreda, where the main rainy season (June–September) exacerbates socio-economic and health vulnerabilities. This study assesses the determinants of farmers' adaptation to flood hazards, the socio-economic impacts of flooding, and the barriers to effective adaptation strategies. Using logistic regression analysis, key factors influencing flood adaptation were identified, including household head's gender, marital status, family size, livelihood diversification, previous flood experience, and access to credit, all of which positively impacted adaptation decisions. Conversely, age, educational level, access to irrigation, farm size, and extension services negatively influenced adaptation strategies. Farmers primarily adapted by using flood-tolerant crops, shifting to higher ground, and diversifying livelihoods. However, major barriers such as lack of financial resources, information, labor, and government support hindered effective adaptation. The findings highlight the urgent need for improved information dissemination, financial support, effective extension services, and community-based flood management systems. These measures can significantly enhance the adaptive capacity of vulnerable households and build resilience to flooding in the region.

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Introduction

Natural hazards, such as floods, are phenomena that cause significant damage to life, property, and ecosystems, leading to social and economic disruption (United Nations International Strategy for Disaster Reduction [UNISDR], 2009). Floods, in particular, are among the most widespread and devastating natural hazards globally, accounting for a substantial portion of natural disaster-related damage (UNISDR, 2010; Ologunorisa & Abawua, 2005). Dilley *et al.,* (2012) noted that around 19% of the Earth's land area and over 50% of its population are exposed to natural hazards, with floods affecting a large proportion of the global population. Human activities, such as deforestation and poor land use, exacerbate flood risks, particularly in agricultural areas (Kebede, 2012).

The frequency and intensity of floods are increasing due to factors like unplanned urbanization, poor watershed management, and climate change (Balaban, 2009; Stocker *et al.,* 2013). Flooding can result from heavy rainfall, snowmelt, deforestation, overgrazing, and poor water management (Woubet & Dagnachew, 2011; World Food Program [WFP], 2014). It particularly affects low-lying areas and regions near rivers, where soil erosion and deforestation contribute to increased runoff and river overflow (WFP, 2014).

Floods cause significant agricultural losses, negatively impacting farmers' livelihoods, particularly in flood-prone regions (Schellnhuber *et al.,* 2013; Bandara & Cai, 2014). Studies indicate that floods have resulted in an average of 12,700 deaths annually and displaced millions worldwide (Kundzewicz, 2004). In Sub-Saharan Africa, rapid urbanization, poverty, and environmental mismanagement have heightened vulnerability to floods (Ashok & Saroj, 2005). The Amhara region in Ethiopia, including Fogera district, is particularly vulnerable, with floods exacerbated by the proximity of communities to the Rib and Gumara Rivers, which drain into Lake Tana (UNOCHA, 2006; Wubet, 2006).

The impacts of flooding in Fogera are severe, affecting infrastructure, agriculture, and health services. Recurrent flooding in this low-lying region has led to displacement, damage to homes, and disruptions in services (Legesse, 2011). Despite various studies on flood hazards in Ethiopia, there is a lack of research on the socio-economic effects of flooding in Fogera, particularly regarding farmers' adaptation strategies. This study aims to assess the socio-economic impacts of flooding in Fogera and explore the adaptation strategies employed by local farmers.

The study's objectives include analyzing flood trends, examining the socio-economic effects of flooding, and identifying the factors influencing farmers' adaptation strategies. Understanding these dynamics is crucial for designing sustainable flood management strategies and informing policymakers and stakeholders about effective adaptation measures to mitigate flood risks in the region.

By investigating the socio-economic impacts of flooding and adaptation strategies in Fogera, this study provides valuable insights into the challenges faced by farmers and the broader community, helping to develop targeted interventions that reduce the negative effects of flooding in the region.

Materials and Methods

Descriptions of the Study Area

Fogera is a fertile and food-secure woreda in the Amhara Region, located in the South Gondar Zone. It is situated between 11°57' and 12°30' N latitude and 37°35' to 37°58' E longitude, bordered by Dera Woreda, Lake Tana, Rib River, and Farta Woreda. The area covers 117,414.02 km² and is divided into 33 rural and two urban kebeles, with Woreta as the administrative center (FDADO, 2021). The land is mostly flat, prone to flooding, with 76% of the area being lowland plains. The altitude ranges from 1,774 m to 2,410 m above sea level, with an average annual rainfall of 1,216 mm. The agro-climatic zone is Woina-Dega, and temperatures range from 11.5°C to 27.3°C. Vertisols and Luvisols dominate the lowlands, while Leptisols are found in the mountains (FDADO, 2021; Woubet, 2007; Endaweke, 2007).

The Rib and Gumara Rivers flow through the woreda, causing seasonal flooding that creates swamp areas. Lake Tana forms the western boundary, also flooding during the rainy season (Muluken, 2011; Shiferaw & Wondafrash, 2006). Land use includes arable land (53.8%), grazing land (18.7%), and grassland (7.7%) (FDADO, 2021). The total population of Fogera is 226,595, with a population density of 206 people per square kilometer, and the region's growth rate is 1.7%. Agriculture is the main economic activity, with rice, livestock, and fish farming practiced. Fogera is known for its indigenous Abyssinian zebu cattle and its significance as the birthplace of Aleka G/Hana (Desta, 2019). The district has 95 km of asphalt roads and 82.15 km of rural roads, along with multiple schools and health facilities (Fogera Woreda Administration Plan Commission Office, 2021).

Research Design and Approach

The researcher employed both cross-sectional and longitudinal research designs, utilizing primary and secondary data sources. A cross-sectional design was used to collect data from rural households through a questionnaire survey at a single point in time. This approach is simple, time-efficient, and cost-effective, allowing the researcher to study a large population simultaneously. In contrast, a longitudinal design was applied to analyze time-series data on rainfall and temperature. Overall, the study adopted a mixed-methods approach, combining both quantitative and qualitative methods to mitigate the limitations of using a single approach.

Sample Size and Sampling Techniques

Sample Size Determination

The sample size depends on the desired precision, and there is no single rule for determining it. However, a larger sample is more likely to be representative of the population. Following Yamane (1967), the sample size was calculated considering the confidence level, variability, and precision level. The formula used to calculate the sample size is:

$$n = \frac{N}{1 + N(e^2)}$$

- n = sample size,
- N= population size (total number of households),
- e = precision level (5%).

For the study, N=2130N and e=0.05. Applying the formula:

$$n = \frac{2130}{1 + 2130(0.05^2)} = 337$$

Thus, the estimated sample size is 337 households.

To select the sample households from each kebele, proportionate sampling was used. The proportion formula is:

$$n_j = \frac{N_j \times n}{N}$$

Where:

- nj = number of samples to be taken from each kebele,
- Nj_jNj = total population in each kebele,
- n = total sample size,
- N= total population of the selected kebeles.

