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COLLEGE OF DRY LAND AGRICULTURE AND NATURAL RESOURCES

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Effect of war on natural resources management and implication for alternative energy use in the Samre and Tsirae-Wemberta dstrict , Tigray, Ethiopia

By

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ABSTRACT

The Tigray war (November 2020 to march 2022) profoundly disrupted natural resource management (NRM) practices and alternative energy use in Samre and Tsirae-Wemberta Weredas, Tigray, Ethiopia. This study investigated the war's impact on NRM, governance bylaws, and the potential of alternative energy use, particularly solar cookers and lighting, to minimize resource damage and cope with energy resource shortage. *Using a mixed-methods approach, data were collected from 251 households through surveys, focus group discussions, key informant interviews, and observations in Adgba (Samre) and Hayelom (Tsirae-Wemberta) kebeles. Findings reveal widespread damage to soil and water conservation structures (e.g., 80.9% reported stone bund destruction) and biological conservation, with firewood collection doubling (2.19 to 4.86 donkey loads annually) and grazing in ex-closure areas surging fourfold (39 to 155.69 days/year) during the war. NRM bylaws collapsed, with 65.5% (Samre) and 61.5% (Tsirae-Wemberta) of respondents noting severe disruption, leaving only 24% and 16% perceiving active bylaws post-war. Despite 98.4% familiarity with solar energy, reliance on traditional fuels persisted (wood: 3.39 to 3.98 donkey loads/month; charcoal: 1.31 to 1.75 during the war), driven by cost, access barriers, and disrupted supply chains. The study underscores the need for rehabilitate NRM infrastructure, restore governance, and promote solar technology through support and aid, training, and pilot programs to mitigate environmental degradation and support post-conflict recovery. These findings inform policies for sustainable resource management and energy transitions in war-affected regions.*

Keywords: Environment, War, Deforestation, Governances, Bylaws, Energy use

DECLARATION

I, Alemu Girmay, hereby declare that this thesis, titled *"*Effect of War on Natural Resource Management andinplication for Alternative Energy Use in the Samre and Tsirae-Wemberta Wereda, Tigray, Ethiopia*,"* is my own original work, carried out in fulfillment of the requirements for the Master's degree at Mekelle University.

This research was conducted independently during my period of academic enrollment, and has not been submitted, in part or in full, to any other institution for the award of any degree or academic qualification.

I further declare that this work was carried out in adherence to the ethical standards of Mekelle University. All data collected during the research were treated with confidentiality, and the rights and dignity of participants were respected throughout the process.

Student Name: Alemu Girmay   Signature ______________   Date: ___________________

APPROVAL

Name of the main adviser ________________________Signature & date __________

Name of chief examiner _________________________Signature & date __________

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Name of Department head _______________________Signature & date __________

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ACRONYMS AND ABBREVIATIONS

χ^2 ____ Chi-Square (statistical test)

Df ____ Degrees of Freedom (in statistical tests)

DRC ____ Democratic Republic of Congo

e ____ Level of Precision (in sampling formula)

ETB ____ Ethiopian Birr (currency)

FAO ____ Food and Agriculture Organization

FDRE ____ Federal Democratic Republic of Ethiopia

FGD ____ Focus Group Discussion

HS ____ Household Survey

IEA ____ International Energy Agency

KI ____ Key Informant Interview

n ____ Sample Size

N ____ Total Population

NGO ____ Non-Governmental Organization

NRM ____ Natural Resource Management

p ____ Probability value (p-value in statistical tests)

SD ____ Standard Deviation

SWC ____ Soil and Water Conservation

TLU ____ Tropical Livestock Unit

UNEP ____ United Nations Environment Program

CHAPTER 1: INTRODUCTION

1.1. Background of Study

Dependence on conventional biomass fuels like wood and charcoal caused serious environmental and natural resource management problems in areas afflicted by war. Natural resources, such as forests, grazing lands, and water sources, are vulnerable to overexploitation since armed war often undermines governance structures (Koirala et al., 2020). Due to unsustainable coping strategies used during war, communities usually experience long-term environmental deterioration in addition to acute recovery challenges following war**.**

The natural resources in the Tigray area of Ethiopia were significantly impacted by the violence that started in November 2020. Soil erosion and biodiversity loss stemmed from the abandonment of agricultural land caused by facilities devastation, including the destruction of roads, networks, and blocked irrigation systems (Veldman et al., 2021). Excess grazing and the loss of native plant and animal species were made worse by the breakdown of traditional methods including smallholder farming and rotational grazing, due to the weakening of local government systems (Lemessa, 2022).

Due to mass displacement brought on by the humanitarian crisis, many communities were unable to obtain basic supplies like food, clean water, and cooking fuel (International Crisis Group, 2021). As fuel became scarcer, many households turned to felling trees for firewood, which accelerated deforestation and increased ecosystem degradation and vulnerabilities associated to climate change (Hassan, 2020).

The war also shifted local power dynamics, which further undermined resource governance. Before the war, community leaders and local institutions typically regulated the sustainable use of shared resources. However, during the war, informal groups often armed or operating under survival pressures prioritized short-term gains over long-term sustainability (Lefort, 2022).

Considering these challenges, alternative energy technologies such as solar cookers and solar lighting have emerged as viable solutions to reduce reliance on biomass fuels (Karekezi & Kithyoma, 2002; Practical Action, 2010). The Tigray region, particularly the Samre and Tsirae-

Wemberta Woredas, possessed high solar energy potential, which made such technologies logistically and technically feasible in off-grid, rural contexts. By reducing the dependence on firewood and charcoal, solar technologies had the potential to ease deforestation pressures and contribute to sustainable post-war recovery.

Despite national-level efforts, including Ethiopia's Climate-Resilient Green Economy Strategy, to promote forest conservation and rural energy access, deforestation in Tigray persisted, underscoring the need for scalable and culturally accepted alternatives. Renewable energy sources such as solar, wind, and biogas offered environmentally friendly substitutes for cooking, lighting, and household energy needs and helped mitigate further environmental damage (Smith et al., 2019).

However, the use of these technologies faced several barriers, including limited awareness, cultural preferences for traditional firewood-based cooking, and logistical challenges related to the transportation, installation, and maintenance of equipment in remote and mountainous terrain (Hassan et al., 2020). These obstacles highlighted the need for investment in training, public awareness, and government or NGO support through subsidies and outreach.

In the rural districts of Samre and Tsirae-Wemberta, which were among the areas most affected by war and environmental degradation, the use of alternative energy, particularly solar cookers and lighting, represented a potential solution to ease pressure on forest resources and reduce household fuel expenditures. Given the combination of rugged topography and abundant solar exposure, these districts served as ideal settings for studying post-war t alternative energy use.

This research therefore examines the impact of war on natural resource management and assesses the potential of alternative energy use to minimize resource damage and cope with energy resource shortage in Samre and Tsirae-Wemberta. The findings were intended to inform policy decisions and post- war natural resource damage restoration planning in Tigray and other similar contexts.

1.2. Statement of the Problem

The Tigray war, erupting in November 2020, severely disrupted natural resource management (NRM) practices and bylaws in Samre and Tsirae-Wemberta, exacerbating environmental degradation. The war destroyed critical infrastructure, such as irrigation systems and transportation networks, leading to the abandonment of agricultural lands, increased soil erosion, and biodiversity loss (Veldman et al., 2021). The collapse of local governance institutions weakened traditional NRM bylaws, resulting in unregulated practices like overgrazing and depletion of plant and animal species (Lemessa, 2022). As collective resource management faltered, environmental degradation accelerated, undermining soil and water conservation efforts and biological conservation (Korf, 2020).

In response to these disruptions, households in Samre and Tsirae-Wemberta used coping strategies, often relying on unsustainable practices such as increased use of firewood and charcoal, which further strained biomass resources. The war intensified energy scarcity, escalating fuel costs and disproportionately burdening women and children, who, due to cultural norms, primarily collect firewood under heightened risks in war affected zones (Seyoum & Belete, 2022; UN Women, 2021). Alternative energy technologies, such as solar cookers and lighting, offer potential to reduce biomass depletion, yet their use remains limited. Barriers include cultural resistance, low awareness, and logistical challenges, such as costly installation and maintenance in remote areas, compounded by economic barriers like long payback times (Dadzie et al., 2018). Moreover, there is limited research on how these technologies could alleviate pressure on natural resources and strengthen post-war governance systems.

Despite Ethiopia's Climate-Resilient Green Economy and Strategy promoting renewable energy to address environmental and climate challenges, the role of alternative energy in post-war Tigray remains underexplored. Critical gaps persist in understanding how these technologies can support NRM, mitigate biomass depletion, and enhance energy access in war affected areas. This study addresses these gaps by assessing the Tigray war impact on NRM practices and bylaws, community perceptions of these effects, and the extent of alternative energy use in Samre and Tsirae-Wemberta Wereda. By exploring these dynamics, the study aims to inform policies for sustainable recovery, improved resource governance, and energy resilience in post- war settings.

1.3. Objectives of the Study

1.3.1. General Objective

The study aims to assess how the Tigray war influenced natural resource management practices and institutions, as well as household coping strategies, including the use of alternative energy in Samre and Tsirae-Wemberta.

1.3.2. Specific Objectives

The specific objectives of this research were

- To identify community perceptions of the war's effects on natural resource management practices, focusing on soil and water conservation structures and biological conservation.
- To assess the war's impact on bylaws governing natural resource management.
- To examine the extent of alternative energy use by households in the study areas in the post-war situation

1.4. Research Questions

The research questions for the specific objectives of this study were as follows:

- To what extent did the conflict damage soil and water conservation structures and biological conservation practices in the study areas?
- How did the war affect local bylaws established to govern natural resource management?
- What is the extent of alternative energy use by households in the study areas?

1.5. Significance of the Study

This study was important for various stakeholders, including local communities, policymakers, and development practitioners in war-affected Tigray. First, it examined community perceptions of soil and water conservation practices impacted by the war. These insights informed the design of effective conservation strategies aligned with community needs, fostering engagement in post-war recovery. Second, the research assessed the war's impact on natural resource governance and existing bylaws, identifying gaps and challenges that informed reforms to strengthen governance frameworks. These findings enhanced institutional resilience for future war. Third, the study evaluated the extent of alternative energy use in post- war situation in light on the economic feasibility of renewable energy solutions. Insights from this analysis guided efforts to promote solar cooking and lighting technologies, reducing reliance on traditional fuels and addressing environmental issues. Overall, the study provided a comprehensive understanding of the war effects on natural resource management and sustainable energy use, supporting informed decision-making and policy development in Tigray, Ethiopia.

1.6. The Scope and Limitation of the Study

This study investigates the impact of the Tigray war on natural resource management and alternative energy use among peri-urban households. The research focuses on two woredas, Samre and Tsirae-Wemberta, and two kebeles, Adgeba and Hayelom, in the Tigray region. These areas were selected for their shared socio-economic characteristics, despite geographical differences, to provide insights into war-affected peri-urban communities. The study examines household-level changes in resource use, particularly wood consumption, and explores shifts toward alternative energy sources during and after the war.

limitation of study, examining the Tigray war's impact on natural resource management and alternative energy use in peri-urban households, is limited to two woredas (Samre and Tsirae-Wemberta) and two kebeles (Adgeba and Hayelom), which may not represent all war-affected areas in Tigray, limiting generalizability. It relies on self-reported data (N=251), potentially affected by recall bias and limited sample variability, particularly for pre-war and wartime periods. Unforeseen factors, such as disrupted fuel supply chains, market price fluctuations, or post-war policies, may have influenced results. The study's temporal scope, capturing data at specific points (before, during, and after the war), may miss long-term trends or seasonal variations, warranting caution in extrapolating findings.

1.7. Organization of the Thesis

The thesis is organized into five chapters. Chapter one introduces the background of the problem, the statement of the problem, the objectives of the study, and the significance of the research. Chapter two presents the literature review, providing a comprehensive overview of relevant studies and theories related to the study's objectives. Chapter three outlined the research methodology, including the study area, sampling methods, data collection techniques, and data analysis procedures. Chapter four discussed the results and findings from the research, offering a detailed analysis of the data collected. Finally, chapter five provides the conclusions, recommendations, and policy implications based on the study's findings.

CHAPTER 2: LITERATURE REVIEW

2.1. Definitions and Key Concepts

2.1.1. War

War is a prolonged, organized conflict involving violence, societal disruption, and environmental degradation, often resulting in direct physical damage and indirect socio-economic crises. Hanson et al. (2009) describe war as a destructive force that inflicts severe ecological harm, such as deforestation and habitat loss, particularly in biodiversity hotspots.

2.1.2. Natural Resources

Natural resources encompass soil, water, forests, and biodiversity, critical for livelihoods and ecosystem services like soil fertility and water regulation. Ostrom (1990) and Blaikie and Brookfield (1987) define them as shared assets requiring governance to ensure sustainability.

2.1.3. War and Natural Resources

War disrupts natural resource management through direct (tactical) and indirect (non-tactical) pathways, leading to environmental degradation. Dudley et al. (2002) explain that military actions, like bombings, and socio-economic pressures, such as fuel wood extraction, degrade resources.

2.1.4. Alternative Energy Use

Alternative energy, such as solar, biogas, or wind, reduces reliance on biomass fuels, mitigating environmental degradation. Sovacool (2021) and Mulugetta et al. (2000) define it as sustainable technologies hindered by cost and infrastructure barriers.

2.1.5. Post-War Recovery

Post-war recovery involves restoring environmental and social systems through reforestation, sustainable energy, and community engagement. Jensen and Lonergan (2012) describe it as a process to rebuild ecosystems and livelihoods.

2.2. Theoretical Review

2.2.1. Political Ecology

Political ecology highlights how power imbalances during conflicts exacerbate environmental degradation by marginalizing communities and undermining governance (Robbins, 2012). In Tigray, military targeting of ex-closures caused soil erosion and vegetation loss in Samre, while socio-economic disruptions like property destruction limited farmers' resource access, mirroring global patterns in Syria, where water infrastructure was weaponized, and Colombia, where forests were controlled by armed groups (Meaza et al., 2024; Dinc & Eklund, 2023; Sánchez-Cuervo & Aide, 2013). Weakened institutions enabled overexploitation, as seen in Tigray's unregulated tree cutting and Kosovo's war-induced soil contamination (Baumann & Kuemmerle, 2016; Verheyen, 2017).

2.2.2. Environmental Security Theory

Environmental security theory posits that resource scarcity from conflict fuels instability, necessitating restoration to prevent tensions (Homer-Dixon, 1999). In Tigray, war-damaged SWC structures and deforestation in Samre heightened land and water scarcity, echoing Sudan's land disputes and Afghanistan's water conflicts (Meaza et al., 2024; Suliman, 1997; Bove & Gavrilova, 2014). Displacement and livelihood losses increased resource pressure, similar to

Syria's agricultural abandonment (Eklund et al., 2017). Atsbi's preserved resources highlight local governance's role, paralleling Rwanda's post-genocide reforestation (Markandya et al., 2020).

