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Original Research Paper

Environmental Impacts of Tigray War: Evidence from 2020-2026

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Abstract: This paper endeavors to analyze the environmental impact caused by the Tigray War in northern Ethiopia between 2020 and 2026. The study specifically examines the effect of the war on deforestation, soil erosion, destruction of water resources, biodiversity loss, as well as the indirect impacts including biomass usage in siege environments. Besides, it also highlights some of the lacunas found in existing literature regarding this issue and the priorities for environmental recovery following the war. The method adopted is qualitative desk review of peer reviewed papers, institutional and governmental reports and NGO papers The literature review reveals that Tigray War has undone all the efforts made for the past several decades for environmental rehabilitation in the region. Deforestation, collapse of soil and water conservation works, serious land degradation, and disturbance of watersheds are among the negative impacts observed in the area. Also, through remote sensing data, significant loss of vegetation cover can be noted in the regions affected by war. Furthermore, the indirect environmental impacts like high biomass consumption in siege environments have also been observed. The study bases its findings in the global theories on war and the environment that include concepts such as ecocide and the war ecology theory. According to this study, the Tigray war created a serious socio-ecological crisis that negates all the environmental improvements that have been made over the past few decades, making a close link between environmental destruction and humanitarian/ livelihood crises. Based on the findings above, the recommendations are that ecosystem restoration be undertaken through reforestation, restoration of water and soil conservation infrastructure and environmental governance institutions. Further research is needed on the long-term effects of ecological recovery and post-conflict resilience of communities in Tigray.

Keywords: Armed Conflict, Environmental Degradation, Environmental Governance, Post-Conflict Recovery, Tigray War.

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1. Introduction

Across the globe armed conflicts inflict a profound and lasting toll on natural environment contaminating the environment with swage and industrial pollution. As UNEP 2025 has emphasized environmental damage from conflict pushes people into to hunger, disease, and displacement; while the destruction of natural environmental system that regulate carbon and stabilize global temperature [1].

Following the end of Derg regime, for three decades, the Tigray region of northern Ethiopia stood as a globally recognized model for landscape restoration and community based environmental rehabilitation [2] [3]. The regional government initiated an ambitious Programme of soil and water conservation, mass reforestation and community-led land management, mobilizing local labour for 20 to 40 days annually to restore degraded lands.

As a result, there is restoration of degraded hill slopes and catchment, shrubs and trees recover, improved water availability, reduction in soil erosion, food security with other livelihood improvements are among the benefits of such programs with earned Tigray international recognition, including the Global Gold Award for land restoration [4]. This transformation was driven by integrated natural resource management, the construction of terraces and stone bunds, exclosures to allow vegetation recovery, and the strengthening of local environmental governance institutions, creating a socio-ecological system that was widely regarded as a success story for dry land restoration in Africa.

However, outbreak of the armed conflict in Tigray in November 2020 fundamentally reversed this environmental progress, triggering a severe socio-ecological crisis that rapidly untravelled three decades of painstaking restoration work. The conflict involved the Ethiopian National Defense Forces, the Eritrean Defense Forces and allieoregoonal forces, was characterized by intense ground offensives, aerial bombardment, the imposition of a devastating blockade, and the systematic dismantling of public services and environmental management systems [5] [6].

Beyond the direct human toll, the war inflicted widespread and lasting damage on the region's ecosystem, forest, soil, water resources and biodiversity, leading to what scholars have described as one of the most alarming socio-ecological crises in recent history [7). These environmental consequences have been compounded by IDPs, military operations, weakening of conservation infrastructures, collapse of environmental governance and institutional destruction then the overall conditions of the siege are among the main contributing factors for environmental damage [8].

However, despite growing international attention to the humanitarian dimensions of the war the lasting consequences of it's environmental damage has only recently begun to receive systematically documented. Therefore, urgent systematic review of the empirical evidence on the environment impact of the Tigray war across the period 2021 to 2026 is demanded to synthesize what is known about the environmental impact of Tigray war, identify critical evidence gap and to inform conflict sensitive restoration and peace building strategies. The main objective of this review is to assess environmental impacts of Tigray war from published and unpunished materials released from 2021-2026. While the humanitarian cost of the Tigray War has attracted increasing attention, the environmental impacts have been systematically under-documented: studies to date are fragmented, lack ground validation, do not account for indirect siege-induced biomass consumption, do not consider vulnerability dimensions, are limited in solutions, and do not synthesize 2021–2026. The gap is that there is no multi-dimensional review combining direct and indirect environmental damage with policy and recovery priorities. This desk review therefore aims to synthesize evidence on deforestation, soil degradation, water destruction, biodiversity loss and siege-related biomass consumption in Tigray from 2021 to 2026. Objectives: (1) to synthesize documented evidence of vegetation, soil and wildlife impacts; (2) to assess indirect siege-induced biomass consumption; (3) to identify policy gaps; and (4) to outline priorities for post-conflict environmental recovery and resilience building.

2. Literature Review

2.1. Global Theories on Conflict and Environmental Degradation

When we examine practical experiences across the world, wars are closely associated with environmental destruction. The interconnection on how war causes deforestation, pollution, bio diversity loss, soil and water contamination, and long-term toxic landscape is mostly investigated under war and ecology studies. Recent scholars argue that contemporary conflicts do not affect only harm human beings, since it also causes the destruction of earth's life support systems.