Sampling Techniques

To draw inferences about the population, multi-stage sampling techniques were employed. In the first stage, Fogera woreda was selected purposively from three flood-prone woredas in the South Gondar Zone, as it is cost- and time-effective. Fogera was chosen for the following reasons:

The woreda is prone to flooding due to its location in the downstream part of the catchment, where the Rib and Gumara rivers join Lake Tana. Woubet Gashaw's analysis shows that 99.7% of swamps, 93.8% of grasslands, 27.9% of shrublands, and 24.1% of agricultural lands are at high to very high flood risk. The Rib and Gumara rivers overflow, and Lake Tana backflows frequently flood the woreda, displacing 43,127 and 8,728 people, respectively (UNOCHA, 2006).The Fogera Plain is one of the most severely flood-affected areas in Northwest Ethiopia, particularly in the Lake Tana catchment (Woubet & Dagnachew, 2011).

According to the Fogera Woreda Disaster Prevention and Preparedness Office (FWDPPO), there are 33 Rural Kebele Associations (RKAs). Ten of these (Nabega, Wagetera, Kidist-Hana, Shina, Shaga, Abua-Tihua, Tihua-Zakena, Quhar-Abo, Quhar-Michael, and Woreta-Zuria) are affected by flooding during the rainy season, with six of them (including Nabega-Kokit) identified as severely flood-affected every year (Shiferaw & Wondafrash, 2006; FWDPPO, 2021).

In the second stage, three RKAs (Nabega, Wagetera, and Abua-Tihua, also known as Kokit) were selected by simple random sampling (lottery method) to ensure equal selection chances.

In the third stage, households were selected using systematic random sampling from the list of household heads in each kebele, as the socio-economic characteristics of the households are similar. The sampling interval (K) was determined by dividing the total number of households in each kebele by the total sample size for that kebele. A reference number (R) was randomly chosen, and every K^{th} household head was selected thereafter (Feige & Marr, 2012).

Data Type, Sources, and Method of Data Collection

Source of Data

The study utilized both primary and secondary data sources to gather quantitative and qualitative information. Quantitative primary data were collected through a structured questionnaire targeting rural households. Secondary data on rainfall trends (1992–2021) were obtained from the Amhara National Meteorology Agency, Bahir Dar branch, to analyze flood hazard trends.

Additionally, socio-economic data were sourced from the annual reports of the South Gondar Zone Disaster Risk Prevention and Preparedness (DRPP) Office and the Fogera Woreda DRPP. Qualitative primary data were gathered through focus group discussions (FGD) and key informant interviews (KII).

Method of Data Collection

This study employed three main instruments for data collection: a household questionnaire (HHS), key informant interviews (KII), and focus group discussions (FGD). The questions covered demographic characteristics, flooding issues, and adaptation strategies against the socio-economic effects of floods. All instruments were prepared in the local language (Amharic) to ensure clarity and understanding among the respondents.

Household Questionnaire

The household questionnaire was the primary method used to collect data from the sample households. The questions were initially prepared in English and then translated into Amharic for ease of comprehension.

Both closed- and open-ended questions were included in the questionnaire. Closed-ended questions provided respondents with specific options to choose from, while open-ended questions allowed them to express their opinions, attitudes, and experiences regarding the socio-economic impacts of flooding, particularly on agriculture, livestock, and health.

The questionnaire was pre-tested with eight respondents (2.37% of the total sample size) who were not part of the main survey group. Based on feedback from the pre-test, necessary modifications were made before administering the final version to the actual respondents. Well-trained enumerators, supervised by the researcher, distributed and collected the questionnaires.

Key Informant Interviews (KII)

Key informant interviews were conducted to gather in-depth information from knowledgeable individuals about the study area's environmental, social, and economic conditions, as well as the adaptation strategies employed by farmers. Informants included local elders, the woreda natural disaster prevention focal person, development agents (DAs), health post workers, and the chairman of the kebele.

The primary objective of these interviews was to gain detailed insights into the occurrence of floods around Lake Tana and the two rivers (Gumara and Rib), as well as the broader socio-economic impacts and the adaptive measures used by farmers. A checklist was developed to guide the interviews.

Focus Group Discussions (FGD)

Focus group discussions were used to collect qualitative data and identify key contributing factors to the study. Two FGDs were conducted, each consisting of 7–10 participants, including household heads and experts with sufficient experience to understand the socio-economic effects of flooding and the adaptation strategies employed in the study area. Participants were selected based on their knowledge of local flooding issues and their involvement in flood adaptation practices.

Method of Data Analysis

After data collection, both quantitative and qualitative methods were used to analyze the data and achieve the study's objectives.

Qualitative Data Analysis

The qualitative data were analyzed using descriptive statistics, including frequency distributions, percentages, and graphical presentations such as tables, charts, and graphs. These methods helped in presenting the socio-economic effects of flooding based on the perceptions of the respondents.

Quantitative Data Analysis

The quantitative data were analyzed using an econometric model, with the help of software programs such as SPSS and Microsoft Excel. Data collected from the household survey questionnaires were processed, coded, and entered into the Statistical Package for Social Sciences (SPSS) version 23. Descriptive statistics, including means, standard deviations, and frequency distributions, were used to analyze the socio-economic impacts of flooding.

A five-point Likert scale was employed to measure the perceptions of farmers regarding the effects of flooding on their social and economic conditions in the sample kebeles of Fogera woreda. Additionally, simple statistical tools such as percentages, pie charts, tables, and bar graphs were used to present the data collected from the survey questionnaires.

Analysis of Meteorological Data

The meteorological data were analyzed using descriptive statistics. Missing data were filled in using the arithmetic mean calculation, which is simpler and more effective when the data from the nearest station's monthly rainfall are less than ten millimeters (ratio and distance methods were not used in this case).

Econometric Analysis

The relationship between dependent and independent variables was examined through binary logistic regression, as the dependent variable in this study is dichotomous. This method helped in identifying factors influencing farmers' adaptation strategies to flood risks. Additionally, line graphs and bar graphs were used to visually represent the survey results and to illustrate the relationship between variables.

In this version, I have simplified and streamlined the text for clarity, ensuring consistency and eliminating repetitive statements. I also made minor grammatical improvements. The references to software (SPSS, Microsoft Excel) and methods (binary logistic regression) were kept as part of the analysis approach, but if specific studies or authors were cited, they should be included in the references section.

Econometric model specification: Binary logistic regression model

The econometric method was applied to analyze the quantitative data to achieve the third objective: "To analyze the determinants of farmers' choice of adaptation strategies in response to flooding." Since the dependent variable is binary (1 = if any adaptation strategy was adopted in response to flood incidence; 0 = otherwise), the appropriate empirical model to capture the relationship between the dependent and explanatory variables is the logistic regression model.