2.2.3. Common-Pool Resource Theory

Common-pool resource theory underscores governance in managing shared resources, with conflict-induced institutional collapse leading to degradation (Ostrom, 1990). In Tigray, weakened forest governance caused 60% ex-closure loss in Samre, while Atsbi's bylaw adherence limited damage to 20%, reflecting Nepal's 40% forest mismanagement and Colombia's 50% bylaw collapse during conflicts (Meaza et al., 2024; Baral & Heinen, 2006; Torres et al., 2022). Displacement and institutional failures, as seen in Syria's deforestation, further disrupted Tigray's SWC (Dinc & Eklund, 2023). Community-driven bylaws, like Rwanda's post-conflict governance, are vital for recovery (Markandya et al., 2020).

2.2.4. Socio-Technical Transition Theory

Socio-technical transition theory examines barriers to sustainable technology adoption, worsened by conflict-driven disruptions (Geels, 2002). In Tigray, war-disrupted supply chains increased biomass reliance (85% firewood use post-war), exacerbating deforestation, similar to Somalia's 7% biogas adoption and Amhara's 5% solar use (Meaza et al., 2024; Ali et al., 2022; Belay, 2023). Low solar cooker adoption (8%) in Tigray, due to high costs and cultural resistance, mirrors Nepal's innovation challenges during conflict (Kebede et al., 2020; Baral & Heinen, 2006). Rwanda's post-conflict solar subsidies offer a model for Tigray's recovery (Markandya et al., 2020).

2.2.5. Resilience Theory

Resilience theory focuses on communities' adaptive capacity to recover from conflict-induced shocks through innovative solutions (Folke et al., 2010). Tigray's pre-war SWC boosted vegetation cover by 16.8%, but war destroyed 60% of structures in Samre, challenging resilience, unlike Atsbi's 20% loss due to sustained bylaws, akin to Nepal's post-conflict forest restoration (Meaza et al., 2024; Gebremedhin et al., 2022; Baral & Heinen, 2006). Syria's reforestation efforts and Rwanda's 25% forest cover increase highlight community-driven recovery (Dinc & Eklund, 2023; Markandya et al., 2020).

2.3. Empirical Review

2.3.1. Community Perceptions of War's Effects on Natural Resource Management

In Tigray, farmers reported significant losses due to the war, with many citing damage to crops, land, and concerns for long-term agricultural productivity. The destruction of crucial infrastructure, including irrigation systems and farming tools, worsened these challenges, forcing communities to cut trees and sell charcoal for survival, exacerbating environmental degradation and soil erosion (Tesfay et al., 2023). This pattern underscores how conflicts disrupt immediate food production and long-term sustainability, pushing communities into unsustainable practices (Machar, 2021). Similar struggles are evident in other conflict zones. In Syria, the war devastated agricultural infrastructure, leading to crop losses and soil erosion due to land abandonment (Mohammed et al., 2022). In South Sudan, prolonged conflict caused land degradation, pushing farmers to cut trees for firewood (Deng, 2022). In Ukraine, damage to farming infrastructure led to resource exploitation, causing long-term environmental harm (Kozak et al., 2023). These global examples demonstrate that war-induced hardships drive unsustainable practices, hindering recovery (Meaza et al., 2024).

2.3.2. Effects on Soil and Water Conservation Structures

War leads to significant damage to soil and water conservation (SWC) structures, critical for preventing soil erosion and maintaining agricultural productivity. In Tigray, the 2020–2022 war disrupted SWC infrastructures, including stone bunds and check dams, with an estimated 20,591 kilometers of stone bunds left unconstructed and 54 irrigation pumps destroyed, increasing soil erosion (0.9 to 5.5 tons/ha/year) (Nyssen et al., 2019; Gebremichael, 2005). This accelerated erosion impacted agricultural productivity, compounding post-war recovery challenges. In Syria, the war destroyed 65% of terraces, increasing erosion rates by 45% (Mohammed et al., 2022). In Rwanda, the 1994 genocide destroyed 60% of terraces, reducing crop yields by 25% (Bizimana et al., 2020). These examples show that conflict-related destruction of SWC structures undermines agricultural foundations.

2.3.3. Effects on Biological Conservation

War severely disrupts biological conservation by destroying forests, degrading wildlife habitats, and reducing biodiversity. In Tigray, the 2020–2022 war led to a 15% decline in forest cover, with damage to indigenous trees supporting pollinators like bees (Aklilu et al., 2022; Berhe et al., 2021). The Abergelle-Yechila district saw significant vegetation loss due to tree cutting for survival (Meaza et al., 2024). Similar patterns emerged in South Sudan, where tree cutting increased by 55% around refugee camps (Deng, 2022), and in the DRC, where deforestation doubled near settlements (Kabila et al., 2021). In Iraq, forest cover dropped by 60% due to military activity and displacement (Alwan et al., 2023). These wars exacerbate biodiversity loss through unsustainable resource exploitation, threatening agriculture and ecosystem resilience (Aklilu et al., 2022). Reforestation and habitat restoration, as seen in Rwanda and Nepal, are vital for recovery through community involvement (Baral & Heinen, 2006; Ordway, 2015).

2.3.4. Effects on Governance Institutions (Bylaws)

War often weakens governance systems responsible for managing natural resources, leading to unregulated exploitation and environmental degradation. In Tigray, the destruction of agricultural and environmental offices and reduced forest law enforcement led to increased illegal logging and deforestation (Gebrehiwot & Beyene, 2021). The collapse of institutional authority rendered bylaws ineffective, limiting communal resource management (Rustad & Binningsbø, 2012). In Yemen, war shattered water governance, causing disputes and uncontrolled extraction (Al-Absi, 2023). In Nigeria, the Boko Haram insurgency reduced forest law enforcement by 50%, facilitating illegal logging (Okafor, 2022). In the DRC and Colombia, prolonged war undermined conservation laws, escalating deforestation (Nackoney et al., 2014; Torres et al., 2022). Restoring governance through institutions, bylaws, and community involvement is critical for sustainable resource management (Agrawal & Ostrom, 2001; Le Billon, 2001; Bruch et al., 2016). In Tigray, strengthening local capacity and revitalizing frameworks are key (Matthew et al., 2009; Hishe, 2024).

2.3.5. Use of Alternative Energy Sources in War-Affected Settings

Access to alternative and clean energy sources is often limited in war-affected regions due to infrastructure damage, insecurity, and economic challenges. During the Tigray war (2020–2022), power outages forced communities to rely on biomass fuels like firewood and charcoal, leading to rapid deforestation (Mondal et al., 2021). Before the war, only 8% of households used solar cookers due to high costs and lack of infrastructure (Kebede et al., 2020). In Sudan, the Darfur war disrupted energy supply chains, with only 12% of households adopting solar cookers due to affordability and safety concerns (Ahmed & Elturabi, 2022; Abdelrahman & Eltahir, 2023). In Somalia, instability limited biogas adoption to 7% (Ali et al., 2022). However, successful examples show potential. Rwanda’s post-1994 genocide solar mini-grids and cook stove initiatives reduced firewood use by 70% in some districts, improving health and air quality (Bergen et al., 2019). In Nepal, post-2006 civil war, community-managed renewable energy projects reduced deforestation by 60% (Baral & Heinen, 2006). In Colombia, solar programs in off-grid areas created income opportunities, particularly for women (Torres et al., 2022). Jordan’s Azraq refugee camp, powered entirely by solar energy, cut carbon emissions by 4,500 tons annually (UNHCR, 2020). These cases highlight that subsidies, training, and partnerships can reduce environmental degradation and improve resilience in war-affected areas, offering strategies for Tigray.

2.4. Conceptual Framework of the Study

The conceptual framework for this study positions the Tigray war as a central driving force that triggers a series of interrelated environmental, institutional, and socio-economic impacts in the Samre and Tsirae-Wemberta woredas of Ethiopia. The war acts as a catalyst for three major disruptions: degradation of natural resources, the breakdown of governance institutions and bylaws, and the emergence of resource scarcity. Resource degradation manifested through deforestation and the destruction of conservation structures directly affects natural resource management (NRM) by increasing the need for restoration efforts. At the same time, the disruption of local governance structures undermines the regulation and enforcement mechanisms necessary for effective resource management. Additionally, the scarcity of essential resources such as firewood forces households to implement coping strategies, including the use of alternative energy technologies like solar cookers, though the extent of their use is limited by financial constraints.

These war-induced effects are further shaped by socio-economic factors, particularly education and income levels, which influence the effectiveness of governance recovery, the implementation of sustainable NRM practices, and the feasibility of using alternative energy sources. The interaction of these elements contributes to a range of outcomes, including the promotion of sustainable land use and conservation practices, the reconstruction and strengthening of governance frameworks, and a shift toward more resilient energy use patterns. Overall, the framework illustrates how conflict, governance, resource availability, household responses, and socio-economic conditions are interconnected, collectively determining the pathways toward resilience and recovery in war-affected communities.

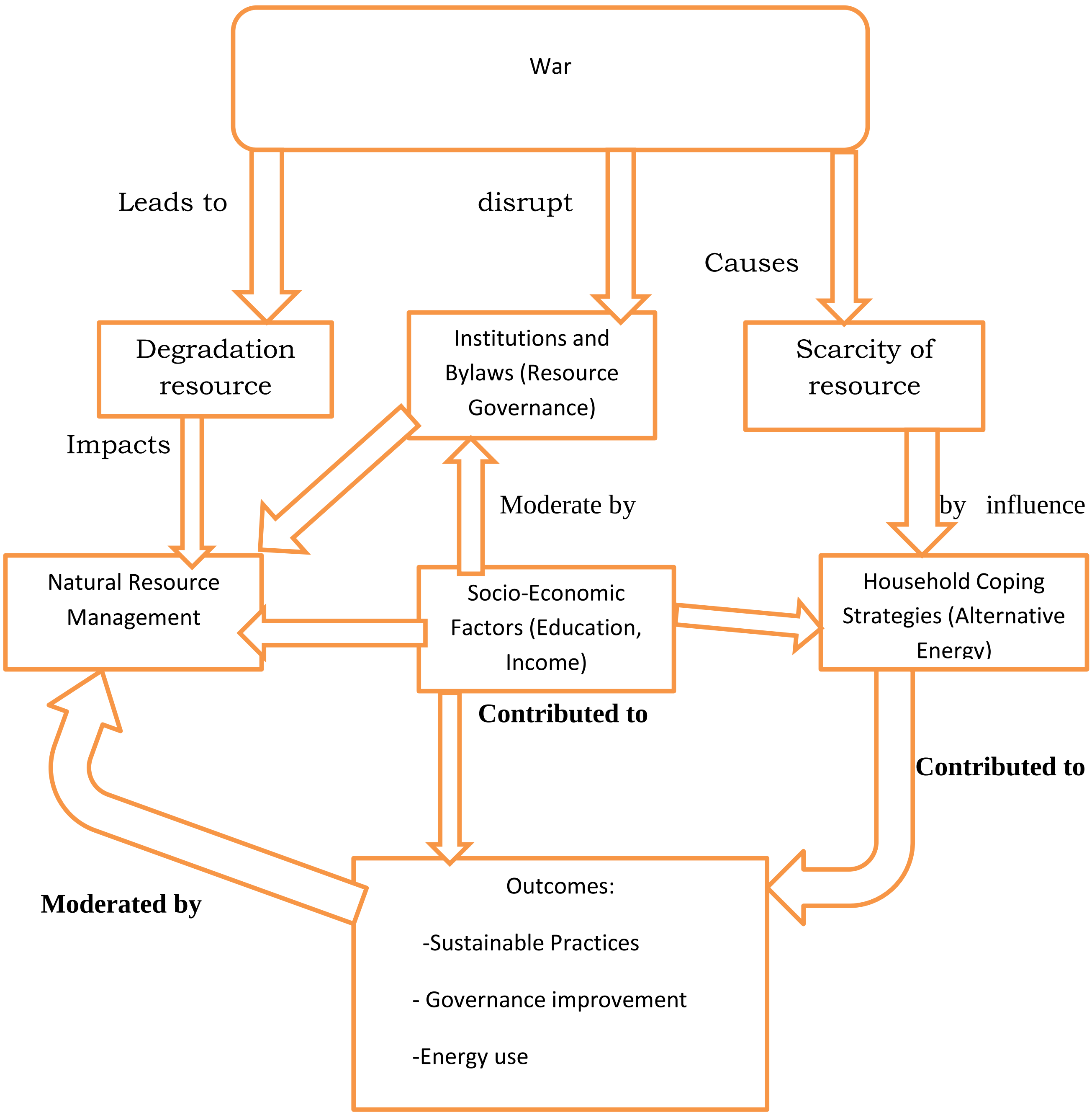


Figure 1: conceptual Framework

Adopted from former Homer-Dixon (1999)

CHAPTER 3: METHODOLOGY

3.1. Description of the Study Area

This study purposively selected Samre and Tsirae Wemberta woredas in Tigray to examine the war's severe impacts on natural resource management, starting in November 2020. Located in the South-Eastern and Eastern zones, respectively, these woredas were chosen for their exposure to war-induced disruptions, including violence, displacement, and resource degradation. The war exacerbated socio-economic and environmental challenges in the kebeles of Adgeba (Samre) and Hayelom (Tsirae Wemberta), selected for their distinct yet complementary experiences. Statistical evidence, such as a 55.5% vegetation loss in Samre and 10.9% in Tsirae Wemberta from 2020 to 2024 (Birhane et al., 2024), and woreda-level reports of restricted access during the war, validate their selection as representative areas of war-driven resource stress.

In Samre Woreda's Adgeba kebele, the war caused intense disruptions, with armed clashes and restricted humanitarian access from 2020 to 2022, leading to an 81% crop loss and 48% loss of farm tools among Tigray's smallholder households, intensifying food insecurity. Vegetation cover declined by 55.5%, driven by increased fuelwood extraction and damaged conservation structures, causing a 5.5 tons/ha/year soil loss increase (Birhane et al., 2024). In Tsirae Wemberta's Hayelom kebele, the war worsened water scarcity, with tensions over access disrupting community resource-sharing. A 2021 survey noted 9.3% of Eastern zone civilians, including Tsirae Wemberta, suffered war-related injuries, reflecting the war's impact on resource access. These woredas' contrasting severity severe in Samre, moderated by conservation bylaws in Tsirae Wemberta supports their selection for studying the war's multifaceted effects on resource management

3.1.1. Location

The study was conducted in two purposefully selected weredas of Tigray: Samre and Tsirae Wemberta. Samre Wereda was chosen as it was among the areas most severely affected by the war, specifically Adgba Kebele, which was located near the town of Samre Wereda. This Kebele was situated 10 km away from the town along the Mekelle main road. Samre was positioned between 13°11′N and 39°12′E, experienced a mean annual temperature of 15°C, and was located 827.6 km from Addis Ababa and 58 km from the main city of Mekelle. Tsirae Wemberta was reported to have well-established natural resource management institutions (bylaws to govern forests and irrigation water) around the Gergera watershed before the outbreak of the Tigray war, particularly in Hayelom kebele, which was located near the Agulae town. This kebele was situated 18 km away from the town along the main road. Tsirae Wemberta was positioned at 13°39′59.99″N and 39°44′59.99″E, experienced a mean annual temperature of 11.4°C, and was located 832 km from Addis Ababa and 65 km from Mekelle.