The concept of Ecocide was developed as a pillar to show the long-lasting devastation. Here ecocide refers to the long lasting and extensive harming of the ecosystems and environments which in turn leads to total destruction of the natural systems that maintain life. The concept itself gained global attention

during the war happened in Vietnam. It gains global attention after the US military Releases powerful chemical which has the power to kill peoples and plants over enormous regions. The spraying of chemicals by US forces caused three main destructions over the environment, i.e. (1) huge deforestation which in turn lead to the destructions of dense forests, (2) pollution of soil and water which leads to continues contamination of the environment in general and soil and water in particular, and (3) long lasting bio diversity loss which leads to the destruction of insects, birds, and other animal's home.

In addition to the above-mentioned war, the same happenings practically appear in other conflicts. When we see in Sudan, the long-lasting civil war to control natural resources faced desertification and land degradation. This indicates that conflicts over grazing and water increased environmental destruction and decline. The united nation environment program report shows that the over use of natural resources leads to war, and in similar to those wars destroy environment.

Some literature and research on environmental peace building states three main ways how war harms and impacts the environment. The first one is the direct damage from the military fighting itself (from the war itself). That means the immediate destruction caused from the military operation. Second, the indirect pressure and destruction happened not because of the immediate war but because of the secondary effects [9]. For example, when we see the effects like displacement, resource over exploitation, and livelihood crisis, they are secondary effects that occur because of the war not from the fighting itself. Third, the long term cumulative and combined effects which increases and deepens over time. Sometimes this effect is known as vicious circles, since it goes from environmental degradation to food security, from food security to instability and conflict, and lastly from conflict to environmental damage [10].

Generally, these impacts create dangerous vicious cycles. When the environment gets badly damaged, it creates quarrels over the scarce resources, leads to poverty and a lack of food. This quarrel to control resources leads to the conflict by sparking new wars and making the existing wars to stay for a long period of time. Thinkers name this war -ecology connection. That means wars and environments are strongly connected since each one leads the other worse. Therefore, war ecology studies the three stages of war like war preparation (building military bases, training), active quarrel (active conflict), and post war recovery (reconstruction, cleaning up pollution).

In addition to the above, there are other real-world examples that strengthen and support these theories we have been discussing. In the 1991 gulf war (the time when Iraq invaded Kuwait), retreating of Iraqi forces leads to firing of hundreds of oil well, massive air pollution, spelled vast amount of oil. This resulted to the damages like: contamination of soil, ground water for a number of years [11]. Additionally, in Ukraine (current Russia- Ukraine war) attacks on chemical industries and other energy materials caused pollution and destruction of forests. In similar to this, in Colombia the war affected the industries, and attacks the oil and chemical pipelines. These examples show that the exact effect of war on environment can differ depending on the location, type, conditions or depending on the context of the war; however how war causes damage is always the same.

Scholars have developed many theories that to explore how war is connected to environmental damages. For example, the green war hypothesis critically investigates how ecological scarcity like droughts, land degradation, and shortage of water causes violence. For this reason, climate change increases the risk of conflict especially in the poor or fragile countries. However, the environmental problems as it is can't cause wars, because they are hazardous when they combined with political, economic, and social problems [12].

The other challenge is the post-conflict recovery once rebuilding the damaged infrastructure needs long lasting contribution. That means the damaged land, polluted water, and destroyed forests leads to fragile peace which in turn leads to new fighting. Therefore, restoring ecosystems requires time, money, and stable governance that can manage recovery projects without corruption. Mostly international laws do not put their attention to punish countries or armies that damages the environment. However, there is a growing movement to make ecocide the 5th international crime (along with genocide and war crimes) at the International Criminal Court. This would allow leaders who cause huge environmental devastation to be prosecuted.

2.2. Conceptual Framework of Environmental Impacts of Tigray War

The Tigray War (2020–2022) serves as the root driver, producing direct impacts (bombing, military operations, and destruction of soil and water conservation structures) and indirect impacts (siege, displacement, and forced biomass dependence) [13]. These war-induced pressures lead directly to environmental degradation, including deforestation and vegetation loss, soil degradation, water damage,

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and biodiversity loss. In turn, this environmental breakdown results in food insecurity and livelihood vulnerability for affected communities. To break this causal chain, post-conflict environmental recovery and resilience building are required not as an afterthought, but as a necessary pathway to restore ecosystems, rebuild livelihoods, and prevent long-term humanitarian collapse.