Following Agresti (1996); Adesina (2000), and Santosh (2021), the logit model can be expressed as follows:

$$\ln(Y) = \ln(\text{odds}) = \ln\left(\frac{1-p}{p}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_p X_p$$

Where:

- Y is the binary response variable (1 = adopted any flood adaptation strategies; 0 = otherwise),
- β0 is the intercept term,
- β1,β2,…,βp are the regression coefficients of each explanatory variable,
- P is the predicted probability of adoption, and
- p1−p is the predicted probability of the decision not to adopt a particular adaptation option.

In logistic regression, the exponent of the coefficients (exp (β)\exp(\beta)exp(β)), also known as the odds ratio, is used to interpret the likelihood of an event occurring. The dependent variable (flood adaptation status) is determined by assigning a value of 1 to household farmers who have adopted adaptive measures in response to the negative effects of flooding. A value of 0 is assigned to household farmers who did not adopt any adaptive measures. For example, a farming household that uses at least one adaptation strategy to mitigate the negative impacts of climate-related shocks is considered to have "adopted" (1) (Mtinsilana, 2016).

Results and Discussion

General Characteristics of the Respondents

This chapter presents the results, interpretation, and discussion of the findings obtained from the analysis of primary data gathered from 337 household heads. Both descriptive statistics and an econometric model were used for data analysis. Descriptive statistics were employed to describe the demographic and socio-economic characteristics of the sampled households, while the econometric model helped analyze the farmers' decisions regarding the adoption of flood adaptation strategies in the study area. The socio-demographic attributes of the sampled households include sex, educational status, marital status, religious affiliation, and the status of alternative income sources (livelihood diversification). Table 2 below presents the frequency and percentage distribution of these variables.

As shown in Table 2, male-headed households constitute 268 (79.5%) of the sample, while female-headed households account for 69 (20.5%). This indicates that male-headed households dominate in the study area.In terms of educational status, the survey results revealed that 44.5% of the respondents had basic education (grades 1-12), 34.4% were illiterate, and 21.1% were able to read and write. This suggests that nearly half of the respondents (44.5%) had access to formal education.

The marital status of the respondents was categorized as married, divorced, and widowed. The majority of respondents, 91.4%, were married and living with their spouses, while 4.7% were widowed and 3.9% were divorced. The proportion of married respondents was significantly higher than those who were widowed or divorced. Regarding religious affiliation, 99.1% of the respondents were followers of Orthodox Christianity, while 0.9% adhered to Islam. In terms of livelihood diversification, 80.7% of households did not have off-farm income, while only 19.3% reported having additional sources of income outside of agriculture.

Descriptive Analysis of Continuous Variables

Table 3 below presents the descriptive statistics, including the minimum, maximum, mean, and standard deviation, for the continuous variables (age, family size, annual income, and farmland size) of the sampled households.

As shown in the table, the age of the respondents ranges from 18 to 72 years, with a mean age of 44.1 years. This indicates that the majority of respondents are relatively young, experienced, and within the productive age group. The household size in the study area varies from 1 to 12 members, with an average of 6.1 people per household and a standard deviation of 2.22.

This average household size (6.1) is higher than the national average of 4.3 and the regional average for Amhara (4.5) (Central Statistical Agency [CSA], 2010).The study also found that the average annual income of households is 129,608.16 Birr, with a minimum of 7,000 Birr and a maximum of 8,150,000 Birr. The significant variation in income is due to a few households benefiting from compensation for their land through the Rib's small-scale irrigation project. However, the majority of households earn between 35,000 and 105,000 Birr annually, indicating a relatively good income level. In terms of farmland size, the average landholding is 1.23 hectares.

Trends of Flood Hazards

The analysis of rainfall variability was conducted using mean monthly long-term rainfall data (1992 to 2021). This data was aggregated into annual averages for three decades from four selected stations: Debre Tabor, Ebinat, Addis Zemen, Woreta, and Wanzaye. These stations were chosen due to their significant contributions to the flooding of the Rib-Gumara catchment, which is influenced by poor watershed management at the top of Mount Gunna. Additionally, the downstream area's high-water availability contributes to the frequent bursting of rivers and their tributaries, originating from the highland mountains and flowing through lowland plains, with natural drainage systems formed by principal rivers (Dagnachew & Muluken, 2011; FDRE-NDRMC, 2018). The objective of the study was to examine the general rainfall trends in the study area.

Farmers in the study area are acutely aware that flood hazards have become a serious issue, affecting their social, economic, and environmental conditions.

To assess this, the sample households were asked whether flood hazards were present in their locality (see Figure 2). According to the survey, 97% of the respondents confirmed the presence of flood hazards, while 3% reported no such occurrence in their area.

Regarding rainfall trends, 48.4% of the respondents indicated that rainfall had increased, 43.9% reported no change, and 7.7% observed a decreasing trend. However, key informant interviews (KII) and focus group discussion (FGD) participants emphasized that it is challenging to precisely compare past and present flood trends without scientific investigations. Despite this, the majority of respondents and FGD participants agreed that flooding regularly occurs during the rainy season (June to September). The researcher concluded that flood hazards in the study area have increased over time, significantly affecting farmers' social, economic, and environmental conditions. This finding aligns with Tsega Gashu's (2013) study, which highlighted rainfall variability as a major risk for farmers dependent on crop production. The results are also consistent with the findings of Shiferaw and Wondafrash (2006), who documented severe floods in 1996, 1998, 1999, 2000, 2001, 2003, and 2006, which caused significant damage in Fogera Woreda, using GIS and remote sensing data.

Evidence indicates that flooding in the area east of Lake Tana is primarily caused by rising water levels and the back-and-forth flow of water into farmlands (MoWR, 2008). The World Meteorological Organization (WMO, 2010) also highlights that the fluctuating water levels of Lake Tana, particularly along its adjacent shores, are common. Poorly constructed weirs, such as the one at Chere-chera, have worsened the flooding situation by allowing the lake level to exceed its intended capacity.

Survey results revealed that 97% of respondents confirmed that floods occur regularly each year, with the majority reporting high (54%) to medium (42.1%) flood magnitudes.

Additionally, 95.5% of respondents stated that floods significantly impact their socio-economic conditions. Field observations corroborated these findings, showing that flooding is mainly caused by runoff and overflow from the lake, especially during the summer season when the lake's water level rises.