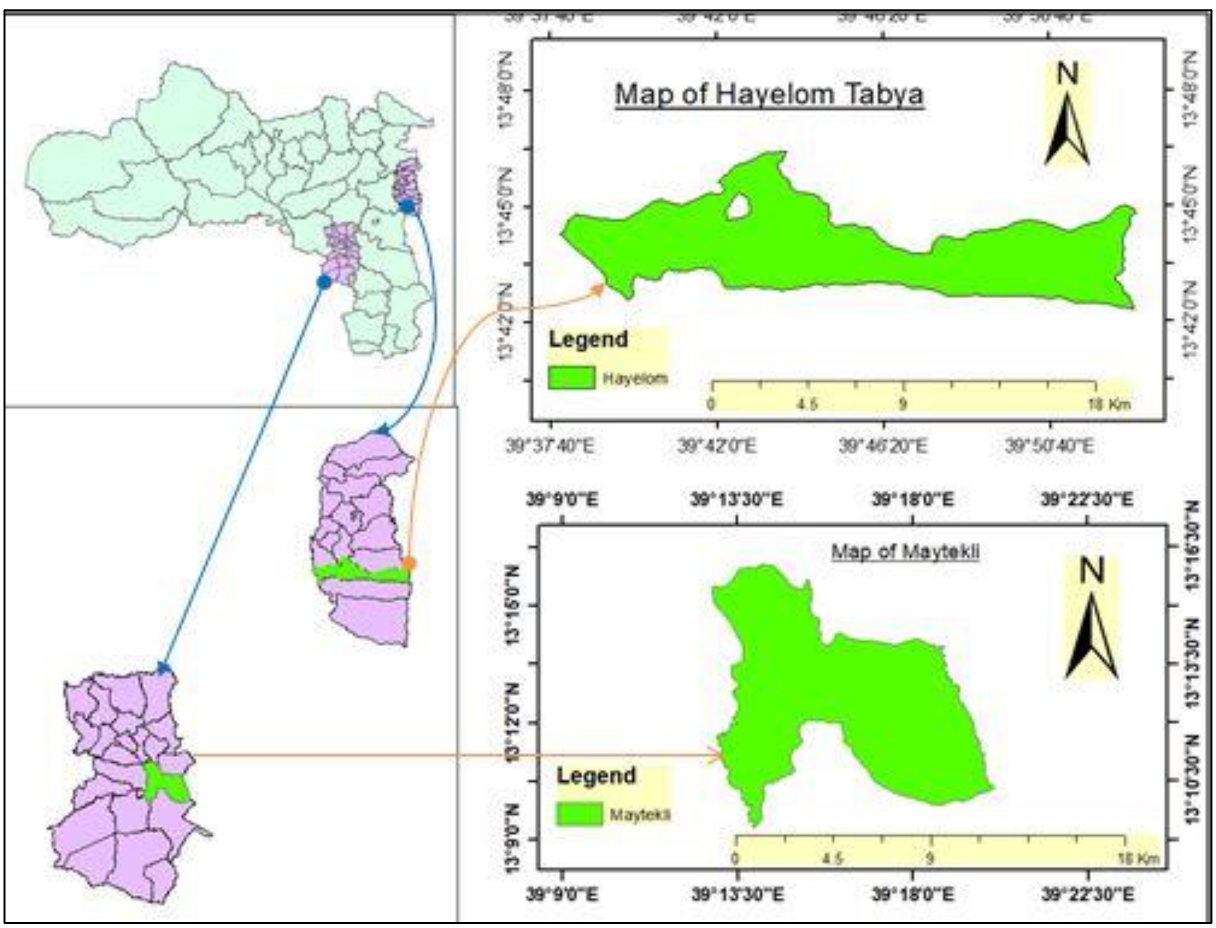


Figure 2: Location of the study area

3.1.2. Topography

The Ethiopian climate condition is determined by altitude. Samre Wereda, located in the Tigray region of Ethiopia, features a diverse topography characterized by a mix of hills valleys. The area includes rolling hills and steep slopes, typical of the Ethiopian highlands. The district is elevation 1855 meters above sea level. The region is primarily agricultural, with terraced farming common due to the terrain. The landscape is also dotted with various natural features, such as rivers and small water bodies, which play a crucial role in irrigation. The combination of elevation and climate supports a range of vegetation, from arid zones to more fertile areas.

Tsirae Wemberta Wereda, located in the Tigray region of Ethiopia, has a diverse topography. The area is part of the Ethiopian highlands, with elevations typically ranging from about 918 to 3069 meters above sea level. The region features rugged terrain with steep slopes and deep valleys, contributing to both scenic landscapes and challenges for agriculture and infrastructure. Due to the hilly nature, terracing is common, allowing for cultivation on steep slopes and making efficient use of the land. Several rivers and streams flow through the area, providing essential water resources for farming and supporting local ecosystems.

3.1.3. Climate

The average annual temperature in Samre typically ranges from 10°C to 20°C, with cooler temperatures at higher elevations and warmer conditions in the valleys. Samre experiences a bimodal rainfall pattern, with the main rainy season occurring from June to September, contributing the majority of annual rainfall. A shorter rainy season takes place from February to May, providing additional precipitation. The period from October to January is notably dry, affecting water availability and agricultural practices. Due to the diverse topography, there are varying microclimates that influence local vegetation and agricultural yields (FAO, 2018).

In Tsirae wemberta wereda the average annual temperature typically ranges from 15°C to 25°C. Cooler temperatures are found at higher elevations, while warmer conditions are prevalent in the lower valleys. The area experiences a bimodal rainfall pattern, with the main rainy season (Kiremt) occurring from June to September, contributing the majority of the annual precipitation. A shorter rainy season (Belg) takes place from February to May, offering additional but lesser rainfall compared to Kiremt. From October to January, the region is usually dry, resulting in decreased water availability that can affect agricultural productivity and local livelihoods. The diverse topography creates distinct microclimates within the wereda, impacting local vegetation, soil moisture, and farming practices (FAO, 2018).

3.1.4. Land use

The land use in Samre Wereda, located in the Tigray region of Ethiopia, is characterized by a mix of agricultural and pastoral activities, along with some areas designated for conservation and infrastructure. The predominant land use is agriculture, with both crop cultivation and livestock rising. Key crops include cereals (like teff and barley), pulses, and vegetables. Smallholder farms are common, with farmers practicing subsistence agriculture. Some communities engage in pastoralism, raising livestock such as cattle, sheep, and goats. This practice is especially important in more arid areas where crop cultivation is challenging. There are efforts to preserve forested areas for biodiversity and conservation, though deforestation has been a concern due to agricultural expansion and resource extraction. Open grazing lands are utilized for livestock, particularly in the dry seasons, to support pastoral communities.

Similarly Land use in Tsirae wembetra, a locality in the Tigray region of Ethiopia, is characterized by a mix of agricultural practices, pastoralism, and some areas of forest. Agriculture is predominant, with farming focusing on crops such as teff, wheat, and barley, as well as some legumes. Livestock raising is also common, with animals like cattle, goats, and sheep contributing to local livelihoods. The region's rugged terrain and climate conditions influence land use patterns, with terracing and other soil conservation methods often employed to maximize agricultural productivity. Additionally, community practices may include communal grazing lands and the management of natural resources to sustain livelihoods in the area.

3.1.5. Soil type

Samre wereda features a variety of soil types, influenced by its topography, climate, and land use practices. The main soil types, which include vertisols, regosols, andosols and luvisols, are found in various parts of the wereda. They are fertile and support good agricultural production, particularly for cereals and pulses. They have limited agricultural potential due to their low nutrient content and susceptibility to erosion. Soil Erosion, Soil erosion is a significant issue in Samre wereda, exacerbated by deforestation and unsustainable agricultural practices. Conservation efforts, such as terracing and reforestation, are essential to combat erosion and maintain soil health (Tigray Bureau of Agriculture, 2020).

Similarly, Tsirae wemberta wereda, located in the Tigray region of Ethiopia, exhibits a variety of soil types shaped by its topography, climate, and land management practices. The main soil types found in this area include andosols, vertisols, vuvisols, and regosols are typically shallow and poorly developed, often found on steep slopes. They have limited agricultural potential due to their low nutrient content and are more susceptible to erosion. Soil erosion is a significant concern in Tsirae Wemberta, exacerbated by deforestation and unsustainable agricultural practices. Efforts to combat erosion through conservation measures, such as terracing and reforestation, are essential for maintaining soil health and agricultural productivity (Tigray Bureau of Agriculture, 2020).

3.1.6. Farming system

The farming systems in Samre Wereda, and Tsirae wemberta located in the Tigray region of Ethiopia, typically reflect a combination of traditional and mixed agricultural practices. Farmers cultivate staple crops such as teff, barley, wheat, and maize, often using traditional farming techniques. Legumes are also common, contributing to soil fertility and nutrition. Many households engage in livestock farming, raising cattle, goats, sheep, and poultry. Livestock serves as both a source of food and income, as well as a means of transportation and agricultural labor. A combination of crop cultivation and livestock rising is prevalent. This integrated approach helps diversify income and provides organic fertilizers through manure. Given the hilly terrain, farmers often employ terracing and other soil conservation practices to prevent erosion and enhance productivity. In some areas, farmers utilize irrigation, particularly in valleys or near rivers, to supplement rainfall and improve crop yields. Collective practices may include shared grazing areas and cooperative farming initiatives, promoting community resilience and resource management.

3.2. Sampling Techniques and Sample Size

The research adopted a stratified random sampling method to ensure that the sample accurately represented the diversity within the selected weredas of Samre and Tsirae-Wemberta. This technique involved dividing the population into distinct subgroups, or strata, based on key demographic characteristics. From each stratum, samples were then randomly selected. The stratification process ensured that all relevant subgroups, such as households with varying socio-economic backgrounds, were adequately represented, thereby enhancing the reliability and generalizability of the findings.

The total sample size accounted for approximately 6% of the total households in the selected weredas. This percentage was carefully selected to balance statistical accuracy with practical constraints. A 6% precision level (e = 0.06) was chosen as it is commonly used in social research when aiming for a reasonable margin of error while remaining manageable in terms of resources and accessibility. This precision level ensures that the sample is sufficiently representative of the population without being excessively large or unmanageable.

The sample size was calculated using Yemane's formula (Yemane, 1967), a widely accepted method in statistical research for determining sample sizes in large populations. Yemane's formula is appropriate for large populations because it provides a simple and effective way to calculate the necessary sample size while accounting for variability and population size. The formula is:

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

Where, n= sample size; N= total Population, and e = level of precision (0.06)

Thus N=4957 e (0.06)

Therefore $n = \frac{4957}{1+4957(0.06)^2}$ = 251

Table 1.Total Population and Sample Size

No	Name of sub-district (kebele)	Total population size (N)	Sample size (n)

1	Adgba	2805	142
2	Hayelom	2152	109
	Total	4957	251

3.3. Data Type and Data Source

This study adopted a mixed-methods approach, integrating quantitative and qualitative data to address its objectives. Quantitative data, including household demographics and solar cooker adoption rates, were collected through structured surveys and analyzed statistically. Qualitative data, capturing stakeholders' perceptions of conflict-induced environmental degradation and energy choices, were gathered via semi-structured interviews and focus group discussions, followed by thematic analysis.

Primary data were sourced directly from rural household heads, farmer cooperatives, and key informants (e.g., local administrators) in Samre and Tsirae Wemberta, ensuring firsthand accounts of post-conflict challenges. Secondary data were derived from peer-reviewed literature, regional government reports (e.g., Tigray Bureau of Agriculture, 2023), NGO assessments, and institutional archives, which were critically evaluated for relevance and reliability. By triangulating primary fieldwork with secondary evidence, this approach enhanced the validity and depth of findings while contextualizing local experiences within broader socio-environmental frameworks.

3.4. Methods of Data Collection

To achieve the objectives of this study, both quantitative and qualitative data were utilized. Quantitative data, such as the number of households using solar cookers or the household size, were collected through numerical measures. These data allowed for statistical analysis and objective comparisons. On the other hand, qualitative data were gathered to provide deeper insights into community perceptions and experiences. This included understanding how local populations viewed the impact of the conflict on natural resource management (NRM) and their choices regarding alternative energy. Qualitative data helped to build a narrative around the broader context of energy use, environmental degradation, and governance challenges during the conflict.

Data were sourced from two primary categories: primary and secondary sources. Primary data were collected directly from the field, involving rural household heads, farmer groups, and key informants from Samre and Tsirae-Wemberta who had firsthand knowledge of the conflict’s effects. These participants provided valuable insights into the local experiences of environmental degradation, resource management issues, and the potential for alternative energy solutions.

Secondary data were gathered from a variety of external sources, including books, journals, government reports (such as those from Tigray’s regional bureaus), NGO publications, and online sources. This secondary data helped to contextualize the study within broader academic and policy frameworks, providing background information on the historical, economic, and political factors influencing resource management in conflict-affected regions.

The combination of primary and secondary data sources enriched the study, offering a comprehensive and nuanced perspective on the issue. Primary data contributed real-life experiences and community-based knowledge, while secondary data provided factual and theoretical grounding from existing literature and previous studies.

3.4.1. Primary Data

Primary data for this study were collected from a total of 251 households located in Adgba (Samre) and Hyelom (Tsirae Wemberta). Several data collection methods were employed to capture diverse perspectives and ensure a comprehensive understanding of the conflict's impact on natural resource management (NRM) and the adoption of solar cookers. These methods included household surveys, focus group discussions (FGDs), key informant interviews (KIIs), and physical observations, each contributing distinct insights into the study’s objectives.

- Household Survey (HS): A semi-structured questionnaire was administered face-to-face to the 251 households. The questionnaire included both closed and open-ended questions, allowing respondents to provide quantitative data on solar cooker use, perceptions of the conflict’s impact on NRM, and changes in governance structures. The flexibility of the semi-structured approach ensured that important aspects of the community’s experiences were captured, providing both numerical data and personal insights.

- Key Informant Interviews (KIIs): In-depth interviews were conducted with individuals who possess significant knowledge about the local community and the effects of the Tigray war. These included household heads (5), women (3), elders (2), and leaders from local or government organizations (2, one from Samre and other Tsirae wemberta). Their experiences of living through the war, and their understanding of its impact on land, trees, and alternative energy use, provided valuable qualitative data that helped contextualize the broader findings from the surveys.
- Focus Group Discussions (FGDs): Separate FGDs were organized for men and women in the communities, with each group consisting of 8 men and 4 from women and similarly 7 men and 5 women from Tsirae wemberta participants from the selected kebeles. These discussions were guided by a checklist of questions focusing on the impacts of the war on NRM and the use of solar cookers and lighting. FGDs facilitated a deeper exploration of the social dynamics and collective experiences of the community, offering rich qualitative data that supplemented the surveys and KIIs.
- Physical Observations: The researcher conducted on-site visits to observe firsthand the conditions of the affected areas. This included inspecting fields for signs of damage such as broken terraces, deforestation, and the use of solar cookers and lighting. Physical observations provided concrete evidence to corroborate the data gathered from interviews and surveys, enhancing the reliability of the findings.