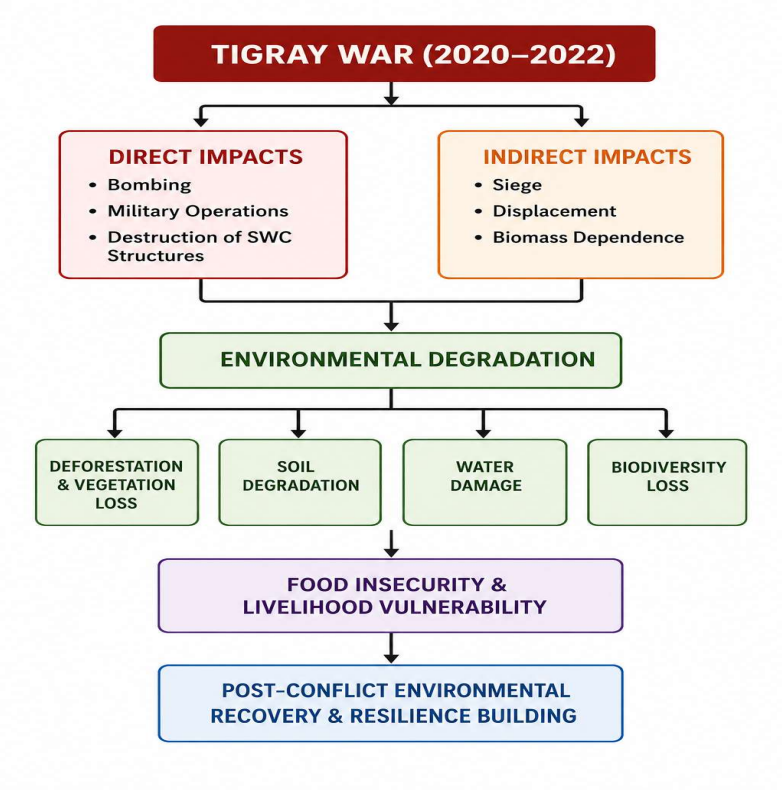

Figure 1. Tigray War

2.3. Legal And Policy Frameworks on War Affected Environment

In situations of armed conflict, the protection of the environment is based on a layered legal framework that combines the international humanitarian law, international environmental law, international criminal law and human rights law. For instance, the international humanitarian law has specific and general provisions aimed at minimizing environmental harm in the context of warfare. According to this law, states have the obligation to avoid widespread, long-term and severe damage to the natural environment [14].

From an international legal perspective, the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD), has addressed the environmental consequences of war. The convention restricts hostile environmental modification and the Rome Statute recognizes serious environmental destruction as a war crime when committed in the context of armed conflict [15]. The Rome statute in its article 8 (2) criminalizes attacks that knowingly cause widespread, long-term, and sever environmental damage that is clearly excessive in relation to the anticipated military advantage. The ICRC's revised Guidelines call states to integrate environmental protection in military manuals, national policy and domestic legal system [16]. The United Nations has also given an emphasis to the impact of conflict on the ecosystem, pollution of land and water and the health and livelihoods of affected populations for generations [17].

In addition to the legal frameworks, there is also the need of preventive and remedial policy measures to protect the war affected environments. Preventive approaches designating environmentally sensitive areas, restriction on military activities in fragile eco-systems, and training for armed forces on environmental safeguards [18]. The remedial policy measures include post-conflict environmental assessment, cleanup of contamination, restoration of damaged ecosystems, and compensation or

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reparation for environmental harm [19]. The reason why to protect the environment is that environmental harm affects access to water, food, health, and livelihoods and to protect citizens' right to a healthy environment.

In Africa, the African Charter on Human and peoples' Rights (Banjul Charter), in its article 24 reads as "*All peoples shall have the right to a general satisfactory environment favorable to their environment."* in addition, Environmental protection during armed conflict in Africa is increasingly understood as part of broader peace, security, and human rights governance. In the continent under issue, particularly in fragile and climate-vulnerable settings, deforestation, land degradation, water scarcity, biodiversity loss, and the weakening of conservation institutions are linked to conflict [20] [21]. Although the African regional human rights instruments do not yet contain a single comprehensive treaty aimed at protecting the war-affected environments, the African Union's peace and security architecture, together with regional environmental governance mechanisms, provides an important normative basis for integrating environmental protection into conflict prevention and recovery [22] [23]. In this regard, war-related environmental harm should be treated not only as an ecological concern but also as a driver of livelihood insecurity, displacement, and renewed violence [24] [25].

The strongest legal and policy basis for protecting the environment affected by war in Africa is derived from general environmental governance commitments, natural resource management norms, and peace and security frameworks rather than from a dedicated "environment and armed conflict" treaty. Both the African Union Constitutive Act and the African Peace and Security Architecture emphasize the prevention of instability and the promotion of peace, which creates space for environmental considerations where resource degradation contributes to conflict or where conflict damages ecosystems needed for recovery. Furthermore, regional environmental policy thinking across Africa increasingly recognizes the relationship between natural resource governance, conflict prevention, and sustainable development, particularly in areas affected by climate stress, land scarcity, and displacement. Accordingly, the African policy environment supports the argument that environmental restoration should be incorporated into peace building and post-conflict reconstruction rather than treated as a separate sectorial issue.

In the context of Ethiopia, there is an environmental policy which establishes principles for sustainable natural resource use, conservation, and environmental management (Federal Democratic Republic of Ethiopia [27]. In addition, the Ethiopian constitution also recognizes environmental rights and duties, including the state's obligation to protect the environment and citizens' responsibility to care for natural resources (FDRE, 1995). Article 44(1) of the FDRE constitutions reads as "All *persons have the right to a clean and healthy environment."* The constitution in it article 92 (1) obliges the government to make sure that all citizens are living in a clean and healthy environment.

Though the laws were not specifically designed for the environmental affected by war, Ethiopia has adopted more recent environmental management and conservation-related legal instruments intended to regulate land, water, forests, and environmental impact assessment processes.

In war affected regions like Tigray where war reversed decades of watershed rehabilitation, reforestation, soil and water conservation and ecological restoration, there is a visible legal environmental protection. As revealed in recent academic and policy reports, the war in Tigray intensified pressure on forests through firewood dependence, destroyed water and irrigation systems, and weakened environmental governance structures that had previously supported landscape restoration [28]. This ecological damage has also caused a direct threat to food security (the right to food), public health (the right to health) and to the realization of the right to a healthy environment. In such a setting, the legal framework must move beyond general environmental protection and explicitly address war-related ecological harm.

2.4. Empirical Findings

The Tigrai War (2020-2026) used as a typical sample case study is similar to what we have seen in other wars (Vietnam, Gulf War, Ukraine, Colombia,). The war leads to deforestation, pollution, land degradation, and damage to natural systems that sustain life. Even though there are some developments in stopping the war, the environmental harm is still ongoing. The damages are: unexploded landed mines and bombs, destroyed forests, soil erosion, and degradation. The recent empirical and data-based studies on (from 2020-2026) prove that the war resulted and caused large scale and long-lasting damage which cannot be recovered with in the short period of time. The war affected human livelihood, agriculture, the ecosystem, and water systems.