Trends of Rainfall in the Study Area

This study analyzes 30 years of rainfall data from five meteorological stations in the upper study area, which contribute to flooding in the Fogera plain. The highest rainfall recorded was at Addis Zemen (381.1 mm) in 2016, while the lowest was at Ebinat (9.4 mm) in 2015. The variation in rainfall is influenced by altitude, with higher stations generally receiving more rainfall. Floods in Ethiopia are common from June to September due to heavy rains from the highlands. Over the past 30 years, rainfall has increased, leading to annual flash floods, especially in the summer months. While some stations show an increasing rainfall trend, others, like Wanzaye, show a decrease. Ebinat station experienced steady rainfall, with significant variation recorded at Addis Zemen between 2015 and 2016.

The analysis of rainfall data is crucial for informing policy decisions related to cropping patterns, sowing dates, infrastructure construction (such as roads and dykes), implementing adaptive measures for flooding, and providing drinking water to rural communities. Figure 3 presents the linear trend line equation, illustrating the overall rainfall trend from 1992 to 2021. Based on the data from the household survey, focus group discussions (FGD), key informant interviews (KII), and the National Meteorological Agency, the general trend indicates an increase in rainfall. The trend line equation in Figure 3 identifies the line that best fits the data points, with the R^2 value reflecting the reliability of the trend. A higher R^2 value, closer to 1, indicates a better fit of the trend line to the data.

Economic Effects of Flooding

According to Amal Mohamed (2016), the scale for assessing opinions is as follows: 1 to 1.8 (strongly disagree), 1.81 to 2.6 (disagree), 2.61 to 3.4 (agree to some extent), 3.41 to 4.2 (agree), and 4.21 to 5 (strongly agree). Using this scale, respondents were asked to share their views on the impact of flooding on their cultivated land. The findings revealed that flooding significantly affected infrastructure such as rural roads, water supply, schools, health posts, farmer training centers, religious institutions, local administration offices, and small bridges, particularly during the rainy season. According to the Likert scale results, 90% of respondents agreed that flooding impacts these areas, while 45% were undecided and 15% strongly disagreed with the statement. These perceptions align with the survey results from the study area, showing that flooding severely affects local infrastructure and agricultural productivity each year.

The respondents agreed that flooding has caused significant damage to infrastructure across all three kebeles. During the field survey, respondents were asked to express their level of agreement or disagreement regarding the impact of floods on infrastructure. As shown in Table 4, 81.9% of respondents agreed that floods devastated infrastructure, 11.3% strongly agreed, and 6.8% disagreed that floods had damaged their infrastructural facilities. Additionally, when respondents were asked about the damage to their income from livestock due to flooding, the results indicated that 69.1% agreed, 16.3% strongly agreed, 8.3% were neutral or undecided, and 6.2% disagreed. This suggests that the majority of respondents reported a significant reduction in their income from livestock production due to flooding. Regarding agricultural products, the survey results indicated that 76.6% of respondents strongly agreed that flooding had negatively impacted their agricultural products, while 15.4% also strongly agreed. Conversely, 5.3% disagreed, and 3% were undecided. This further confirms that flooding has caused substantial damage to agricultural production in the study area. Furthermore, more than half of the respondents (64.7%) reported that flooding forced them to sell their cattle at significantly lower prices than the market value. This highlights the severe economic impact of flooding on farmers in the area.

The Social Effect of Flooding

The respondents were asked about the social effects of flooding, which were measured by damage to houses, environmental pollution, health impacts, and loss of life. The results revealed that 86.4% agreed on the health impact, 82.8% on environmental pollution, and 73.9% on house damage. However, only 24.0% acknowledged the loss of human life due to floods. These findings were further supported by the focus group discussions, where participants reported that frequent flooding forced them to rebuild their homes annually, as floods eroded the foundations, causing the houses to collapse. As a result, flooding disrupted social interactions within the community, particularly among farming households.

Regarding sanitation, 76.9% of farm households reported practicing open defecation, while 17.2% used traditional pit latrines and 5.9% used improved latrines. This indicates that open defecation was widespread, leading to contamination of water sources.

The impact of flooding on health was also evident, with 55.8% of households reporting incidences of diarrheal diseases, 26.1% affected by malaria, 12.6% by skin diseases (itching), and 5.5% suffering from coughs. This finding aligns with the study by Samson Wakuma (2008), which highlighted that floods increase the transmission of diarrheal diseases due to contamination of water and food sources. Similarly, outbreaks of diarrheal diseases were reported in various regions of Ethiopia following floods (UN OCHA, 2006). The outbreak of diarrheal diseases was particularly severe when displaced populations returned to their villages (Ethiopian Red Cross/Crescent, 2005). These findings underscore the significant adverse effects of flooding on the health, livelihoods, and social structures of the affected communities (Wakuma, 2008; UN OCHA, 2006; Ethiopian Red Cross/Crescent, 2005).

Determinants of Farmers' Decision to Adopt Flood Adaptation Strategies

This section presents the results of a binary logistic regression model analyzing the determinants influencing farmers' decisions to adopt flood control measures. Twelve explanatory variables were included in the model, comprising four continuous variables and eight dummy variables. The analysis revealed that eight of these variables—age (Age), sex (SEX), family size (FAMSIZ), livelihood diversification (LIVLHDV), previous flood experience (PRVSFLEXP), educational level (EDUC), access to extension services (ACCESEXENT), access to credit (ACCESSCRED), and access to irrigation (ACCESSIRRIG)—significantly influence farmers' flood adaptation decisions.

The regression results show that the age of the household head negatively affects the decision to adapt to flooding, with statistical significance at the 5% level. Specifically, older household heads are less likely to adopt flood adaptation measures (OR = 0.955), meaning younger household heads are more inclined to adapt to floods. Furthermore, male household heads are more likely to adopt flood adaptation strategies compared to female heads, with this difference being statistically significant at the 1% level.

Education also plays a role in adaptation decisions. Household heads who can read and write (OR = 0.166) or have basic education (OR = 0.176) are less likely to adopt flood adaptation strategies compared to illiterate heads. Larger farm sizes are associated with a lower likelihood of flood adaptation (OR = 0.675).Livelihood diversification is a key factor; farmers with additional income sources are more likely to adopt flood adaptation measures, with an odds ratio (OR) of 4. Additionally, prior flood experience significantly influences farmers' preparedness, with an OR of 103.68, indicating that those with past flood experiences are much more likely to take adaptive measures.

Access to irrigation, however, reduces the likelihood of adopting flood strategies (OR = 0.022), while access to credit increases the likelihood of adopting flood control strategies (OR = 5.28). This suggests that households with access to credit are more likely to implement flood adaptation practices than those without access.These results highlight several key factors influencing farmers' decisions to adapt to flood risks, with access to resources and past experiences playing significant roles.