3.4.2. Secondary Data

Secondary data came from various sources, like the Tigray government reports, NGO papers, books, journals, and websites. We looked at past studies on conflict, NRM, and solar energy in Ethiopia and other places. This extra info helps explain our primary data, giving a bigger, clearer picture for the study.

3.5. Method of Data Analysis

After collecting the necessary data from the target respondents, the next step was to analyze the data to address the research objectives. To achieve this, different analytical methods were used for each objective.

For the first objective, qualitative analysis was employed to identify community perceptions on the effect of the conflict on natural resource management (NRM) practices. Data collected through interviews and focus group discussions were coded to identify recurring themes and patterns. This method helped capture the depth of community views on the impact of the conflict, particularly on soil and water conservation structures and biological conservation. The qualitative approach provided a nuanced understanding of how the conflict shaped local NRM practices and how these perceptions influenced resource management decisions.

The second objective was addressed using comparative analysis, which focused on assessing the effect of the war on local bylaws governing natural resource management. By comparing bylaws and regulations before and after the conflict, the study identified specific changes in governance structures, such as grazing rights, water-sharing agreements, and forest protection measures. Document analysis of official bylaws, amendments, and related legal texts provided concrete evidence of how the war disrupted or altered local resource management systems, highlighting the effects of conflict on sustainability.

To address the third objective, descriptive statistics were used to analyze the extent of household use of alternative energy sources, particularly solar cookers and lighting. Descriptive statistics involved the summarization of data through frequencies**,** means**,** and percentages to quantify the use of solar energy technologies across different households. This method allowed for clear comparisons of energy use patterns based on various demographic variables, such as household size, income levels, and access to information. The statistical analysis helped identify trends in solar cooker use, potential barriers to use, and the factors influencing the demand for renewable energy solutions in the post-conflict recovery phase. By examining these patterns, the study assessed the feasibility of scaling up alternative energy solutions as a means of improving sustainability in the region.

3.6. Relationships among Variables and Conceptual Linkages

This study explores how various household, economic, and social characteristics are interconnected with the impacts of war on natural resource management and the use of alternative energy sources. War often leads to environmental degradation damaging soil and water conservation structures, undermining forest protection, and weakening local governance systems. These disruptions reduce community coordination and the enforcement of bylaws, which in turn exacerbates unsustainable practices such as overgrazing, deforestation, and overuse of firewood. As natural resources deteriorate, households face increased scarcity, pushing them toward short-term coping strategies that harm long-term sustainability.

The likelihood that households will shift toward alternative energy sources, such as solar cookers, is shaped by several interconnected factors. For example, households with better access to education and training tend to be more aware of solar technologies and their benefits, increasing their willingness and ability to use them. Similarly, familiarity with solar energy and past exposure through community programs or local organizations can significantly influence whether households adopt these solutions. Economic capacity plays a reinforcing role larger farms, higher livestock ownership, and income from non-farm activities provide the financial resources needed to invest in solar energy. Moreover, demographic characteristics, such as the age and gender of the household head, also correlate with energy decisions: younger and female heads are generally more inclined toward sustainable and modern energy use. In addition, higher fuel expenditures may act as a catalyst for change, encouraging households to explore cheaper, cleaner alternatives.

Taken together, these variables form a network of influences. War not only undermines natural resource systems directly but also weakens the social and economic structures that support sustainable energy use. The correlations among environmental degradation, governance breakdown, socio-economic conditions, and energy behavior are strong and mutually reinforcing. Recognizing these linkages is essential for understanding household responses and designing policies that promote both environmental recovery and greater energy resilience in war-affected regions.

CHAPTER 4: RESULTS AND DISCUSSION

4.1. Demographic and Socio-Economic Characteristics of the Respondents

Household Head Age (in calendar years)

The average household head is approximately 46 years old, with a standard deviation of 14.05 years, indicating a diverse age range from younger (around 30) to older (around 60) individuals. This middle-aged leadership suggests reliance on traditional knowledge for natural resource management (NRM) practices, such as soil conservation or agroforestry, which are vital for sustainable land use. However, the wide age variation may hinder the transfer of this knowledge to younger generations, especially in war-affected areas where displacement disrupts community learning. Older heads may prefer traditional energy sources like firewood, while younger ones might be more open to alternative energy solutions, such as solar power, if accessible.

Household Head Education (in years of schooling)

With an average of only 2.89 years of schooling and a standard deviation of 3.50 years, household heads have very limited formal education, with some having none and others up to 6–7 years. This low education level restricts their ability to adopt modern NRM techniques, such as efficient irrigation or reforestation, and limits understanding of alternative energy technologies like biogas or solar systems. In post-war settings, where new resource management bylaws may be introduced, this educational gap could lead to non-compliance or continued reliance on unsustainable practices, such as overexploitation of forests for fuel, exacerbating environmental degradation.

Farm Size (in tsmad)

Households cultivate an average of 1.88 tsmad of land (a local measure for small plots), with a standard deviation of 1.21 tsmad, indicating most farms are small, though some are slightly larger or smaller. These limited landholdings mean families heavily depend on their plots for food and income, making them vulnerable to soil degradation or war-related damage to conservation structures like terraces. Small farm sizes also increase pressure to maximize yields, often leading to unsustainable practices that deplete natural resources. Without access to alternative energy for farming, such as solar-powered irrigation, households may rely on labor-intensive methods that further strain the land.

Livestock Endowment (in Total Livestock Unit)

On average, households own 1.68 Total Livestock Units (TLU), with a standard deviation of 1.56, reflecting variation where some have more animals (e.g., cows, goats) and others very few. Livestock are vital for food, income, and resilience during crises, but unregulated grazing, often worsened by weakened post-war bylaws, can degrade pastures and contribute to soil erosion. This environmental strain reduces the land's capacity to support sustainable agriculture. Additionally, reliance on livestock for energy-intensive tasks, such as plowing, rather than alternative energy solutions, perpetuates traditional, resource-heavy practices.

Non-Farm Income (in birr)

Households earn an average of Birr 8,114.98 annually from non-farm activities, such as small businesses, but the high standard deviation of Birr 14,259.21 shows stark disparities some earn significantly more, while others earn little. Wealthier households may invest in alternative energy sources, like solar panels, reducing their dependence on firewood and supporting forest conservation. In contrast, poorer households, limited by low income, often resort to cutting trees for fuel, accelerating deforestation and undermining NRM efforts. This income gap highlights inequities in adopting sustainable energy practices in post-war recovery.

Support or Aid Income (in birr per year)

Households receive an average of Birr 1,982.87 annually in aid or support, with a standard deviation of 6,594.51 birr, showing that some receive substantial aid while others get none. This uneven and generally low aid limits the ability to invest in sustainable NRM practices or alternative energy solutions, such as solar lanterns. Without adequate support, households may resort to unsustainable coping strategies, like illegal logging for fuel, which damages forests and undermines post-war environmental recovery. Stronger aid could facilitate access to cleaner energy and resource conservation.

Frequency of Training (number in years)

Household heads attended an average of 1.13 training sessions on topics like farming or NRM, with a standard deviation of 1.51, indicating many attended none while some attended a few. This low exposure to training limits knowledge of sustainable practices, such as agroforestry or soil conservation, and alternative energy options like biogas. In post-war areas, where local NRM committees may have collapsed, this lack of guidance perpetuates reliance on traditional, often unsustainable, resource use and energy consumption patterns, slowing environmental recovery.

Distance to Main Road (in minutes)

Households are, on average, 18.83 minutes from the main road, with a high standard deviation of 19.45 minutes, meaning some are very close while others are up to 40 minutes or more away. Remote households face significant barriers to accessing markets, aid, or alternative energy technologies, such as solar panels or clean cook stoves, forcing continued reliance on firewood or charcoal. This dependence exacerbates deforestation and hinders NRM efforts. Improved road access could enhance th e adoption of sustainable energy and resource management practices, supporting post-war recovery.

Table 4.1: Characteristics of Respondents: Continuous Variables

Variables	Mean	Std. Deviation
Household head age (in calendar years)	46.04	14.05
Household head education (in years of schooling)	2.89	3.50
Farm size(tsmad)	1.88	1.21
Livestock endowment (in Total Livestock Unit)	1.68	1.56
Non-farm income(in birr)	8114.98	14259.21
Frequency training	1.13	1.51
Distance to main road (minute)	18.83	19.45
Support or aid income (in birr per year)	1982.87	6594.51

Source: own survey (2025)

Sex of Household Head

In Table 4.2 the results showed that 66.5% of households were headed by men, while 33.5% were headed by women. This is common in rural Tigray. However, female-headed households may manage resources differently from male-headed households. Studies suggest women often focus more on family health and the environment, making them more likely to use cleaner energy like solar. In the post-conflict setting, where families needed safe and easy energy, women could play a key role in promoting solar cookers and solar lighting.

Non-Farm Regular Work (Wage Employment)

About 41% of households had someone earning a regular wage from non-farm work, while 59% did not. Families with wage income were more financially stable, especially after the war disrupted farming. Having another income helped them rely less on natural resources like firewood. It also made it easier to afford solar energy, which supports the third objective of this study understanding how solar technology is used.

Non-Self-Employment Income

Only 12.7% of households had income from formal jobs or remittances. Most (87.3%) depended on farming or self-employment. Because of the conflict, formal jobs were rare, and families without stable income had a harder time buying clean energy technologies. These households were more likely to keep using firewood, which worsens environmental problems. This shows that boosting income sources is important for post-war recovery and energy use.

Familiarity with Solar Energy

Almost all households (98.4%) said they knew about solar energy. This shows that awareness was high, even after the war. But knowing about solar doesn't always mean people use it. Many families still faced problems like cost, availability, or lack of support. This shows the need for more help, like subsidies or better access to credit, so that people who know about solar energy can actually use it.

Table 4.2: Sample Household Characteristics: Categorical Variables

Variables	Category	Frequency	Percent
Sex of the household head	Yes	84	33.5
	No	167	66.5
Non-farm regular work /wage	Yes	103	41

	No	148	59
Non self-employment	Yes	32	12.7
	No	219	87.3
Familiarity with solar energy	Yes	247	98.4
	No	4	1.6

Source: own survey (2025)

4.2. Community Perceptions of the War Effects on Natural Resource Management Practices

4.2.1. Damage to Soil and Water Conservation Structures

Table 4.3 presented the perceptions of 251 households in Samre and Tsirae-Wemberta Weredas regarding the war's impact on soil and water conservation (SWC) structures, supplemented by insights from focus group discussions (FGDs) and key informant interviews (KIIs) from these respondents.

Effect on Soil Bunds

In Samre and Tsirae Wemberta, 71.3% of households (179 out of 251, with 101 in Samre and 78 in Tsirae Wemberta) said that soil bunds piles of dirt built to stop soil from washing away and keep water for crops were damaged by the war, while 28.7% (72 households) said they were not. Samre had more damage, likely because tanks and soldiers crushed or dug up bunds, as farmers shared in focus group discussions (FGDs). One farmer [Samre farmer] said, "Where there used to be rows of bunds, there are now paths of destruction or deep tracks left by machinery" (FGD, Samre). This matches research by Meaza et al. (2024), who found soil bunds were easily damaged in the Tigray war. When bunds are broken, rain washes away soil, making it hard to grow crops and hurting the land's health, which is bad for farmers.

Effect on Stone Bunds

A very high 80.9% of households (203 out of 251, with 115 in Samre and 88 in Tsirae Wemberta) reported that stone bunds walls made of stones to slow water and save soil were damaged during the war, while only 19.1% (48 households) said they were okay. Key informant interviews (KIIs) and FGDs showed that soldiers took stones to build war shelters or barriers, making bunds useless. Farmers [Znabu Meles] said this happened a lot in their area, causing more damage there (FGD, Samre). Manaye et al. (2023) noted that many stone bunds were lost in Tigray. Without these bunds, soil washes away, damaging farmland and making it tough to farm in a way that keeps the land good for the future.

Effect on Trenches Integrated with Terraces

About 72.9% of households (183 out of 251, with 103 in Samre and 80 in Tsirae Wemberta) said that trenches with terraces ditches and flat steps on hills to catch water and stop soil from sliding were damaged by the war, while 27.1% (68 households) said they were fine. FGDs showed that soldiers used these hill structures for fighting, digging them up or making them bigger. Farmers [Lelem Gidey] shared that trenches were turned into military spots (FGD, Hayelom kebele). UNEP (2020) and Bruch et al. (2022) say wars often harm structures like these. Samre had more damage. Broken trenches and terraces let water and soil wash away, making farming harder and reducing water for crops.

Effect on Trenches

A large 77.3% of households (194 out of 251, with 113 in Samre and 81 in Tsirae Wemberta) reported that standalone trenches ditches dug to guide water and stop deep cuts in the land were damaged by the war, while 22.7% (57 households) said they were okay. FGDs and KIIs showed trenches were filled in or used as hiding places during battles. A leader [Hailu Brhane Tsirae Wemberta leader] said, "Our conservation trenches turned into combat lines after the war, they are either useless or hazardous" (KII, Tsirae Wemberta). Deng (2022) and Matthew et al. (2020) explain that wars focus on fighting, not protecting the environment. Samre had more damage, and broken trenches cause soil erosion, creating gullies that make farming difficult.

Effect on Terrace Benches

Around 61.8% of households (155 out of 251, with 85 in Samre and 70 in Tsirae Wemberta) said that terrace benches flat, step-like areas on hills to make farming easier and stop soil from sliding were damaged by the war, while 38.2% (96 households) said they were okay. This was the least damaged structure, but still a big problem. FGDs and KIIs showed that heavy rain after the war, with no repairs, caused terraces to collapse, and some were broken to stop soldiers from hiding.