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When we see the issue of forests, the recent assessments show that a huge amount of forest was lost during and after the war. More than 600,000 hectares of forests were destroyed and damaged due to the military operations, air strikes, and increased demand for firewood charcoal production [29]. Before the war, Tigray was a role model of successful projects in building traces, dams, and other activities which are relevant to control soil erosion and conserve water. However, the war leads to destruction of all these projects which were served as a large contribution for long period of time [30].

Scientific studies show that the Tigrai war caused much destruction of trees and bushes near roads and in particular areas in which heavy fighting took place. Although some trees have started to regrow from the conflict-driven deforestation the constant deforestation and fuel wood demand of the soldiers and displaced communities continue affect the forests.

One of the worst effects of the Tigrai war was the total breakdown of agricultural production. Before the war (before 2020), Tigrai had encountered a success story in Ethiopia because of the strong agricultural programs such as building terraces on hill sides, conserving water, and planting trees. However, the war reversed all these progresses Tigrai has made for a long period of time, and leads to the destruction of irrigation systems, orchards, and storage facilities.

Generally, even though there are large-scale ceasefires of hostilities, many people have been starved or can't get enough food even after the signing of the Pretoria agreement. As the recent academic researcher studied in the urban areas, almost 39% of the households experienced food insecurity. Even the study shows that female headed households are hit much harder than male headed households. Additionally, in the rural areas, up to 77% of households experienced food insecurity. That means 3 out of 4 households are affected by the problem [31].

Therefore, these post-Pretoria findings show that environmental effects of the Tigray war was above the direct and active war since it creates long lasting challenges for food systems, health, livelihoods, and peace building.

2.5. Research Gaps

Even though there are many researchers investigated on the impact of the war on environmental damage, almost all of them have a big gap in their knowledge of the damages. The researchers try to understand the impact of the Tigrai war by referring to the satellite images and some pictures; however these pictures are limited in including all sorts of damage that happened in the war. The gap is that, there are limited researchers who practically and physically go to the places where the destruction is happened. So, in order to understand the degree of the destruction, the researchers must check the damage, take soil samples, count trees, talk to farmers, etc.

The other gap is that many researchers have studied environmental damage of the Tigray war without taking into account how long their studies will practically goes to address the damage. So, many studies have examined the Tigray war considering how it affects the environment within 1 to 3 years without taking into account how to recover the damages (forests, soil, and wildlife) with the next 5 to 10 years to protect the environment from droughts.

The third gap is that researchers have not studied the benefits that nature provides in Tigrai, and then how these things are disrupted by the war. That means almost all research is restricted to the studies related to tree loss and soil erosion, and we still lack studies related to deep investigations and research on the environmental issues like water quality, wildlife, bees, etc.

The fourth gap is that very few studies put their attention on the big picture of the environmental impact of the war (like social, economic, and health effects), polluted water, and low productivity; however, the research rarely examines on how the war affects the people differently. That means researchers has limited investigation in discussing how the war affects the gender dimension and vulnerable groups.

In addition to the above gaps, the current researches on environmental impact of the war have weakness in the methods they prefer. Many of them use single methods of research without using mixed research which is helpful to integrate mixed data collections. Even some of them do not use comparative studies which is helpful to compare Tigrai war affected areas with other regions (Syria, Ukraine, Yemen, or Sudan).

Finally, almost all current studies on the environmental impact of the Tigrai war have a limited focus on practical solutions since they put their attention on describing the problem rather than finding real practical solutions. To be practical applied research, they must focus on measures like rebuilding soil and water conservation, reforestation models suitable for post-conflict settings, and policy frameworks that integrate environmental recovery.

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3. Methodology

3.1. Study Area

The study was conducted throughout the Tigray Region, the northernmost regional state of Ethiopia. Geographically, Tigray is situated between 12°15' and 14°57'N latitude and 36°27' and 39°59'E longitude, covering an area of approximately 50,000 to 53,000 square kilometers. The region's elevation varies dramatically, from the lowlands of western Tigray at 600 meters to the high peaks of the Eastern and Central zones exceeding 3,900 meters above sea level. This topographic diversity creates a complex mosaic of agro-ecological zones, including the rugged highlands characterized by steep slopes and the vast lowland plains that have historically served as the region's agricultural breadbasket.

Administratively, Tigray is divided into several zones and woredas (districts), bordering Eritrea to the north, Sudan to the west, the Afar Region to the east, and the Amhara Region to the south. Demographically, Tigray's population was estimated to be over 7 million prior to the 2020 conflict. According to historical census data, the population is predominantly Tigrayan (over 95%), with significant minority groups including the Irob and Kunama. In terms of religious affiliation, the majority of the population (approximately 95%) are Orthodox Christians, with a notable Muslim minority (roughly 4-5%) residing primarily in urban centers and eastern trade corridors.

Socio-economically, the region's backbone is subsistence and commercial agriculture. Before the war, Tigray was internationally recognized for its "green miracle" a three-decade-long success story in environmental rehabilitation. The region transformed degraded landscapes through massive community-led initiatives in soil and water conservation (SWC), stone terracing, and the establishment of "exclosures" to allow natural vegetation to regenerate. These efforts significantly improved groundwater recharge and food security, making Tigray a global model for dry land restoration.