Major Adaptation Strategies Used by Farmers

This section examines the various strategies adopted by sample households to mitigate the impacts of flooding. Respondents identified adaptation methods from a provided list, and their responses were analyzed in terms of numbers and percentages (refer to Figure 5).

The findings indicate that the most commonly used adaptation strategies include adopting flood-tolerant crop varieties such as X-Jigna rice (92.8%), shifting to higher ground (88.1%), selling off livestock (57.4%), and planting trees around homes and farmland (45.1%). Among these, the use of flood-tolerant rice was the most frequently practiced strategy, adopted by 218 respondents (92.8%). This aligns with the findings of Santosh *et al.,* (2021), which highlight the importance of flood-resistant crops in managing flooding impacts.

Approximately 70.3% of respondents employed adaptation strategies, while the remaining 29.7% did not implement any measures. The latter group primarily resides near the shores of Lake Tana, where extreme flooding during the rainy season makes adaptation challenging. Specific villages such as Baregie, Aba Gashu, Wushit, Sendegie, Damotgie, and Engor in Wagetera Kebele, as well as Fogerie Bet, Loha Bet, Aja Gebar, Tigrie Mender, Sarko, and Buabuatie in Nabega, are particularly affected. Focus group discussions (FGD) and key informant interviews (KII) revealed that residents from these areas often migrate temporarily to Kidst-Hana sub-municipality, where they rent housing for 3–4 months during severe flooding.In addition to the strategies mentioned above, FGD and KII participants highlighted that *Kothi* is a vital and widely used adaptation strategy in Fogera Woreda for mitigating flooding impacts. This underscores the adaptability and resilience of farm households in the study area despite the challenges posed by seasonal floods.

Barriers to Flood Adaptation

Communities face various barriers that hinder the successful implementation of flood adaptation strategies at the local level. Respondents who did not adopt any measures to mitigate the negative effects of flooding cited several significant challenges. These barriers and their corresponding percentage distributions are presented in Figure 6.

Among the respondents, 94.1% identified lack of money as the primary barrier to adaptation. Additionally, 80% reported a lack of information, while 82% cited a lack of labor as a challenge. Other significant barriers included shortage of cultivated land (68%), lack of membership in organizations (65%), lack of attention to the issue (56%), lack of support from the government (78%), and lack of access to technological inputs (68%).These findings highlight critical obstacles that prevent households from adopting effective flood adaptation strategies. Addressing these barriers is essential to minimizing the socio-economic impacts of flooding on vulnerable communities. To enhance flood resilience, stakeholders must prioritize interventions such as improving access to financial resources, disseminating relevant information, providing government support, and facilitating access to appropriate technologies.

Flooding is a recurrent issue in Ethiopia, particularly in Fogera Woreda, during the rainy season from June to September. Recent trends indicate an increase in flood occurrences, significantly impacting the socio-economic and health conditions of households in the region. The findings of this study align with prior research by Samson and Garon (2008) and Belay (2012), which documented flooding's adverse effects, including damage to farmlands, livestock, agricultural products, and infrastructure, alongside waterborne diseases such as diarrhea, malaria, and malnutrition.

The logistic regression analysis revealed that several factors positively influence flood adaptation decisions, including male-headed households, marital status, family size, livelihood diversification, previous flood experience, and access to credit. Conversely, factors such as the age of the household head, educational status, access to irrigation, access to extension services, and farm size negatively affect these decisions.

Key Findings

Gender: Male-headed households are more likely to adapt to flood hazards than female-headed households, as men often have better access to resources and networks for implementing adaptation measures. This finding supports the results of Santosh *et al.,* (2021) and Tiwari *et al.,* (2008).

Family Size and Marital Status: Larger family sizes provide more labor for adaptation efforts, making such households better prepared for flood hazards. This result is consistent with Tiwari (2021) and Baylie (2021), who argue that labor availability is crucial for adaptation.

Livelihood Diversification: Households with diversified income sources are better positioned to adopt flood adaptation strategies. Off-farm income provides financial flexibility, as observed in studies by Adesina *et al.,* (2000); Knowler and Bradshaw (2007), and Perez *et al.,* (2013).

Previous Flood Experience: Experience with past flooding positively influences preparedness for future incidents. Farmers accustomed to frequent flooding are more likely to adopt proactive measures. This aligns with the findings of Teshager *et al.,* (2013); Abebe *et al.,* (2020), and Santosh (2021), which emphasize that prior experience motivates adaptation behavior.

Access to Credit: Credit availability significantly enhances the ability of households to implement adaptation strategies, addressing liquidity constraints.

Age of Household Head: Younger farmers are more inclined to adopt flood adaptation measures, possibly due to greater openness to new agricultural technologies and lower risk aversion, as noted by Adesina *et al.,* (2000). However, older farmers may rely on practical experience to manage flood risks, as suggested by Teshager *et al.,* (2013).

Education Level: Surprisingly, education negatively influences flood adaptation decisions. This may be due to the lack of motivation among educated households to engage in proactive measures, as indicated by Protection Motivation Theory (PMT). This result contradicts Adesina *et al.,* (2000), who found education positively impacted adaptation decisions.

Table.1 List of Sample Kebeles and Number of Household Heads to Be Sampled

S/No	Sample Kebele	Total Household Heads (Male/Female)	Sample Size
1	Nabega	406/376 = 782	124
2	Wagetera	435/394 = 829	131
3	Abua-Tihua (Kokit)	271/248 = 519	82
Total		**1112/1018 = 2130**	**337**

Source: Fogera Woreda Administration Plan Commission Office (FWAPO, 2021).

Table.2 Socio-demographic distribution of the sample respondents

Variable	Attribute	Frequency	Percentage
Sex of household Heads	Female	69	**20.5%**
	Male	268	**79.5%**
Educational status	Illiterate	116	**34.4%**
	Read and write	71	**21.1%**
	Basic education	150	**44.5%**
Marital status	Married	308	**91.4%**
	Divorced	13	**3.9%**
	Widowed	16	**4.7%**
Religious status	Orthodox	334	**99.1%**
	Muslim	3	**0.9%**
Livelihood diversification(sources Of alternative income)	Farm income only	272	**80.7%**
	Off-farm income only	**65**	**19.3%**

Source: Household survey data, May2022.