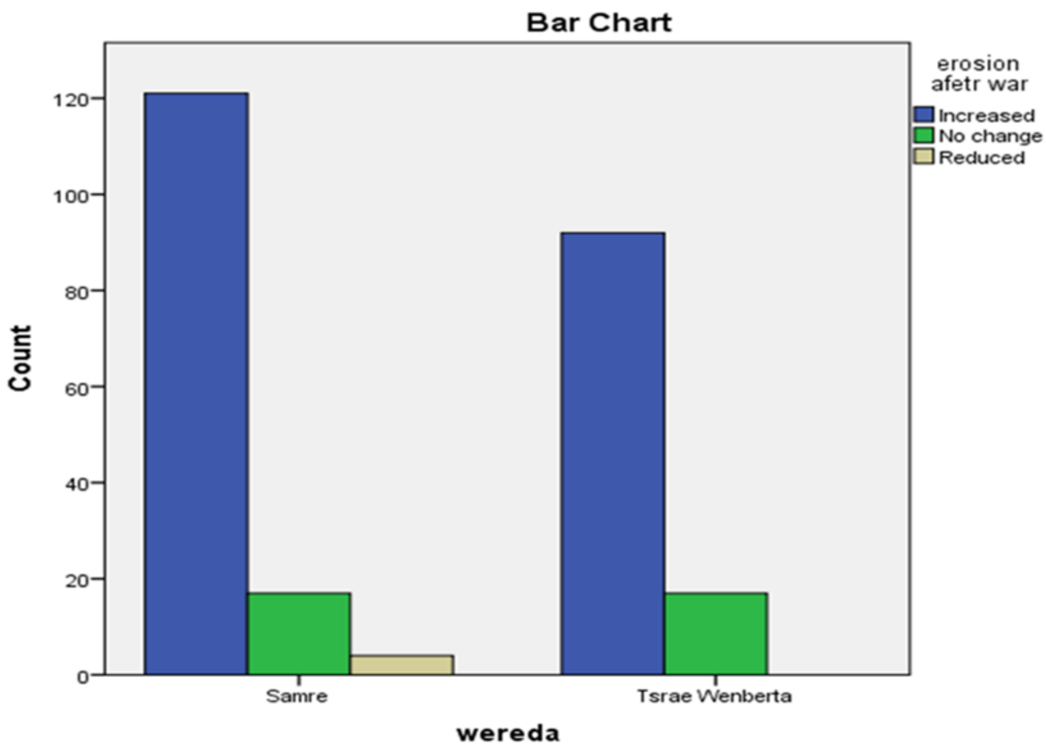
Farmers [Abebe girmay] said damage was worse in their area (FGD, Samre). Gebrehiwot and Beyene (2021) found that neglecting structures during wars causes fast damage. Broken terraces make hill farming harder and let soil wash away, hurting Tigray's hilly lands.

Table 4.3: Perceptions of Household War's Impact on SWC Structures

War effects on Soil and water conservation structures		Wereda		Total	Percent
		Samre	Tsirae wemberta		
War affected the soil bund	Yes	101	78	179	71.3
	No	41	31	72	28.7
War affected stone bund	Yes	115	88	203	80.9
	No	27	21	48	19.1
War affected the trench with terrace	Yes	103	80	183	72.9
	No	39	29	68	27.1
War affected the trench	Yes	113	81	194	77.3
	No	29	28	57	22.7
War affected the bench terrace	Yes	85	70	155	61.8
	No	57	39	96	38.2

Source: own survey (2025)

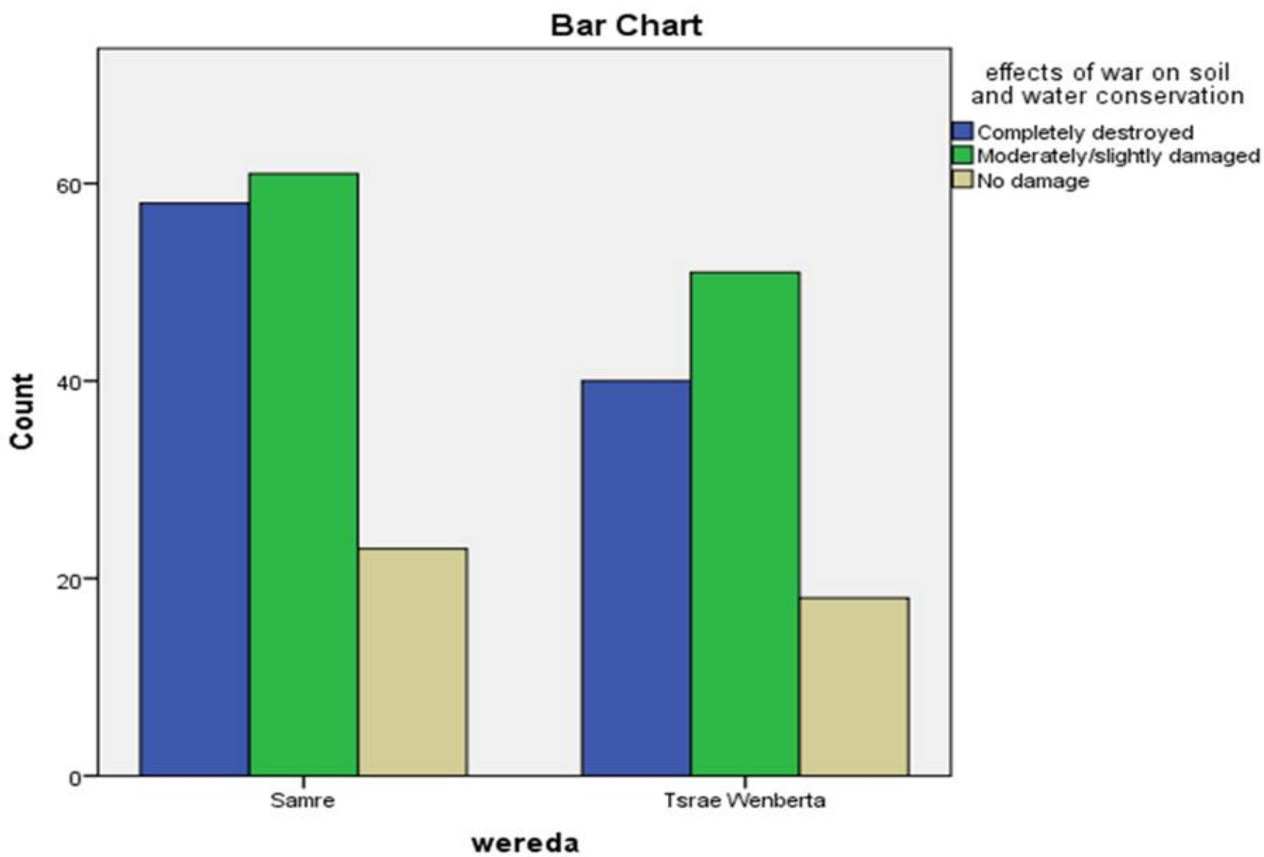
Figure 4.1 shows how households in Samre and Tsirae Wemberta feel about erosion after the war, with most saying it got worse. In Samre, about 120 households said erosion increased (shown in blue), while around 20 said it stayed the same (green), and only a few said it reduced (yellow). In Tsirae Wemberta, around 100 households reported more erosion, about 20 said no change, and a few said it reduced, similar to Samre. This means most people in both areas almost all of the 251 households noticed more soil washing away after the war. Focus group discussions (FGDs) showed farmers were worried, with one elder [Kebede hailu, Hayelom kebele, Tsirae Wemberta] saying, "Before, we had trenches and bunds to stop the water. Now, the land has no protection, the earth goes with the rain" (FGD, Hayelom kebele). In Samre, farmers added that erosion is "eating the land from the edges inward" (FGD, Samre). Key informant interviews (KIIs) with community leaders explained that no one could fix SWC structures during the war because of displacement and fear, so erosion got worse (KII, Tsirae Wemberta leader). This matches studies by Sola et al. (2021) and Kumar et al. (2020), which say erosion often increases after wars because conservation structures are damaged or ignored. Bruch et al. (2022) also note that wars harm land management, causing long-term damage if not fixed. More erosion means less healthy soil for farming, making it harder for these communities to grow food and take care of their land after the war.



Source: own survey (2025)

Figure 4.1: Households' Perceptions on Post-War Erosion

Figure 4.2 shows how the war affected soil and water conservation (SWC) structures in Samre and Tsirae Wemberta, based on what households think. In Samre, about 60 households said SWC structures were completely destroyed (blue), around 60 said they were moderately or slightly damaged (green), and about 20 said there was no damage (yellow). In Tsirae Wemberta, around 40 households reported complete destruction, about 50 said moderate or slight damage, and about 20 said no damage. This means most structures in both areas out of 251 households were harmed by the war, with more serious damage in Samre. Focus group discussions (FGDs) revealed that farmers [Samre farmers] said soldiers broke bunds and trenches for fighting or took stones for shelters (FGD, Samre). A leader [Tsirae Wemberta leader] explained in key informant interviews (KIIs) that the war stopped people from fixing these structures, leaving the land unprotected (KII, Tsirae Wemberta). This matches Meaza et al. (2024) and Manaye et al. (2023), who found that wars often destroy SWC structures, causing soil to wash away and making farming harder. Damaged structures mean less water and soil are saved, which hurts crops and makes the land less healthy after the war.



Source: own survey (2025)

Figure 4.2: Effects of War on Soil and Water Conservation

4.2.2. Quantitative effects of war on SWC practices

Table 4.4 presents the mean number of family members involved in soil and water conservation (SWC) activities before, during, and after the war, highlighting a significant decline during the conflict and a partial recovery afterward. The Friedman Test result ($\chi^2 = 319.891$, $p < 0.001$) confirms that these differences are statistically significant.

Before the War

Table 4.4 shows that before the war, an average of 1.55 family members from each of the 251 households in Samre and Tsirae Wemberta helped with conservation activities, like digging trenches, planting trees, or fixing soil bunds, with a standard deviation of 0.934, meaning some families had 1 or 2 members working while others had a bit more. This shows that many families worked together to take care of their land. Focus group discussions (FGDs) in Adgba and Hayelom revealed that farmers [Adgba farmers] said they used to work as a team to protect their fields (FGD, Adgba). Gebremedhin et al. (2018) noted that Tigray had strong community programs to keep the land healthy before the war, which helped stop soil from washing away and supported farming.

During the War

During the war, the average number of family members helping with conservation dropped to just 0.03, with a standard deviation of 0.226, meaning almost no one in the 251 households was doing these activities. This big drop happened because people had to leave their homes, were scared, or focused on staying safe instead of farming. Focus group discussions (FGDs) showed that a youth [Samre youth] said, “We were hiding in the hills, not building them” (FGD, Samre), explaining why work stopped. Key informant interviews (KIIs) with leaders confirmed that the war made it impossible to coordinate conservation efforts (KII, Hayelom leader). This matches FAO (2021) and Sola et al. (2022), who say wars stop people from caring for the land, causing more soil damage and making farming harder.

After the War

After the war, the average number of family members involved in conservation activities went up to 1.18, with a standard deviation of 1.061, meaning some families in the 251 households had

1 or 2 members helping, but others had more or less. This shows that people started working on conservation again, but not as much as before. Key informant interviews (KIIs) revealed that groups like NGOs are helping, but farmers [Hayelom farmers] said it's tough because they lack tools and feel tired (KII, Hayelom leader). Focus group discussions (FGDs) showed that people want to fix their land but need support (FGD, Hayelom). Sola et al. (2022) explain that after wars, it's hard to get back to normal conservation, but the increase shows families are trying, which could help the land if they get more help.

The Friedman Test in Table 4.4 shows a Chi-Square value of 319.891, with 2 degrees of freedom (Df), and an Asymp. Sig. of .000, which means the differences in how many family members were involved in conservation activities before, during, and after the war are real and not just by chance. In simple terms, this test tells us that the big drop during the war (from 1.55 to 0.03) and the rise after the war (to 1.18) are important changes caused by the war. The small Asymp. Sig. value (less than 0.001) proves these shifts are significant, showing how the war stopped people from working on the land and how they started again after, though not fully back to normal. This helps us understand that the war really affected how families took care of their land, which can lead to more soil erosion if conservation work doesn't pick up more.

Table 4.4: Family Involvement in Conservation Activities Before, During, and After the War

Descriptive Statistics	**N**	**Mean**	**Std. Deviation**
Numbers of family members involved in conservation activities in (a year) before war	251	1.55	0.934
Number of family members involved in conservation activities in (year) during war	251	0.03	0.226
Number of family members involved in conservation activities in (year) after war	251	1.18	1.061
Test Statistics[a]			
N	251		
Chi-Square	319.891		
Df	2		
Asymp. Sig.	.000		
a. Friedman Test			

Source: own survey (2025)

Table 4.5 illustrates how the Tigray conflict severely disrupted household labor contributions to soil and water conservation (SWC) practices, measured in terms of labor days before, during, and after the war. The Friedman test result ($\chi^2 = 307.503$, $p < 0.001$) indicates that these differences are statistically significant.

Labor Days in Conservation Activities before the War

Table 4.5 shows that before the war, each of the 251 households in Samre and Tsirae Wemberta spent an average of 31.88 labor days meaning people working for that many days on conservation activities like building soil bunds or planting trees, with a standard deviation of 20.274, so some families worked more (around 50 days) and others less (around 10 days). This means families were putting in a lot of effort to take care of their land. Focus group discussions (FGDs) showed that farmers [Samre farmers] said they worked together as a community to protect their fields before the war (FGD, Samre). This hard work helped stop soil from washing away, keeping the land good for farming and showing how many families cared about their environment.

Labor Days in Conservation Activities during the War

During the war, the average number of labor days dropped a lot to just 0.68, with a standard deviation of 5.361, meaning almost no one in the 251 households was working on conservation. This big drop happened because people were scared, had to leave their homes, or focused on staying safe instead of farming. Key informant interviews (KIIs) showed that a leader [Tsirae Wemberta leader] said, "No one could work on the land because it was too dangerous during the war" (KII, Tsirae Wemberta). Sola et al. (2021) and Kumar et al. (2020) explain that wars stop people from doing conservation work, which leads to more soil erosion and land damage. With almost no work done, the land became less healthy, making it harder to grow crops.

Labor Days in Conservation Activities after the War

After the war, the average number of labor days went up to 13.36, with a standard deviation of 18.693, meaning some families in the 251 households worked more (around 30 days) and others less (around 0 days). This shows that people started working on conservation again, but not as much as before the war. Focus group discussions (FGDs) revealed that farmers [Hayelom kebele, Tsirae Wemberta] said they wanted to fix their land, but it was hard because tools were broken and they felt tired (FGD, Hayelom kebele). The increase is a good sign, but the land still has problems like erosion because the work isn't back to normal, which makes farming and protecting the environment tougher after the war.

The Friedman Test in Table 4.5 shows a Chi-Square value of 307.503, with 2 degrees of freedom (Df), and an Asymp. Sig. of .000, which means the differences in the number of labor days households spent on conservation activities before, during, and after the war are real and not random. In simple terms, this test tells us that the big drop during the war (from 31.88 days to 0.68 days) and the increase after the war (to 13.36 days) are important changes caused by the war. The very small Asymp. Sig. value (less than 0.001) proves these changes are significant, showing how the war stopped families from working on conservation and how they started again after, but not as much as before. This helps us see that the war really affected how much time people could spend protecting their land, which can lead to more soil erosion and land damage if they don't get back to working more days.