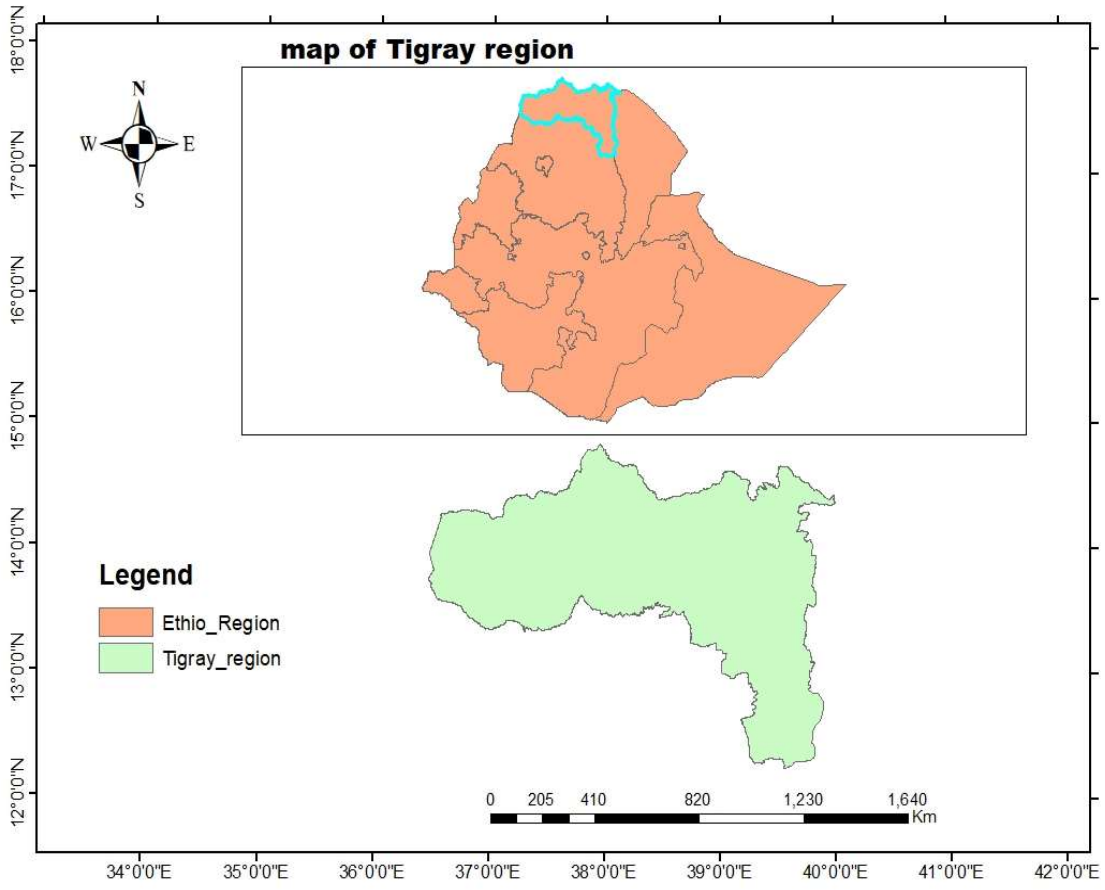

Figure 2. Ethiopian Tigray Region

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The Tigray Region was selected as the focal point for this study due to the catastrophic environmental reversal triggered by the Tigray War (2020–2022). This specific study focuses on the region for three primary reasons. First, the scale of environmental destruction in Tigray is unprecedented in recent history, as the conflict involved the systematic dismantling of the very conservation infrastructures such as irrigation schemes and terraced watersheds; that had taken thirty years to build. Second, the imposition of a total blockade and siege on the region created a unique and tragic environmental phenomenon: the mass consumption of biomass. Without electricity or fuel, millions of people were forced to rely on the region's rehabilitated forests for survival, leading to rapid and widespread deforestation. Third, the collapse of regional environmental governance and the displacement of millions of people have created a "policy vacuum" that requires urgent academic investigation to guide future post-conflict restoration and resilience-building efforts [32].

In order to synthesize the evidence on the impact of the Tigray war since 2020 on the environment, this article employs a qualitative desk review approach. This approach is common method in the fields of social science in general and in environmental governance in particular to synthesize existing knowledge, identify themes, and point to gaps without collecting new primary data [33] [34].

3.2. Research Philosophy

In this article a pragmatic research philosophy was applied. This research philosophy integrates aspects of the positivist and interpretivist paradigms, which enables the authors emphasize "what works" rather than emphasizing a single, absolute version of reality. Based on this research philosophy, environmental change is known through multiple, situated perspectives, for example, those of local communities, policymakers, scientists, and NGOs, and that these interpretations are shaped by cultural, political, and institutional contexts [35]. By foregrounding the socially constructed nature of environmental knowledge, pragmatism supports flexible, mixed methods designs that can accommodate both qualitative narratives and quantitative data, while remaining attentive to the values, interests, and power relations embedded in different accounts of ecological change [36].

3.3. Data Sources

This desk review relied solely on publicly available, published sources such as peer reviewed journal articles, academic books, newspapers, NGO and think tank reports, and government databases and did not involve human subjects or require formal ethical approval; no unpublished or confidential material was used. These Secondary sources are generally acknowledged as a credible and often essential base for conflict related environmental change research in the literature, especially when direct fieldwork is not feasible; researchers stress that the accumulation of evidence from peer reviewed studies, technical reports and remote sensing analyses provide a strong case to demonstrate deforestation, soil erosion and damage to water resources and the violation of the right to healthy environment in war affected areas [37].