Table.3 Descriptive statistics of continuous variables of the study

	Observations	Minimum	Maximum	Mean	Std. Deviation
Age of household	337	18.00	72.00	44.1335	**9.72616**
Family size of household	337	1.00	12.00	6.1454	**2.22130**
Annual income	337	7000.00	8150000 .00	129504.30 86	**530959.099 66**
Farmland size	**337**	**.00**	**4.00**	**1.2344**	**.49093**

Source: Household survey data, May 2022

Table.4 The Socio-economic effects of flooding in different years in the study area

S.No	Major effects of flooding	Events of Flood in Years							
		2005/6	2006/7	2007/8	2008/9	2009/10	2010/11	2011/12	**2012/13**
	Social effects of flooding								
1	Affected people	5214	3241	0	924	4217	5876	2315	**14993**
2	Displaced people	0	0	0	0	0	0	62	**8550**
3	House damaged	68			1416				**9986**
	Economic impacts								
1	Damage to cultivated land (ha)	1205.25	0	0	1255			896.75	**1404.25**
2	Affected Crop (Riceha)	275	985	0	756.5	1217	768	1271	**6063**
3	Damage of livestock (TLU)	796	0	0	646	0	490	10268	**9254**
4	**Dead Animals in (TLU)**	**23**	**0**	**0**	**0**	**0**	**62**	**1224**	**2102**

Source: Fogeraworeda Agriculture Development office

Table.5 Regression Results of Binary Logistic Model

Independent variables	**B(Coefficients)**	**Significance**	**Exp(B)=OR (Odds Ratio)**
Age	-.046	.035**	**.955**
SEX(1=Male,0=Female)	1.703	.009***	**5.489**
EDUC (0=Illiterate)		.003***	
EDUC(1=Read and Write)	-1.795	.003***	**.166**
EDUC(2=Basic education)	-1.737	.002***	**.176**
MART(0=unmarried, 1=married)	2.733	.006***	**15.372**
FAMSIZ	.224	.028**	**1.251**
ACCESSIRRIG(0=noaccess,1=have access	-3.803	.000***	**.022**
ACCESSCRED(0=no access to credit,1=got access)	1.724	.001***	**5.609**
ACCESEXENT(0=no access to extension,1=access to extension)	-.004	.993	**.996**
FARMSIZE	-.184	.675	**.832**
PRVSFLEXP(0=no previous flood experience,1=previous flood experience)	4.637	.000***	**103.204**
LIVLHDV(0=nooff-farm income, 1=farm income)	1.402	.040**	**4.063**
ANNUINCOME	.000	.943	**1.000**
Constant	2.399	.053*	**11.014**
N=337	-2 log likelihood	150	**Pseudo R^2=0.55**

N.B; ****P<1%, **P<5%*and **P<10% are significant levels respectively.*

Figure.1 Location Map of the Study Area

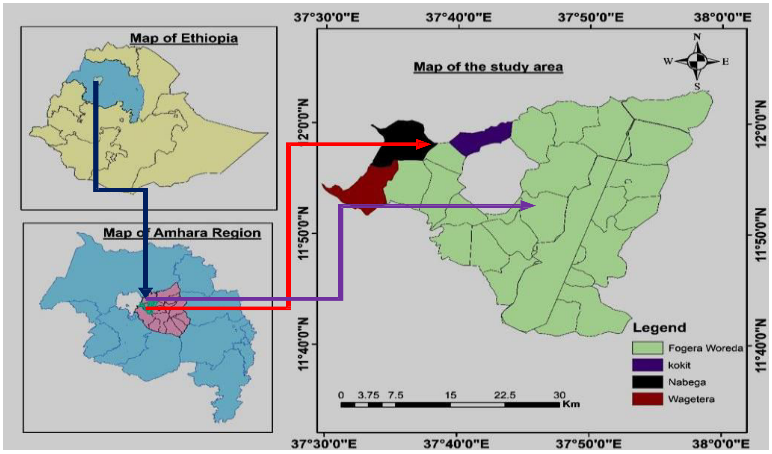


Figure.2 Trends of rainfall based on Households survey data, May 2022

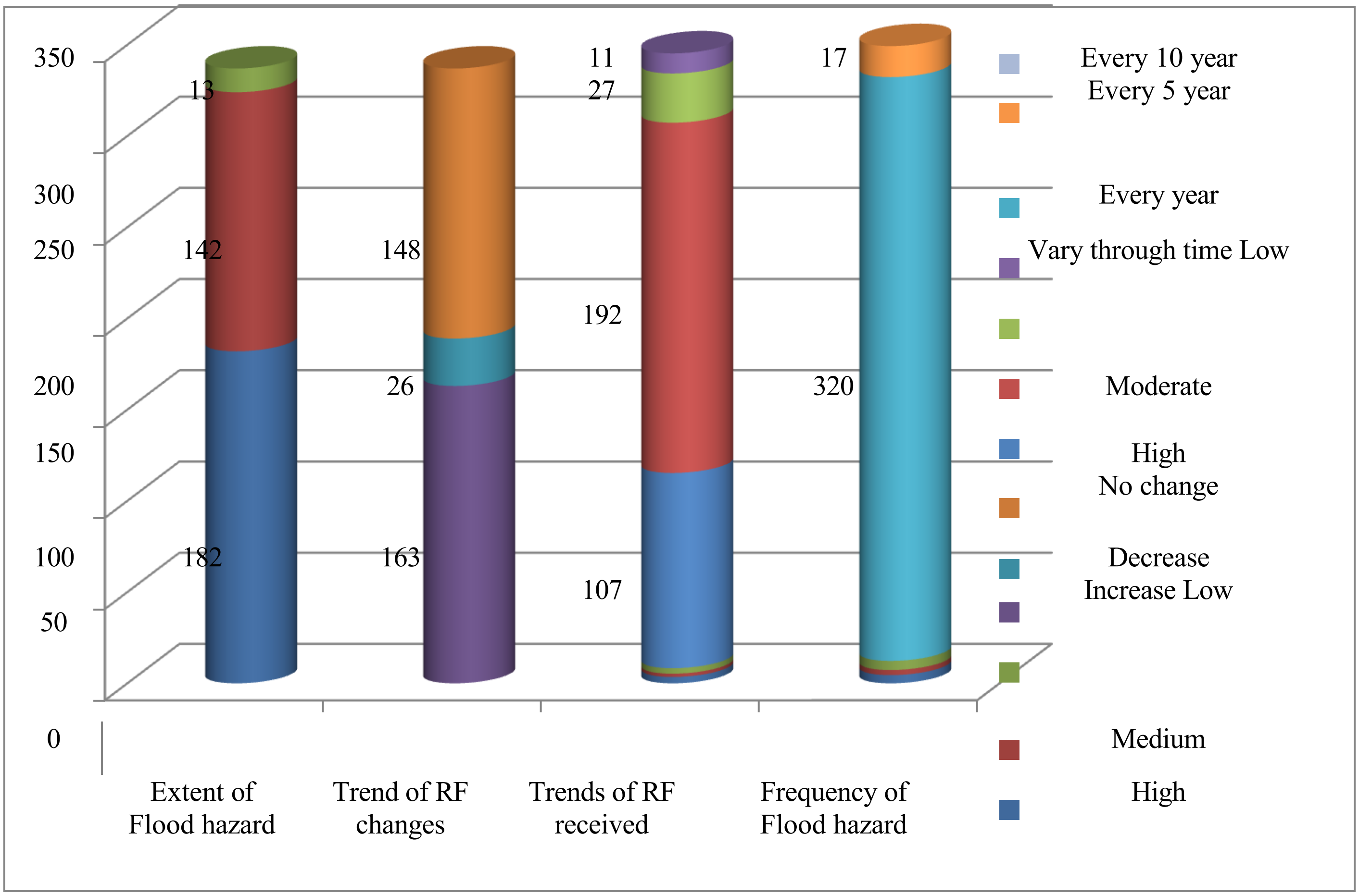


Figure.3 Annual trends of Rainfall of Five meteorological stations (1992-2021)