Table 4.5: Number of labor days (labor *days) Households engaged in conservation activities freely Before, During, and After War

Descriptive Statistics	**N**	**Mean**	**Std. Deviation**
Numbers of labor days(labor *days) household engaged conservation activities freely before war	251	31.88	20.274
Numbers of labor days(labor*days) household engaged conservation activities freely during war	251	.68	5.361
Numbers of labor days(labor *days) household engaged conservation activities freely after war	251	13.36	18.693
Test Statistics[a]			
Chi-Square	307.503		
Df	2		
Asymp. Sig.	.000		
a. Friedman Test			

Source: own survey (2025)

Table 4.6 shows the average number of trees planted annually by households before, during, and after the Tigray conflict, with the Friedman test result ($\chi^2 = 112.973$, $p < 0.001$) confirming significant changes in planting behavior.

Plants Planted Before the War

Table 4.6 shows that before the war, each of the 251 households in Samre and Tsirae Wemberta planted an average of 13.20 plants on their private land, with a standard deviation of 44.275, meaning some families planted a lot (over 50 plants) and others planted just a few (around 0). This shows that families were working hard to grow plants like trees to help their land. Focus group discussions (FGDs) revealed that farmers [Samre farmers] said they planted trees to stop soil from washing away before the war (FGD, Samre). This effort helped keep the land healthy and good for farming, showing how much they cared about their environment.

Plants Planted During the War

During the war, the average number of plants households planted dropped to just 1.90, with a standard deviation of 25.347, meaning almost no one in the 251 households was planting, with some planting none and a few planting a little. This big drop happened because people were scared, had to leave their homes, or couldn't focus on farming. Key informant interviews (KIIs) showed that a leader [from Tsirae Wemberta said, "We couldn't plant trees because we were busy trying to stay safe" (KII, Tsirae Wemberta). Sola et al. (2021) and Kumar et al. (2020) explain that wars stop people from planting, which leads to more soil erosion and land damage. With so few plants, the land lost protection, making farming harder.

Plants Planted After the War

After the war, the average number of plants households planted went up to 3.89, with a standard deviation of 14.894, meaning some families in the 251 households planted a few (around 15 plants) and others planted none. This shows that people started planting again, but not as much as before. Focus group discussions (FGDs) showed that farmers [Hayelom kebele, Tsirae Wemberta] said they wanted to grow plants to fix their land, but it was hard because they lacked seeds and tools (FGD, Hayelom kebele). The increase is a good start, but the low number means the land still faces erosion, making it tough to farm and protect the environment after the war.

The Friedman Test in Table 4.6 shows a Chi-Square value of 112.973, with 2 degrees of freedom (Df), and an Asymp. Sig. of .000, which means the differences in the number of plants households planted on their private land before, during, and after the war are real and not just by chance. In simple terms, this test tells us that the big drop during the war (from 13.20 plants to 1.90 plants) and the small increase after the war (to 3.89 plants) are important changes caused by the war. The very small Asymp. Sig. value (less than 0.001) proves these changes are significant, showing how the war stopped families from planting trees and how they started again after, but not as much as before. This helps us understand that the war really affected how families helped their land by planting, which can lead to more soil erosion if they don't plant more trees to protect the soil.

Table 4.6: Numbers of plant Household planted in their private Land Before, During, and After the War

Descriptive Statistics	**N**	**Mean**	**Std. Deviation**
Numbers of plant household planted in their private land in (year) before war	251	13.20	44.275
Numbers of plant household planted in their private land in (year) during war	251	1.90	25.347
Numbers of plant household planted in their private and in (year) after war	251	3.89	14.894
Test Statistics[a]			
N	251		
Chi-Square	112.973		
Df	2		
Asymp. Sig.	.000		
a. Friedman Test			

Source: own survey (2025)

Table 4.7 presents the quantitative changes in the construction of stone and soil bunds (measured in meters) on privately-owned farmlands before, during, and after the Tigray conflict. The results of the Friedman test ($\chi^2 = 215.026$, $p < 0.001$) indicate that the differences in bund construction across these periods are statistically significant, underscoring the war's substantial impact on soil and water conservation (SWC) activities.

Stone and Soil Structures Constructed Before the War

Table 4.7 shows that before the war, each of the 251 households in Samre and Tsirae Wemberta built an average of 26.37 meters of stone and soil structures, like soil bunds or stone walls, on their land to stop soil from washing away, with a standard deviation of 72.007, meaning some families built a lot (around 90 meters) and others built very little (around 0 meters). This shows that many families worked hard to protect their land. Focus group discussions (FGDs) revealed that farmers [Abrha Kalayu] said they built these structures together to keep their fields safe before the war (FGD, Samre). This effort helped stop erosion and kept the land good for farming, showing how much they cared about their environment.

Stone and Soil Structures Constructed During the War

During the war, the average length of stone and soil structures built dropped a lot to just 3.54 meters, with a standard deviation of 26.615, meaning most of the 251 households built almost nothing, with some building a little and most building none. This big drop happened because people were scared, had to leave their homes, or couldn't focus on building. Key informant interviews (KIIs) showed that a leader [Belete Goitom] said, "We couldn't build anything because we were running from the war" (KII, Tsirae Wemberta). Sola et al. (2021) and Kumar et al. (2020) explain that wars stop people from building structures, which lead to more soil erosion and land damage. With so little built, the land lost protection, making farming harder.

Stone and Soil Structures Constructed After the War

After the war, the average length of stone and soil structures built went up to 7.77 meters, with a standard deviation of 27.610, meaning some families in the 251 households built a bit more (around 30 meters) and others built very little (around 0 meters). This shows that people started building again, but not as much as before. Focus group discussions (FGDs) showed that farmers [Hayelom kebele, Tsirae Wemberta] said they wanted to rebuild structures to save their land, but it was hard because they lacked materials and help (FGD, Hayelom kebele). The increase is a good start, but the low number means the land still faces erosion, making it tough to farm and protect the environment after the war.

The Friedman Test in Table 4.7 shows a Chi-Square value of 215.026, with 2 degrees of freedom (Df), and an Asymp. Sig. of .000, which means the differences in the length of stone and soil structures built by households on their private land before, during, and after the war are real and not random. In simple terms, this test tells us that the big drop during the war (from 26.37 meters to 3.54 meters) and the small increase after the war (to 7.77 meters) are important changes caused by the war. The very small Asymp. Sig. value (less than 0.001) proves these changes are significant, showing how the war stopped families from building structures and how they started again after, but not as much as before. This helps us see that the war really affected how families protected their land, which can lead to more soil erosion if they don't build more structures to save the soil.

Table 4.7: Length of Stone and Soil Structures Constructed on Private Land Before, During, and After the War

Descriptive Statistics	**N**	**Mean**	**Std. Deviation**
Stone and soil constructed in own land (meter) before war	251	26.37	72.007
Stone and soil constructed in own land (meter) during war	251	3.54	26.615
Stone and soil constructed in own land (meter) after war	251	7.77	27.610
Test Statistics[a]			
N	251		
Chi-Square	215.026		
Df	2		
Asymp. Sig.	.000		
a. Friedman Test			

Source: own survey (2025)

Table 4.8 highlights the changes in the construction of stone-faced trenches (measured in meters) on farmlands before, during, and after the Tigray conflict. The results of the Friedman test (χ^2 = 131.891, $p < 0.001$) indicate a statistically significant difference in trench construction over time, showing that the war notably impacted this form of physical conservation infrastructure.

Stone-Faced Trenches Constructed Before the War

Table 4.8 shows that before the war, each of the 251 households in Samre and Tsirae Wemberta built an average of 9.86 meters of stone-faced trenches ditches lined with stones to guide water and stop soil from washing away on their land, with a standard deviation of 33.108, meaning some families built a lot (around 40 meters) and others built very little (around 0 meters). This shows that families worked hard to protect their land from water damage. Focus group discussions (FGDs) revealed that farmers [Samre farmers] said they built these trenches together to save their soil before the war (FGD, Samre). This effort helped keep the land healthy for farming, showing how much they cared about their environment.

Stone-Faced Trenches Constructed During the War

During the war, the average length of stone-faced trenches built dropped a lot to just 0.96 meters, with a standard deviation of 5.596, meaning most of the 251 households built almost nothing, with some building a tiny bit and most building none. This big drop happened because people were scared, had to leave their homes, or couldn't focus on building. Key informant interviews (KIIs) showed that a leader [Tsirae Wemberta leader] said, "We couldn't build trenches because we were trying to survive the war" (KII, Tsirae Wemberta). Sola et al. (2021) and Kumar et al. (2020) explain that wars stop people from building conservation structures, which leads to more soil erosion and land damage. With so little built, the land lost protection, making farming harder.

Stone-Faced Trenches Constructed After the War

After the war, the average length of stone-faced trenches built went up to 3.13 meters, with a standard deviation of 7.893, meaning some families in the 251 households built a bit more (around 10 meters) and others built very little (around 0 meters). This shows that people started building trenches again, but not as much as before. Focus group discussions (FGDs) showed that farmers [Hayelom kebele, Tsirae Wemberta] said they wanted to rebuild trenches to save their land, but it was hard because they lacked stones and tools (FGD, Hayelom kebele). The increase is a good start, but the low number means the land still faces erosion, making it tough to farm and protect the environment after the war.

Table 4.8: Length of Stone-Faced Trenches Constructed on Private Land Before, During, and After the War

Descriptive Statistics	N	Mean	Std. Deviation
Stone-faced trench constructed in own land in (	251	9.86	33.108

meter) before war			
Stone-faced trench constructed in own land(meter) during war	251	.96	5.596
Stone-faced trench constructed in own land(meter) after war	251	3.13	7.893
Test Statistics[a]			
N	251		
Chi-Square	131.891		
Df	2		
Asymp. Sig.	.000		
a. Friedman Test			

Source: own survey (2025)

4.2.3. Effects of war on Biological conservation

Table 4.9 presents the changes in monthly wood consumption (measured in donkey loads) before, during, and after the Tigray conflict. The Friedman test result ($\chi^2 = 34.475$, $p < 0.001$) indicates a statistically significant difference across the three periods, reflecting the war's impact on household energy use and environmental pressure.

Wood Consumption before the War

Table 4.9 shows that before the war, each of the 251 households in Samre and Tsirae Wemberta used an average of 3.40 donkey loads of wood per month for things like cooking or heating, with a standard deviation of 2.23, meaning some families used more (around 5 loads) and others used less (around 1 load). This shows that families relied on wood, but not too heavily. Focus group discussions (FGDs) revealed that farmers [Samre farmers] said they used wood from nearby areas but tried to cut carefully to save trees (FGD, Samre). This level of wood use was manageable and didn't harm the environment too much, helping to keep forests safe before the war.

Wood Consumption during the War

During the war, the average wood consumption went up to 3.99 donkey loads per month, with a standard deviation of 3.79, meaning some of the 251 households used a lot more (around 7 loads) while others used less (around 0 loads). This increase happened because people had no other way to cook or stay warm, as the war made it hard to get other fuel options. Key informant interviews

(KIIs) showed that a leader [Tsirae Wemberta leader] said, "We had to cut more trees because we couldn't find anything else to use" (KII, Tsirae Wemberta). Sola et al. (2021) and Kumar et al. (2020) explain that during wars, people often use more wood, which leads to cutting down too many trees. This higher wood use hurt forests, making the environment less healthy.

Wood Consumption after the War

After the war, the average wood consumption went back down to 3.40 donkey loads per month, with a standard deviation of 3.27, meaning some families in the 251 households used more (around 6 loads) and others used less (around 0 loads), similar to before the war. This shows that people stopped using as much wood once the war ended. Focus group discussions (FGDs) showed that farmers [Hayelom kebele, Tsirae Wemberta] said they tried to use less wood after the war because they saw how many trees were gone (FGD, Hayelom kebele). But the damage from the war means there are fewer trees left, so even this amount of wood use can still hurt the environment, making it important to find other ways to cook or heat, like using solar power.

The Friedman Test in Table 4.8 shows a Chi-Square value of 131.891, with 2 degrees of freedom (Df), and an Asymp. Sig. of .000, which means the differences in the length of stone-faced trenches built by households on their private land before, during, and after the war are real and not just by chance. In simple terms, this test tells us that the big drop during the war (from 9.86 meters to 0.96 meters) and the small increase after the war (to 3.13 meters) are important changes caused by the war. The very small Asymp. Sig. value (less than 0.001) proves these changes are significant, showing how the war stopped families from building trenches and how they started again after, but not as much as before. This helps us understand that the war really affected how families protected their land from water damage, which can lead to more soil erosion if they don't build more trenches to manage water and save the soil.

Table 4.9: Monthly Wood Consumption by Households Before, During, and After the War

Descriptive Statistics	N	Mean	Std. Deviation
monthly wood consumption(donkey load) before war	251	3.3994	2.22668
monthly wood consumption(donkey load) during war	251	3.9871	3.79488

monthly wood consumption (donkey load) after war	251	3.3974	3.26568
Test Statistics[a]			
N	251		
Chi-Square	34.475		
Df	2		
Asymp. Sig.	.000		
a. Friedman Test			

Source: own survey (2025)

Table 4.10 shows changes in monthly charcoal consumption (in donkey loads) before, during, and after the Tigray conflict. The Friedman test result ($\chi^2 = 37.508$, $p < 0.001$) indicates a statistically significant difference, highlighting the conflict's impact on charcoal use and its pressure on biological conservation.

Charcoal Consumption before the War

Table 4.10 shows that before the war, each of the 251 households in Samre and Tsirae Wemberta used an average of 1.31 donkey loads (in chirets) of charcoal per month for cooking or heating, with a standard deviation of 1.09, meaning some families used more (around 2 loads) and others used less (around 0 loads). This shows that families used charcoal, but not too much. Focus group discussions (FGDs) revealed that farmers [Samre farmers] said they used charcoal carefully and often mixed it with wood to save trees (FGD, Samre). This amount of charcoal use didn't harm the environment too much, helping to protect forests before the war.

Charcoal Consumption during the War

During the war, the average charcoal consumption went up to 1.75 donkey loads per month, with a standard deviation of 1.69, meaning some of the 251 households used a lot more (around 3 loads) while others used less (around 0 loads). This increase happened because people couldn't find other ways to cook or stay warm, as the war made things hard. Key informant interviews (KIIs) showed that a leader [Tsirae Wemberta leader] said, "We used more charcoal because we had no other choice during the war" (KII, Tsirae Wemberta). Sola et al. (2021) and Kumar et al. (2020) explain that during wars, people often use more charcoal, which means cutting down more trees. This higher use hurt forests, making the environment less healthy.

Charcoal Consumption after the War

After the war, the average charcoal consumption went down to 1.35 donkey loads per month, with a standard deviation of 1.14, meaning some families in the 251 households used more (around 2 loads) and others used less (around 0 loads), almost the same as before the war. This shows that people went back to using less charcoal after the war ended. Focus group discussions (FGDs) showed that farmers [Hayelom kebele, Tsirae Wemberta] said they tried to use less charcoal because they noticed fewer trees after the war (FGD, Hayelom kebele). But even this amount can still harm the environment since many trees were already cut, so finding other ways to cook, like using solar energy, is important.