3.4. Method of Data Analysis

In data analysis, thematic analysis is very crucial which helps to synthesize concepts, explanations, and patterns across documents through familiarization, initial coding, and the generation of descriptive codes [34]. In this article, thematic analysis was employed to synthesize concepts, explanations, and patterns across documents through familiarization, initial coding generated descriptive codes capturing environmental outcomes and causal narratives, grouping into provisional themes and subthemes while identifying contradictions and gaps across sources. Then, the themes were refined and higher order themes were defined and named and finally, cross study triangulation was assessed whether themes were supported by multiple independent sources and noted where evidence was limited or contested.

3.5. Ethical Considerations

In desk review studies, ethical considerations include accurately representing original findings, avoiding selective citation that distorts authors' conclusions, and being transparent about how sources were chosen, coded, and interpreted [34]. In this Article, source selection was conducted in a non-biased manner and all included works were properly acknowledged and cited.

4. Finding and Discussion

The object of the investigation was to collect evidence on the effect of the Tigray War on soil, natural fauna, deforestation and loss of vegetation cover, with the aim of assessing the indirect impacts of the

war on the environment, in particular the consumption of biomass during the siege. To identify the major policy gaps in the corpus of knowledge on the environmental impacts of the Tigray War. To set priorities for future studies that will support resilience building and post-conflict environmental recovery.

This paper's main goal is to examine, for the first time, how the armed conflict in Tigray has affected important hydro systems and water infrastructures in specific combat zones. This paper uses a qualitative desk review method to compile the evidence regarding the environmental effects of the Tigray war from 2020.

Often used in social scientific fields generally and environmental governance specifically [34] [35]. This strategy is used to synthesize current knowledge, identify themes, and identify gaps without collecting new primary data. In the literature, secondary sources are well recognized as a reliable and often key basis for studies of environmental change related to conflicts. Ethical considerations in desk review studies include presenting original findings accurately, avoiding selective citation that may distort authors' conclusions, and being transparent about the selection, coding and interpretation of sources.

This paper examines the environmental consequences of the armed conflict in Tigray. Ethiopia and TPLF fought in Tigray in 2020. The Tigray conflict of November 2020 that lasted for several years resulted in a series of devastating events, a humanitarian crisis and the collapse of local governance. The global salience of links between armed conflict and environmental degradation has increased in recent years.

However, the outbreak of armed conflict in Tigray in November 2020 was a complete reversal of this environmental progress and a serious socio-ecological disaster that quickly undid three decades of arduous restoration work [5]. The Ethiopian National Defense Forces, the Eritrean Defense Forces and all the regional forces. The war lasted until November 2020. The conflict was marked by intense ground offensives, aerial bombardment, the imposition of a devastating blockade and the systematic destruction of public services and environmental management systems.

The general conditions of the siege are a major contributor to environmental degradation, which has been compounded by IDPs, military operations, the collapse of conservation infrastructures, the breakdown of environmental governance, and institutional destruction [21].

Prior to the onset of the conflict, Tigray was recognized for successful community-based environmental rehabilitation interventions, notably in reforestation, watershed management, soil and water conservation and ecological restoration. For several decades the area had practiced sustainable environmental practices in a bid to combat desertification, drought and land degradation. Such environmental successes were envisioned as a model for other drought-prone areas of Africa and Ethiopia [37].

A multifaceted environmental disaster was brought on by the Tigray conflict (2020–2022), which methodically undermined decades of ecological advancement through both direct fighting and the failure of vital infrastructure. According to research, the region's dry Afromontane Forest cover fell from 17% in 2020 to just 12% by 2022. This decline was caused by both active conflict and a desperate civilian reliance on charcoal and firewood after electrical services were completely suspended.

Deforestation combined with the destruction of physical soil and water conservation (SWC) structures resulted in the rapid and aggressive formation of gullies and widespread land degradation, while former restoration sites meant to stop desertification were turned into "warfare grounds" [34].

Water schemes in conflict corridors like Yechilla fell from a pre-war failure rate of 7.1% to a startling 48.3%, demonstrating the equally catastrophic impact on essential resources. Additionally, the region's once-thriving irrigation and conservation programs are in a condition of severe paralysis due to the intentional destruction of nursery facilities, which are the actual motors of reforestation, paralyzing urgent recovery attempts [35].

According to Kerner et al. Tigray war significantly impacted the environment, particularly land use [19]. This finding shows that the war destroyed land management and agricultural production in almost all parts of Tigray. Although the farming has continued after the end of the war, the war-affected places have been hindered by agricultural sustainability and environmental management. Likewise, researcher found that the Tigrai war led to the distorted decades of environmental rehabilitation, particularly in the rural areas. It contributed to the increase in soil erosion and land degradation by damaging the environment itself and the environmental management structures [37].

Similarly, researcher found how the war affected some districts of Raya Azebo on the destruction of terraces, stone bunds, and check dams; increased land degradation; and reduced ecosystem stability.

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Additionally, examined the impact of the war on environmental governance and natural resource management in Tigrai [38]. This study found that the war leads to the destruction of the environmentally based governmental institutions and local community-based conservations, which in turn lead to the destruction of environments like erosion, land degradation, degradation of forests, and grazing lands.

Another major environmental consequence of the war was the increased pressure on forests and vegetation resources. Researcher examined the conflict driven displacement in Tigray put pressure on natural resources in host communities [39]. That means the displaced populations has destructed the forests for their basic needs like: wood production, shelter, and livelihood need which in turn has the consequence of deforestation and resource depletion in several parts of Tigray.