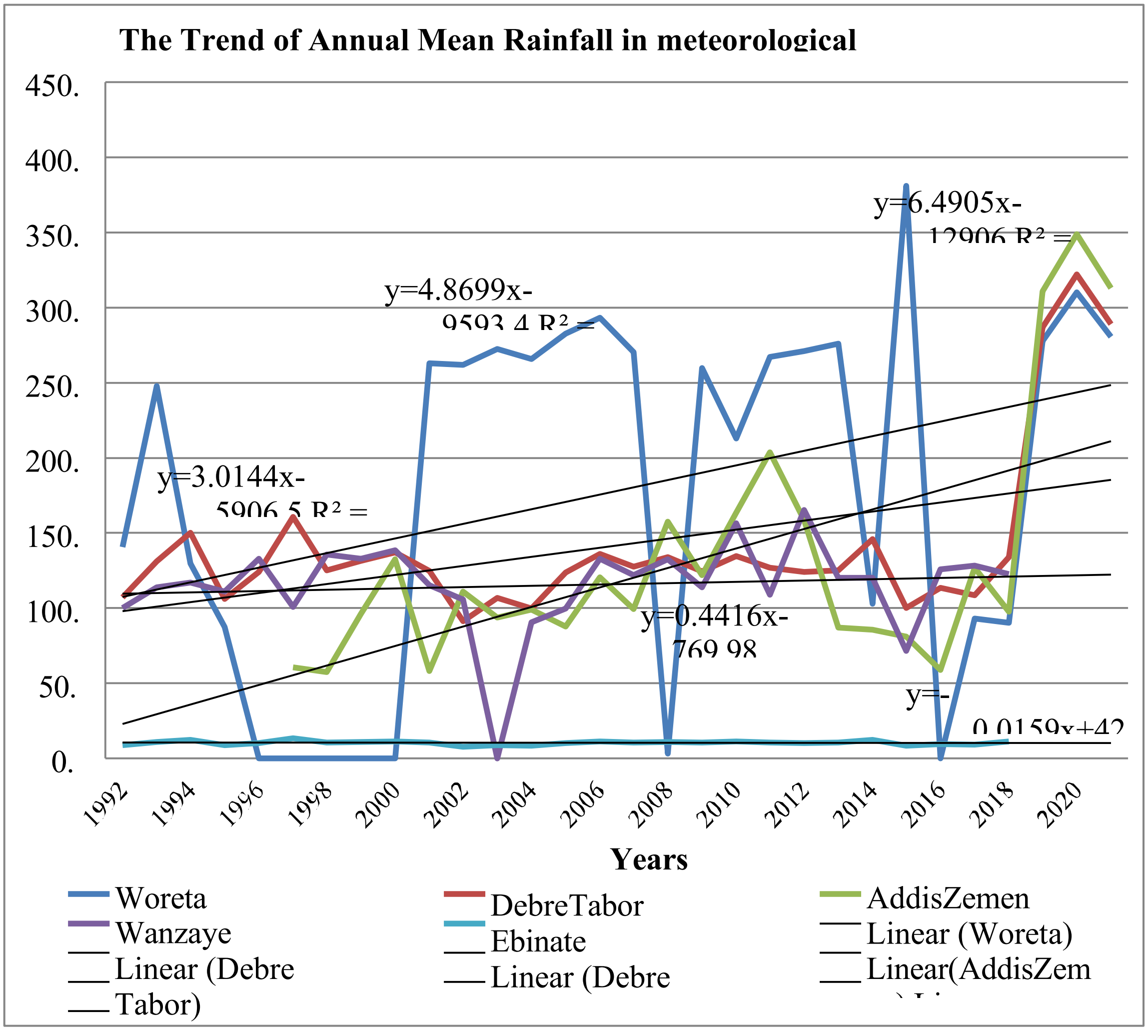
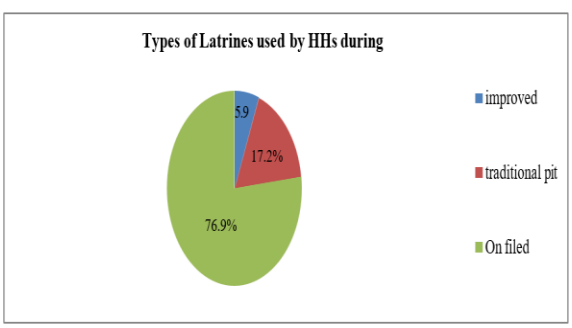


Figure.4 Common diseases experienced and the utilization of latrines by the farm households because of flooding