The Friedman Test in Table 4.10 shows a Chi-Square value of 34.475, with 2 degrees of freedom (Df), and an Asymp. Sig. of .000, which means the differences in charcoal use before, during, and after the war are real and not random. In simple terms, the test tells us that the war really changed how much charcoal people used it went up a lot during the war and then went down after. This test helps us be sure that the changes we see in the numbers are important and show how the war affected people's actions, which hurt the environment by using more trees.

Table 4.10: Monthly Charcoal Consumption by Households Before, During, and After the War

Descriptive Statistics	**N**	**Mean**	**Std. Deviation**
Monthly charcoal consumption (donkey load/chiret) before war	251	1.3082	1.08864
Monthly charcoal consumption (donkey load/chiret) during war	251	1.7470	1.68619
Monthly charcoal consumption (donkey load/chiret) after war	251	1.3542	1.13850
Test Statistics[a]			
N	251		
Chi-Square	37.508		
Df	2		
Asymp. Sig.	.000		
a. Friedman Test			

Source: own survey (2025)

Table 4.11 shows the changes in fodder collected from forests (measured in donkey loads) before, during, and after the Tigray conflict. The Friedman test result ($\chi^2 = 27.098$, $p < 0.001$)

reveals a statistically significant difference, highlighting the war's impact on fodder harvesting and pressure on forest ecosystems.

Fodder Collection before the War

Table 4.11 shows that before the war, each of the 251 households in Samre and Tsirae Wemberta collected an average of 1.73 donkey loads of fodder like grass or leaves for animals from forests each month, with a standard deviation of 3.419, meaning some families collected more (around 5 loads) and others collected less (around 0 loads). This shows that families relied on forests to feed their animals. Focus group discussions (FGDs) revealed that farmers [Samre farmers] said they collected fodder carefully to avoid harming the forest too much (FGD, Samre). This amount of collection was okay and didn't damage the forest a lot, helping to keep the environment balanced before the war.

Fodder Collection during the War

During the war, the average fodder collection dropped a little to 1.56 donkey loads per month, with a standard deviation of 3.719, meaning some of the 251 households collected more (around 5 loads) while others collected less (around 0 loads). This small drop happened because people were scared to go to forests or had to leave their homes, but some still needed fodder for their animals. Key informant interviews (KIIs) showed that a leader [Tsirae Wemberta leader] said, "We couldn't go to the forest often because it was dangerous, but we had to feed our animals" (KII, Tsirae Wemberta). Sola et al. (2021) explain that wars make it hard for people to use forests safely, which can stress the environment if people collect too much from one area.

Fodder Collection after the War

After the war, the average fodder collection dropped more to 0.99 donkey loads per month, with a standard deviation of 2.733, meaning some families in the 251 households collected a bit (around 3 loads) and others collected none. This bigger drop shows that people collected less, maybe because there was less fodder left in the forests or because many animals didn't survive the war. Focus group discussions (FGDs) showed that farmers [Hayelom kebele, Tsirae Wemberta] said they noticed the forests had less to offer after the war (FGD, Hayelom kebele). Kumar et al. (2020) note that after wars, forests often get damaged, making it harder to find resources like fodder. This means families need to find other ways to feed animals, like growing fodder on their land, to protect the forests.

The Friedman Test in Table 4.11 shows a Chi-Square value of 27.098, with 2 degrees of freedom (Df), and an Asymp. Sig. of .000, which means the differences in fodder collection before, during, and after the war are real and not random. In simple terms, this test tells us that the drop during the war (from 1.73 loads to 1.56 loads) and the bigger drop after the war (to 0.99 loads) are important changes caused by the war. The very small Asymp. Sig. value (less than 0.001) proves these changes are significant, showing how the war affected how much fodder families could collect. This helps us understand that the war made it harder to use forests, which can hurt the environment if forests don't recovery.

Table 4.11: Fodder Collection from Forests by Households Before, During, and After the War

Descriptive Statistics	N	Mean	Std. Deviation
fodder collection from forest (donkey load) before war	251	1.73	3.419
fodder collection from forest in(donkey load) during war	251	1.56	3.719
fodder collection from forest in (donkey load)after war	251	.99	2.733
Test Statistics[a]			
N	251		
Chi-Square	27.098		
Df	2		
Asymp. Sig.	.000		
a. Friedman Test			

Source: own survey (2025)

Table 4.12 shows the frequency of livestock grazing in ex-closure areas (measured in days per year) before, during, and after the Tigray conflict. The Friedman test ($\chi^2 = 144.277$, $p < 0.001$)

shows a significant difference between the periods, highlighting the conflict's impact on grazing patterns and biological conservation.

Grazing Frequency before the War

Table 4.12 shows that before the war, each of the 251 households in Samre and Tsirae Wemberta grazed their animals in ex-closure areas places where grazing is usually not allowed to let plants grow an average of 39.00 times per year, with a standard deviation of 61.792, meaning some families grazed a lot (around 100 times) and others grazed less (around 0 times). This shows that some families were already using these protected areas, even though they weren't supposed to. Focus group discussions (FGDs) revealed that farmers [Samre farmers] said they sometimes let animals graze there because they needed food for their livestock (FGD, Samre). This use put a little pressure on the land, but it wasn't too bad before the war.

Grazing Frequency during the War

During the war, the average grazing frequency in ex-closure areas jumped a lot to 155.69 times per year, with a standard deviation of 174.613, meaning some of the 251 households grazed a lot more (around 300 times) while others grazed less (around 0 times). This big increase happened because people had nowhere else to take their animals, as the war made other areas unsafe or unusable. Key informant interviews (KIIs) showed that a leader [Tsirae Wemberta leader] said, "We had to use the ex-closures because there was no other place for our animals to eat" (KII, Tsirae Wemberta). Sola et al. (2021) and Kumar et al. (2020) explain that during wars, people often overuse protected areas, which damages plants and soil. This heavy grazing hurt the ex-closures, making it harder for the land to recover.

Grazing Frequency after the War

After the war, the average grazing frequency dropped to 41.62 times per year, with a standard deviation of 69.336, meaning some families in the 251 households grazed more (around 110 times) and others grazed less (around 0 times), almost back to the level before the war. This shows that people stopped using the ex-closures as much after the war ended. Focus group discussions (FGDs) showed that farmers [Hayelom kebele, Tsirae Wemberta] said they tried to graze less in ex-closures because they saw the land was damaged (FGD, Hayelom kebele). But the damage from the war means the ex-closures are still not fully recovered, so even this amount of grazing can slow down healing, making it important to protect these areas better to help the environment.

The Friedman Test in Table 4.12 shows a Chi-Square value of 144.277, with 2 degrees of freedom (Df), and an Asymp. Sig. of .000, which means the differences in how often households grazed in ex-closure areas before, during, and after the war are real and not random. In simple terms, this test tells us that the big jump during the war (from 39.00 times to 155.69 times) and the drop after the war (to 41.62 times) are important changes caused by the war. The very small Asymp. Sig. value (less than 0.001) proves these changes are significant, showing how the war made families graze more in protected areas and how they reduced it after, but not fully back to normal. This helps us understand that the war really affected how families used the land, which can hurt the environment if ex-closures aren't protected better.

Table 4.12: Frequency of Household Grazing in Ex-Closure Areas Before, During, and After the War

Descriptive Statistics	**N**	**Mean**	**Std. Deviation**
Frequency household grazing animals in ex-ex-closure area in(year)before war	251	39.00	61.792
Frequency household grazing animals in ex-ex-closure area in(year) during war	251	155.69	174.613
Frequency household grazing animals in ex-ex-closure area in(year) after war	251	41.62	69.336
Test Statistics[a]			
N	251		
Chi-Square	144.277		
Df	2		
Asymp. Sig.	.000		
a. Friedman Test			

Source: own survey (2025)

Table 4.13 shows the frequency of firewood collection from the forest (measured in donkey loads) before, during, and after the Tigray conflict. The results from the Friedman Test (χ^2 = 55.907, $p < 0.001$) indicate a statistically significant change in firewood collection across the three periods, suggesting that the conflict had a substantial impact on biological conservation.

Firewood Collection before the War

Table 4.13 shows that before the war, each of the 251 households in Samre and Tsirae Wemberta collected an average of 2.19 donkey loads of firewood from forests each month, with a standard deviation of 5.484, meaning some families collected more (around 7 loads) and others collected less (around 0 loads). This shows that families used firewood for cooking or heating, but it wasn't too much. Focus group discussions (FGDs) revealed that farmers [Samre farmers] said they tried to cut trees carefully to avoid hurting the forest too much (FGD, Samre). This level of collection was okay and didn't damage the forest a lot, helping to keep the environment healthy before the war.

Firewood Collection during the War

During the war, the average firewood collection went up a lot to 4.86 donkey loads per month, with a standard deviation of 12.081, meaning some of the 251 households collected a lot more (around 15 loads) while others collected less (around 0 loads). This increase happened because people needed more firewood to cook or stay warm, as the war made it hard to get other fuels. Key informant interviews (KIIs) showed that a leader [Tsirae Wemberta leader] said, "We had to cut more trees because we had no other way to survive" (KII, Tsirae Wemberta). Sola et al. (2021) and Kumar et al. (2020) explain that during wars, people often collect more firewood, which leads to cutting down too many trees. This heavy use hurt the forests, making the environment less healthy.

Firewood Collection after the War

After the war, the average firewood collection dropped to 2.49 donkey loads per month, with a standard deviation of 6.852, meaning some families in the 251 households collected more (around 9 loads) and others collected less (around 0 loads), close to the level before the war. This shows that people went back to using less firewood after the war ended. Focus group discussions (FGDs) showed that farmers [Hayelom kebele, Tsirae Wemberta] said they tried to cut less because they saw the forest was thinning out (FGD, Hayelom kebele). But the damage from the war means fewer trees are left, so even this amount can still harm the environment, making it important to find other ways to cook or heat, like using solar power.

The Friedman Test in Table 4.13 shows a Chi-Square value of 55.907, with 2 degrees of freedom (Df), and an Asymp. Sig. of .000, which means the differences in how often households collected firewood from forests before, during, and after the war are real and not random. In simple terms, this test tells us that the big jump during the war (from 2.19 loads to 4.86 loads) and the drop after the war (to 2.49 loads) are important changes caused by the war. The very small Asymp. Sig. value (less than 0.001) proves these changes are significant, showing how the war made families collect more firewood and how they reduced it after, but not fully back to normal. This helps us understand that the war really affected how families used the forest, which can lead to more deforestation if trees aren't protected better.

Table 4.13: Frequency of Firewood Collection from Forests by Households Before, During, and After the War

Descriptive Statistics	N	Mean	Std. Deviation
frequency firewood from forest (in donkey load) before war	251	2.19	5.484
frequency firewood from forest (in donkey load) during war	251	4.86	12.081
frequency firewood from forest (in donkey load) after war	251	2.49	6.852
Test Statistics[a]			
N	251		
Chi-Square	55.907		
Df	2		
Asymp. Sig.	.000		
a. Friedman Test			

Source: own survey (2025)

4.3. Impact of the War on Bylaws Governing Natural Resource Management

Table 4.14 presents a cross-tabulation of the perceived effects of the war on natural resource management (NRM) bylaws in Samre and Tsirae-Wemberta woredas. The results show that the war severely affected NRM bylaws in both districts, with 65.5% of respondents in Samre and 61.5% in Tsirae-Wemberta reporting significant disruption. This disruption likely impacted the enforcement of bylaws related to soil and water conservation, forest management, and grazing. A smaller percentage of respondents (18.3% in Samre and 22.0% in Tsirae-Wemberta) felt the impact was slight, suggesting that bylaws were still partially enforced through informal or community-based mechanisms, although their effectiveness was reduced. A small portion of respondents (16.2% in Samre and 16.5% in Tsirae-Wemberta) reported that the bylaws were not affected, indicating stronger community resilience in these areas despite challenges. However, FGDs and KIIs revealed that even in these communities, enforcement was hampered by increased poverty and the collapse of local authority during the war.

The Chi-Square test statistic (0.586, p = 0.746) indicates no significant difference between the two woredas in terms of the perceived impact of the war on bylaws, suggesting that both areas experienced similar levels of disruption. This finding aligns with broader research indicating that conflict often leads to governance breakdowns, regardless of local context. Both weredas faced significant institutional challenges, which compromised their ability to enforce NRM bylaws during the conflict.

Table 4.14: War Impact on NR Management Bylaws

Effects of war on bylaws * wereda Crosstabulation				
		Wereda		Total
		Samre	Tsrae Wenberta	
Effects of war on bylaws	Severely affected	93	67	160
	Slightly affected	26	24	50
	Not affected	23	18	41
Total			142	109

Chi-Square Tests			
	Value	Df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.586[a]	2	.746
Likelihood Ratio	.584	2	.747
N of Valid Cases	251		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 17.80.

Source: own survey (2025)

Table 4.15 examined the perceived existence of NRM bylaws before the Tigray conflict in Samre and Tsirae-Wemberta woredas, showing widespread recognition. In Samre, 96% of respondents (136/142) confirmed bylaws' presence, while 4% (6/142) reported their absence. In

Tsirae-Wemberta, 100% (109/109) acknowledged bylaws, with no reports of absence. Overall, 97.6% (245/251) affirmed bylaws' existence, with only 2.4% (6/251), all from Samre, perceiving otherwise. This indicated bylaws were well-established, reflecting strong local governance, though Samre's slightly higher perception of absence (4% vs. 0%) suggested local governance variations.

Fisher's Exact Test assessed the association between woreda and perceived bylaws' existence, yielding a 2-sided p-value of 0.037 and a 1-sided p-value of 0.031, indicating a significant association at the 0.05 level. This showed Tsirae-Wemberta respondents unanimously reported bylaws, unlike Samre, where a minority perceived their absence. The test's reliability stemmed from its handling of low expected cell counts (2.61 for Tsirae-Wemberta's "No" category). FGDs and KIIs supported this, with Tsirae-Wemberta's informants noting strong bylaws, while Samre respondents cited weak monitoring in some villages, explaining the 4% discrepancy.

The findings aligned with literature emphasizing bylaws' role in sustainable NRM, with effectiveness varying by local context (Tadesse & Bezabih, 2019). Tigray's pre-war land rehabilitation success (Gebremedhin et al., 2018) was evident, with the difference between weredas (p = 0.037) likely due to governance variations (Sola et al., 2021). Tsirae-Wemberta's unanimous recognition provided a strong baseline for post-conflict restoration, while Samre needed targeted interventions for weaker governance areas. This highlighted the need to rebuild bylaws post-war through participatory approaches addressing local differences.