Despite these diverse impacts, some studies also identified evidence of rural environmental degradation. Researcher also investigated that the war lead to the destruction of rural infrastructure once it creates environmental degradation and livelihood insecurity. This becomes an obstacle to post war recovery [40]. Similarly, researcher also found that the war. affected environmental sustainability through destruction of ecosystem, biodiversity, and environmental local governance mechanisms [31].

Examples of damages reported from *Amdiwoyane Tabia* on the *Dongolat–Gijet–Esret–Yechilla* Battle Corridor, shows in Figure 3.

Figure 3. Examples of Damages Reported from *Amdiwoyane Tabia*

Researcher found that the Tigray armed conflict caused significant direct and indirect damage to natural resources and soil and water conservation (SWC) measures in northern Ethiopia. Directly, vegetated landscapes were damaged by artillery and bombs, with surveyed bomb craters along asphalt roads averaging 1.15 m in depth and 2.66 m in surface diameter [40]. Additionally, numerous military trenches constructed along croplands and hillsides exposed soil particles to erosion and water pollution. The conflict also halted annual SWC activities, resulting in approximately 20,591 km/year of stone bunds not being constructed, while existing terraces and stone bunds were deliberately demolished to build temporary ground fortifications. Indirectly, the critical energy crisis increased pressure on forests, forcing poor farmers to shift from long-term sustainability to immediate economic recovery, thereby undermining decades of re-greening programs [40]. Researcher concluded that these pathways of warfare collectively undermined the status of natural resources, and their ground-based findings can be used to prioritize and rehabilitate damaged landscape services.

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Before the war, Tigrai had spent many years in restoring the land; and to make all areas green and to build terracing. The war destroyed and eliminated all these progresses that had been made over many years. Before the war, Tigrai was considered as a good example of Ethiopia's sustainable land management. However, the war destroyed all these activities directly and indirectly. For this reason the finding combines both direct impact resulting from the military bombs, and the indirect environmental impact from survival needs. The direct impact is derived from the bombs and trenches in the war, whereas the indirect impact results from cutting trees for fuel and stopping conservation works.

The direct impact creates immediate damage to the environment. That means when the soldiers fired heavy guns, and the drones had dropped acidic bombs, they left big holes in the ground (bomb craters). As Hailemariam and his team included in their research the average depths of the carters were 1.15 meters deep, 2.66 meters wide, and the "± 0.47" and "± 0.67" show the normal range [5]. So, these bombs thrown in the land damaged vegetation, soil, and farmland directly.

Figure 4. Effect of military activities on natural resources and anthropogenic features during the study period (Hailemariam, 2025, p. 5):
(a) deep crater developed from air bombs at Adi Gudom
(b) construction of fortification using stones from terraces at Ala Asa
(c) road blockade using soil excavated from exclosures and farmlands behind it at Afedena

These explosions destructed vegetation cover, fragmented landscapes, and hindered soil and water conservation (SWC) structures, including stone bunds, terraces, and exclosures. The stone bonds, traces, and enclosures built over the last 30 years to protect soil degradation and to make the soil productive were destroyed. Before the war, Tigray built about 20,591 kilometers of new stone bunds. However, the war leads to completely stop all these activities. As a result of this, the people could not continue the conservation work [5].

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Figure 5. Untargeted bombs destroyed trees in Agbe Village (Tembien) during the war in 2021. (Hailemariam, 2025, p. 6)

Remote sensing analysis further confirmed significant vegetation decline. Researcher documented a extensive reduction of vegetation within a 50 km radius of Mekelle. That means between 2020 and 2022 the net loss was approximately 403 km² (about 5% of the study area).

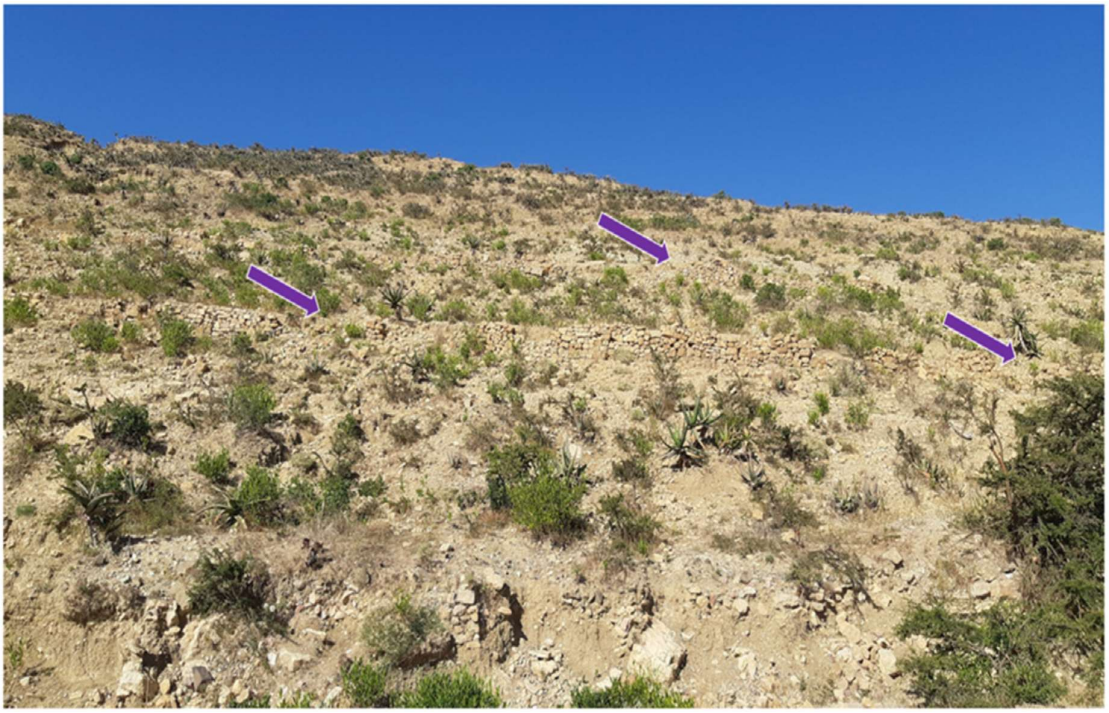

Figure 6. Partial view of the collapsed physical SWC structure at Ala Asa Village. The arrows indicate the fallen stones due to the war.