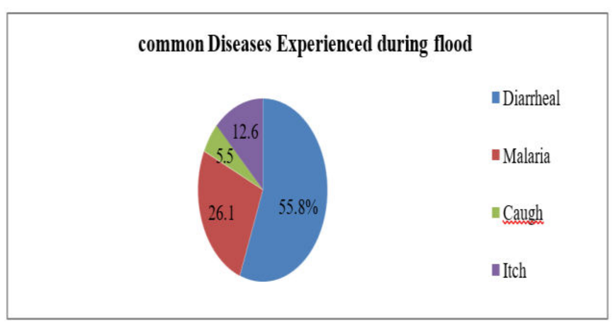


Figure.5 Adaptation strategies used by farm households in response to flooding

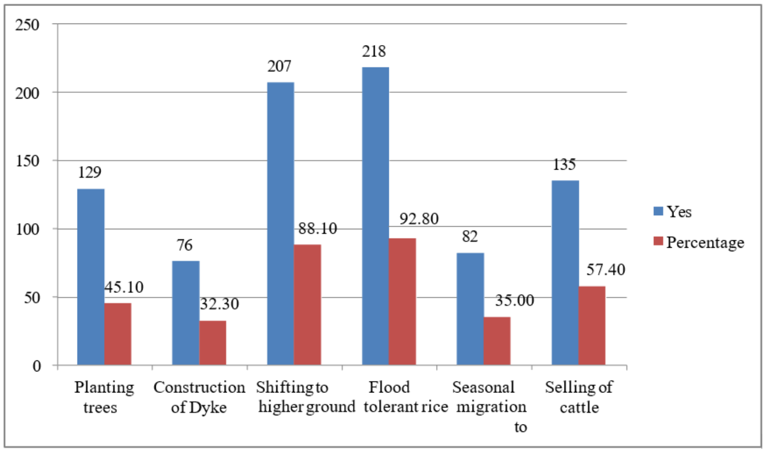
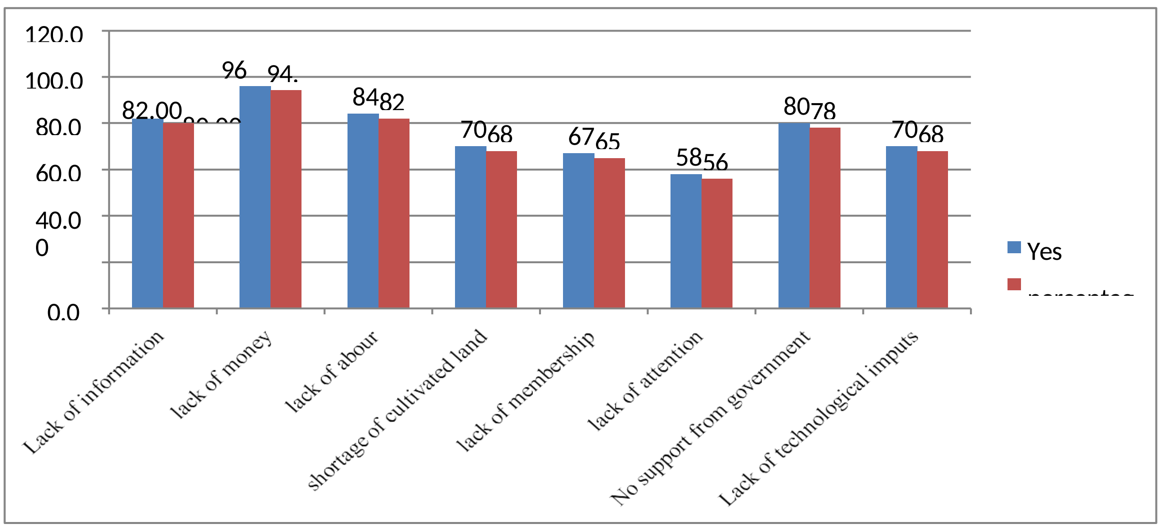


Figure.6 Barriers to Adaptation to Flooding Hazards



Access to Irrigation: Households with irrigation systems are less likely to adopt additional adaptation strategies, possibly because they rely heavily on irrigation as a primary solution.

Access to Extension Services: While extension services provide valuable information, their practical application may be limited. Inefficient implementation and the absence of extension agents during critical flooding periods contribute to the negative influence on adaptation decisions.

Farm Size: Larger farm sizes negatively influence adaptation decisions due to the time, energy, and financial resources required for implementation. This is consistent with Deressa and Hassan (2009) and Teshome and Baye (2018), who noted that smaller landholdings limit adaptive capacity. The findings underscore the complexity of flood adaptation decisions, influenced by socio-economic, demographic, and institutional factors. Addressing barriers such as access to resources, extension inefficiencies, and technological limitations is essential to enhancing adaptive capacity. Tailored interventions that leverage community experiences and diversified livelihoods can better equip households to manage flood risks.

Conclusion and recommendations

Flooding is a recurrent hazard in Ethiopia, particularly in the Fogera Woreda, which experiences significant flooding during the main rainy season from June to

September. The study found that flooding has profound socio-economic impacts, affecting farmlands, livestock, and agricultural productivity, with severe health implications related to waterborne diseases like diarrheal diseases and malaria. The adaptation strategies employed by farmers include the use of flood-tolerant crop varieties, shifting to higher ground, and selling livestock, among others. The study also revealed that male-headed households, married households, those with larger family sizes, diversified livelihoods, prior flood experience, and access to credit are more likely to adopt adaptation strategies. However, barriers such as lack of information, insufficient financial resources, and lack of support hinder many farmers from implementing effective flood adaptation strategies. The age of the household head, educational level, access to irrigation, and farm size were found to negatively influence flood adaptation decisions.

The findings indicate that while there is some adaptation to flood hazards, the capacity of farmers, especially those with limited resources, to implement sustainable and effective strategies is constrained by multiple challenges. A focus on reducing these barriers, improving access to information, and enhancing the adaptive capacity of vulnerable households could significantly improve flood resilience in the region.

Recommendations

1. **Increase Access to Information**: The lack of information was identified as a major barrier to flood adaptation. There is a need for more effective dissemination of knowledge regarding flood risks and available adaptation strategies. This can be achieved through community-based awareness campaigns, extension services, and media outreach.
2. **Enhance Financial Support for Adaptation**: Many farmers reported insufficient financial resources as a major challenge. Access to credit should be expanded, particularly for flood-affected households, to allow them to invest in flood control measures. Government and non-governmental organizations (NGOs) should consider providing financial aid, loans, or subsidies for flood adaptation technologies.
3. **Improve Extension Services**: Given the negative influence of access to extension services on adaptation decisions, it is crucial to improve the quality and effectiveness of agricultural extension services. Extension agents should be trained to better communicate the benefits of flood adaptation practices, and their engagement with farmers should be sustained throughout the year, particularly during flood-prone periods.
4. **Support Livelihood Diversification**: Encouraging farmers to diversify their income sources could improve their resilience to floods. Programs that support non-farm income-generating activities could be effective in reducing vulnerability to flood impacts, especially in flood-prone areas.

4 **Targeted Support for Vulnerable Groups**: Special attention should be given to female-headed households, as they are less likely to adopt flood adaptation strategies. This can include targeted training programs, improved access to financial resources, and social support mechanisms.

5 **Strengthen Community-Based Flood Management**: Local communities in flood-prone areas should be engaged in participatory flood management planning. Strengthening community networks, such as the use of "Kothi" as an adaptation strategy in Fogera Woreda, could improve collective flood resilience and provide better outcomes for vulnerable households.

6 **Promote Research on Flood-Tolerant Crops and Irrigation Systems**: More research should be directed toward developing flood-tolerant crop varieties and sustainable irrigation systems that can withstand flood conditions. These innovations could play a critical role in increasing the agricultural resilience of farmers in flood-prone areas.

By addressing these challenges and implementing the recommended strategies, the resilience of farm households in the study area could be significantly improved, enhancing their capacity to cope with the adverse effects of flooding and other climate-related hazards.

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