Table 4.15: Perceived NR Management Bylaws Pre-War

			Wereda		Total
			Samre	Tsrae Wenberta	
bylaws before war	Yes		136	109	245
	No		6	0	6
	Total		142	109	251
Chi-Square Tests					
	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	4.718a	1	.030		
Continuity Correctionb	3.081	1	.079		

Likelihood Ratio	6.948	1	.008		
Fisher's Exact Test				.037	.031
N of Valid Cases	251				
a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 2.61.					
b. Computed only for a 2x2 table					

Source: own survey (2025)

Table 4.16 looked at whether people thought NRM bylaws existed after the Tigray conflict in Samre and Tsirae-Wemberta woredas. Most people believed bylaws were gone. In Samre, 76% (108/142) said bylaws no longer existed, while 24% (34/142) thought they were still active. In Tsirae-Wemberta, 84% (92/109) reported bylaws were absent, with 16% (17/109) believing they remained. Overall, 79.7% (200/251) of respondents said bylaws were not in place, while 20.3% (51/251) said they were. This showed the war heavily disrupted local rules, with Tsirae-Wemberta slightly more likely to report bylaws' absence (84% vs. 76%).

Fisher's Exact Test checked if perceptions differed between woredas, giving a 2-sided p-value of 0.115 and a 1-sided p-value of 0.070, meaning no strong difference at the 0.05 level. This suggested people in both woredas had similar views, though Tsirae-Wemberta leaned slightly toward reporting bylaws' absence. The test was reliable due to its handling of expected counts (minimum 22.15). FGDs and KIIs backed this up, saying community rules weakened because leaders were displaced. A Samre informant said, "Leaders were scattered, and no one followed rules." In Tsirae-Wemberta, people noted uncontrolled resource use, showing bylaws barely worked.

The results matched studies saying recovery of rules is slow after conflicts (UNEP, 2022). The similar views across woredas, confirmed by Fisher's Exact Test ($p = 0.115$), showed widespread rule breakdowns (Mohammed et al., 2022). KIIs noted that even where bylaws existed, they were rarely enforced due to lack of resources. This pointed to the need to rebuild NRM bylaws after the war using community efforts. The same approach could work in both woredas, building on past strengths to create strong, community-led rules.

Table 4.16: Perceived NR Management Bylaws Post-War

			Wereda		Total
			Samre	Tsrae Wenberta	
bylaws after war	Yes		34	17	51
	No		108	92	200
	Total		142	109	251
Chi-Square Tests					
	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	2.654a	1	.103		
Continuity Correction[b]	2.163	1	.141		
Likelihood Ratio	2.707	1	.100		
Fisher's Exact Test				.115	.070
N of Valid Cases	251				
a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 22.15.					
b. Computed only for a 2x2 table					

Source: own survey (2025)

4.4. Extent of Use of Alternative Energy Sources by Study Households

4.4.1. Extent of Alternative Energy Use

As shown in Table 4.17 the study found that a significant majority of the surveyed households (98.4%) reported being familiar with solar energy, while only a small fraction (1.6%) indicated unfamiliarity. This widespread familiarity suggests that solar energy has gained strong recognition among households in the study area. Such high awareness may stem from increased exposure to solar technologies through government or NGO initiatives, informal networks, or community-based awareness campaigns.

However, it is important to emphasize that familiarity with solar energy does not necessarily equate to its active use. While households may know about solar energy, factors such as affordability, accessibility, and perceived reliability could influence actual adoption. The high level of familiarity nonetheless indicates strong potential for future expansion and promotion of solar energy use, especially as a cleaner and more sustainable alternative to traditional biomass fuels.

Table 4.17: Household Familiarity with Solar Energy

Familiarity with solar energy			
		Frequency	Percent
Valid	No	4	1.6
	Yes	247	98.4
	Total	251	100.0

4.4.2. Reliance on Traditional Fuels

Table 4.18 presents descriptive statistics on household reliance on traditional fuels specifically wood and charcoal before, during, and after the conflict, alongside average monthly fuel expenditures. The findings reveal notable shifts in energy consumption patterns that closely correspond to the war period and its aftermath.

Households reported an average monthly fuel expenditure of 642.84 ETB, with a high standard deviation of 797.44. This significant variation suggests large disparities in energy needs and access among households. Insights from Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) indicated that while better-off families could afford to purchase firewood or charcoal from markets, poorer households often resorted to collecting fuel from nearby forests, especially during the war and recovery periods.

In terms of wood consumption, households used an average of 3.40 donkey loads per month before the war, reflecting regulated use under existing community bylaws. During the war, this figure rose to 3.99 loads, indicating a breakdown in enforcement systems and a turn toward survival-driven resource use. FGD participants frequently mentioned how the collapse of electricity and market systems forced widespread reliance on forest biomass. KII respondents further emphasized that ex-closures and communal forests became open-access areas due to the collapse of traditional governance structures. After the conflict, wood consumption returned to 3.40 loads, though the relatively high standard deviation (3.27) points to continued disparities in access and regulation. This pattern aligns with findings from Meaza et al. (2024), who observed that post-conflict environments often struggle to re-establish sustainable practices without institutional restoration.

Charcoal consumption followed a similar pattern, rising from 1.31 loads before the war to 1.75 loads during the war, before slightly dropping to 1.35 loads post-war. FGDs indicated that charcoal became a key coping mechanism and income source, particularly during the siege period when alternative fuels were inaccessible. The standard deviation in charcoal use increased notably during the war (1.69), highlighting how conflict affected households differently some intensified their use for income, while others had limited access due to insecurity or displacement.

Overall, the data underscores a strong and continued reliance on traditional fuels throughout the war and recovery periods. Despite some stabilization post-war, the findings reflect a lingering dependency that FGDs and KIIs attribute to poverty, lack of affordable alternatives, and weakened institutional enforcement. These results emphasize the need for targeted interventions to support energy transitions in conflict-affected regions

Table 4.18: Household Reliance on Traditional Fuels & Energy Expenditure

Descriptive Statistics	N	Mean	Std. Deviation
Fuel expenditure	251	642.84	797.441
Monthly wood consumption before war	251	3.3994	2.22668
Monthly wood consumption during war	251	3.9871	3.79488
Monthly wood consumption after war	251	3.3974	3.26568
Monthly charcoal consumption before war	251	1.3082	1.08864
Monthly charcoal consumption during war	251	1.7470	1.68619
Monthly charcoal consumption after war	251	1.3542	1.13850
Valid N (listwise)	251		

Source: own survey (2025)

Chapter 5: Conclusions and Recommendations

5.1. Conclusions

This study looked at how the Tigray war (2020–2022) affected NRM practices and the use of solar cookers and lighting in Samre and Tsirae-Wemberta woredas. It showed the war badly damaged soil and water conservation (SWC) structures, like stone bunds (80.9% damaged) and soil bunds (71.3% damaged), due to fighting and military use. Firewood collection doubled (from 2.19 to 4.86 donkey loads yearly), and grazing in protected areas jumped from 39 to 155.69 days per year. People saw more erosion and broken conservation systems, matching studies (Meaza et al., 2024) that described environmental harm from conflicts. The war disrupted community work needed to protect natural resources.

The war also weakened NRM bylaws, which were strong before (96% in Samre, 100% in Tsirae-Wemberta knew them). After the war, only 24% in Samre and 16% in Tsirae-Wemberta said bylaws still worked, as leaders were displaced and rules were ignored. This led to a big governance gap, with 65.5% in Samre and 61.5% in Tsirae-Wemberta noting major disruption. Studies (Bruch et al., 2023) confirmed that conflicts often break local rules. Without enforcement, practices like overgrazing and tree-cutting worsened, making recovery harder.

Most people (98.4%) knew about solar energy, but few used solar cookers or lighting, sticking to wood and charcoal. Wood use grew during the war (3.40 to 3.99 donkey loads monthly) and stayed high after (3.40 loads), with charcoal use showing a similar trend (1.31 to 1.75 to 1.35 loads). High costs and lack of access stopped solar use as noted by Sovacool (2023). This heavy use of wood and charcoal hurt forests, showing the need for better access to solar energy to support recovery and protect the environment.

5.2. Recommendations

- Local governments and NGOs should repair damaged SWC structures, like stone and soil bunds, to protect land from erosion. Community work programs, such as food-for-work, can encourage people to help rebuild these structures. Planting more trees and giving out free seedlings can ease pressure on forests, while experts should guide communities to limit grazing in protected areas to help nature recover.

- Communities should restore NRM bylaws, which stopped working during the war. Local leaders, including women and youth, should rewrite these rules together. Training new leaders can help them enforce the bylaws effectively. Governments and donors should provide funds to hire forest guards and support workers, ensuring rules are followed and communities regain trust in the system.

- To reduce reliance on wood and charcoal, governments and NGOs should offer discounts on solar cookers and lights, especially for poor families and women. Simple community classes can teach people how to use and maintain solar tools. Setting up local shops to sell solar products can make them easier to access, helping families save wood and protect forests.

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APPENDIX

Impact of the 2020-2022 Tigray War on Natural Resources and use of alternative energy

Section I: Household Demography and Socioeconomic Information

1.0. Study Woreda /district

1.1. Name of the respondent/HH head

1.2. Age of the household head

1.3. Gender of the household head

Male

Female

1.4. Years of education completed by the household head

1.5. Farm size (in tsmad)

1.6. Livestock holding (in number)

Oxen

Cow

Heifer

Calves

Goats and sheep

Horse

Donkeys

Chicken

1.7. Does any member of your household regularly work for wage, salary, commission or any payment?

Yes

No

1.8. How much annual nonagricultural labor income earn your household (in Birr)?

1.9. Does your household have any business?

Yes

No

1.10. how much the household earned from business per year (in Birr)?

1.11. How much your household receive from remittance, aid or support (in Birr) per year?

1.12. Are you/ any member of your household a member of social organization?

Yes

No

1.13. How many times your household get training on agricultural extension in the last 12 months?

1.14. How much does your household spent for fuel (charcoal, fuelwood, kerosine) per month?

Section II: Impacts of the Tigray War on Natural Resources

2.1. Monthly firewood consumed in Donkey Load (DL): Start from (a).

a) Before the war in (2012 E.C)

b) During the war (2013 -2014 E.C)?

c) After the war (2017 E.C)?

2.2. Monthly charcoal consumed by the household in Chiret: Start from (a)

a) Before the war (2012 E.C)?

b) During the war 2013 - 2014)?

c) After the war (2017 E.C)?

2.3. Frequency of timber harvested from forest areas in a year: Start from (a)

a) Before the war (2012 E.C)?

b) During the war 2013 - 2014)?

c) After the war (2017 E.C)?

2.4. Fodder collection in DL from forests: Start from (a)

a) Before the war (2012 E.C)?

b) During the war (2013 - 2014 E.C)?

c) After the war (2017 E.C)?

2.5. The frequency of your household graze animals in ex-closure areas in a year: start from (a)

a) Before the war (2012 E.C)?

b) During the war (2013 - 2014 E.C)?

C) After the war (2017 E.C)?

2.6. Frequency of fire wood collection from protected forest in a month:

a) Before the war (2012 E.C)?

b) During the war (2013 - 2014)?

c) After the war (2017 E.C)?

2.7. How many minutes take to reach the nearest community forest/ exclosure in your locality?

2.8. Walking distance between your house and all-weather road in minutes?

Section III: Participation in Environmental Restoration

3.1. Number of family members involved in conservation activities in a year: Start from (a).

a) Before the war (2012 E.C)?

b) During the war (2013 - 2014 E.C)?

c) After the war (2016 E.C)?

3.2. Number of labor days (labor*days) your household engaged in conservation activities freely: Start from (a)

a) Before the war (2012 E.C)

b) During the war (2013 - 2014 E.C)?

c) After the war (2016 E.C)?

3.3 Number of plants your family planted in your private land? Start from (a)

a) Before the war (2012 E.C)?

b) During the war (2013 - 2014 E.C) ?

c) After the war (2016 E.C)?

3.4. How many meters of Stone and soil bund (Hamed /Emni Zala) is constructed in your own land? Start from (a)

a) Before the war (2012 E.C)?

b) Durning the war (2013 - 2014 E.E)?

c) After the war (2016 E.C)?

3.5. How many meters of stone-faced trenches is constructed in your own land? Start from (a)

a) Before the war (2012 E.C)?

b) During the war (2013 - 2014 E.C)?

c) After the war (2016 E.C)?

3.6. How many labor days would you like to contribute freely to soil and water conservation measures per year?

3.7. Does soil bund (Hamed Zala) significantly affected by the war in your surrounding catchments?

Yes

No

3.8. Does stone bund (Emni Zala) significantly affected by the war in your surrounding catchments?

Yes

No

3.9. Does terraces with trench significantly affected by the war in your surrounding catchments?

Yes

No

3.10. Does bench terraces significantly affected by the war in your surrounding catchments?

Yes

No

3.11. Does check dams (Zhaweye Guhmi) significantly affected by the war in your surrounding catchments?

Yes

No

3.12. Rank from the most affected to the least:

Soil bund (Hamed Zala)

Stone bund (Emni Zala)

Terraces with trench (Trench)

Bench terraces

Check dams (Zhaweye Guhmi)

3.13. What is the impact of the war on the installed SWC structures in your farm land?

Completely destroyed

Moderately/slightly damaged

No damage

3.14. What change have you observed regarding the erosion status of your farm land and your surrounding after the war?

Increased

No change

Reduced

Section IV: Institutions to Govern Natural Resources

4.1. Which communal land in your surrounding serve as source of livelihood?

Forest

Enclosures

Grazing land

Irrigation water

Other (specify)

4.2. Is there any bylaws to govern communal resources (e.g., forests) in your locality?

Yes

No

4.3. What is the extent of impact of the war on local bylaws to govern communal resources?

Severely affected

Slightly affected

Not affected

4.4. Do you know any local bylaws to govern natural forest/ ex-closures in your Tabia that works properly?

Yes

No

4.5. If your answer to question #4.4 is no, what do you think the reason?

The law enforcing institutions has become weak because of the war

The community members deliberately violate the local bylaws

The governance structure of local bylaws is weak

Other

Section V: alternative energy use

5.1. Are you familiar with solar energy sources such as solar panel for lighting and cooking purposes?

Yes

No

5.2. Have you used any solar panel or related energy technology?

Yes

No

Section VI: Focus Group Discussions (FGDs) and KII

1. Impact of Conflict on Natural Resources:

1.1. Can you describe the changes you have observed in the land, water, and forest resources in your community since the conflict began?

1.2. How has the conflict affected farming and grazing activities in your area?

1.3. Have you noticed any significant changes in soil quality, water availability, or biodiversity in the past few years?

1.4. What specific challenges has the community faced in managing natural resources during and after the conflict?

2. Perceptions of Resource Governance and By-laws

2.1. How do you think the conflict has affected the enforcement of bylaws related to resource management (e.g., water management, grazing land, forest protection)?

2.2. Before the conflict, what rules or bylaws were in place to regulate the use of natural resources in your community?

2.3. Have any new regulations been introduced since the conflict, or have any old ones been modified or removed?

2.4. In your opinion, what role do local authorities and community leaders play in managing natural resources, and how has this changed during and after the conflict?

3. Alternative Energy Use:

4.1. Do you think the use of solar energy or other alternative sources could help reduce the pressure on natural resources like firewood and charcoal? Why or why not?