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This decline was shown in areas close to major roads, military corridors, and urban centers once the biggest damage was shown in these specific locations. As the Satellite-derived NDVI (Normalized Difference Vegetation Index) values showed positive vegetation trend was observed from 2000 to 2020. however, the war disrupted long-term ecological recovery.

Indirect impacts were also the serious issues of the environment. The longlasting energy crisis forced urban and rural communities to increase utilization of firewood and charcoal production. This survival centered deforestation resulted land degradation, soil erosion risk, and reduced biodiversity in fragile highland ecosystems. In addition to this, the fragmentation of local governance and conservation structures also leads to the desertion of seedling nurseries, regular maintenance of SWC structures, resulting in millions of lost seedlings and degraded protected areas [5] [8].

5. Conclusion

The war in Tigray has caused a lot of harm to the environment not during the fighting. From 2021 to 2026 the war ruined years of work to restore the landscape conserve soil and manage watersheds. The area was cut off and the economy and infrastructure were badly damaged. This forced people to use the surrounding environment to survive. They cut down trees for fuel, and important irrigation systems were destroyed, causing good farmland to dry out and erode.

The information from these five years shows that environmental damage and humanitarian crises are closely linked. The war stopped people from managing resources in a way. This created a cycle where the environment and people suffered together. For Tigray to recover, have peace and be food it needs more than just politics and economics. It needs a plan to fix the environment restore watersheds and heal the ecosystem. The people of Tigray and the environment need to be restored. Environmental healing is necessary for long-term food security, in Tigray.

The Tigray conflict from 2020 to 2026 really shows how war hurts the environment in a way. This five-year period was very bad for the environment because the government was not working and important things like roads and buildings were destroyed. This made the environment get worse quickly and it stopped people from taking care of the land like they used to. The people in the area had to do what they could to survive because they were blocked from getting food and other things they needed. They had to cut down trees for firewood. This hurt the environment even more.

The war also hurt the water systems and the way people used water to grow food. This made the land less good for growing things. The soil got washed away very quickly. What happened from 2020 to 2026 shows that the environment getting hurt is not a small part of the problem it is a big part of why people are suffering. It is making it hard for people to have food. It is making the area more vulnerable to climate change. To really make things better in Tigray after the war people need to focus on fixing the environment and making the natural areas healthy again. This is just as important as making the government and economy work better. The Tigray conflict and its effects, on the environment need to be addressed in a way to make sure people can live in a healthy and safe place.

Recommendations:

1) A conflict-sensitive environmental recovery plan focused on watershed rehabilitation, terrace reconstruction, soil conservation and reforestation should be initiated and implemented.
2) Priority should be given to water infrastructure. This means, there should be rehabilitating irrigation schemes, springs, reservoirs and community water systems in areas where farming and daily survival depend on water access.
3) To relieve the pressure on bio-mas, other sources of energy should be utilized. There should also be recovery programs to expand fuel efficient stoves, solar options and other low cost energy alternatives for households and institutions.
4) The reforestation program should be owned by the community in which local labor, elders, women's groups and youth structures have active engagement.
5) The environmental recovery should be integrated in to food security and livelihood programs since repairing the environmental program with farming support will improve resilience and reduce repeated dependency on emergency aid.
6) There should be strong environmental governance through the establishment of watershed committees, land management institutions and technical and financial support in order to resume oversight of forests, soil conservation and water resources and monitoring strategies.
7) Field based damage assessment should be conducted since response planning should go beyond satellite images and include soil testing, vegetation, and water quality.

8) The government should discharge its obligation to the protection of the right to healthy environment. This right should be explicitly integrated in to conflict prevention, humanitarian response, and post conflict recovery frameworks.
9) Armed conflict should be recognized as a serious driver of environmental degradation that undermines access to safe water, clean air, fertile land, bio-diversity and sustainable livelihood.
10) To address intentional environmental damages during armed conflict and treat environmental harm as a human rights concern, the documentation, monitoring and accountability mechanisms should be strengthened.
11) The Government of Ethiopia should adopt a national "Environment in Armed Conflict" Policy that integrates International Humanitarian Law (IHL) obligations, requires military manuals to include environmental safeguards, and mandates restriction of military activity in ecologically sensitive areas.

Declarations

- Author contributions: we announce that, we all are the authors of this research work. Regarding the author's contribution: GG: Contributed in Conceptualization, HZ: Methodology, Validation, Writing-review and editing. Contributed in Methodology SA: Review, Writing Original Draft, Writing-review and editing. RH: Also Contributed in Methodology, Scoping Review, NB: Writing Original Draft, Writing-review and editing. Finally, declare that all authors read and approved the final manuscript for publication.
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- Data availability: The scientific papers reviewed can be accessed through links as we did not use primary data.

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