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# Local innovations for resilience and survival during war-led crisis in Tembien, Ethiopia

**Article**

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## ABSTRACT

The main objective of this article was to examine farmers' local solutions for resilience and survival strategies during war and siege (2020–2022) in the Tigray region of Ethiopia. The study reveals that Tembien communities adopted various strategies to cope with the critical crisis. They paired an ox with a donkey or camel, cultivated labor-efficient and early-maturing crop varieties to produce crops. With the help of the government, the residents initiated the transformation of non-agricultural spaces into croplands to increase root, vegetable, and crop yields. In the absence of agrochemicals, farmers relied on local solutions such as compost, manure, traditional pest control methods, and indigenous seeds to sustain their cultivation. In the low-lying areas, moreover, the consumption of edible fruits provided critical sources of food and income. Particularly, the years-long social cohesion, religious institutions, remittances, and mutual aid networks also played a vital role during the crisis. These local solutions, however, weakened over time in the war-stricken sites of Tembien. Following poor economic intervention before the war, the communities were severely starved during the crisis. As a response, the implementation of sustainable sand and gold mining, geo-tourism, integration of beekeeping with area exclosures, and proper utilization of indigenous fruits could enhance sustainable livelihoods of the communities, while safeguarding the multifunctional landscapes.

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**Keywords:** Resilience, farming innovations, social capital, war, siege, Tigray

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## INTRODUCTION

The Horn of Africa has been a “laboratory” for many wars in the world (De Waal, 2015). Sudan, Eritrea, Somalia, and Ethiopia have been hotspots of war in the region. Particularly, Ethiopia has experienced numerous wars since ancient times (Zewde, 2002). Most of these battles took place in northern Ethiopia (Rubenson,1991). Recently, the Tigray War (2020-2022) was among the deadliest human-made crises in the Ethiopia's history (ACAPS, 2022). A devastating siege accompanied the long-lived crisis. This siege sealed off the Tigray region, which prevented the entry and exit of lifesaving supplies. The region remained isolated from national supply routes and disconnected from the rest of the country and the world (WFP & FAO, 2022). The lives of millions of civilians were trapped under siege. Comparable siege experiences have also occurred in Sudan, Gaza, Libya, and Syria (Power, 2016; Veronese et al., 2021; Winter, 2016; Young et al., 2016).

The agricultural sector collapsed, unable to support the farmers during the recent war (Abay & Demissie, 2022; OCHA, 2022; Nyssen et al., 2022). Also, the blockade paralyzed the local trade, transportation, banking, electricity, and communication services (OCHA, 2021). Moreover, farmers in relatively war-free zones or liberated sites depended on poor local harvests (WFP, 2022a). In 2022, over 90% of the population remained on food alert, and key livelihood sources declined from 55% in November 2021 to 34% in June 2022 (WFP, 2022b). Hence, the inability to meet basic needs forced many farmers into a state of desperation. The population found itself caught between the "hammer" and the "anvil" of war (Pellet, 2021; Meaza et al., 2024), with widespread malnutrition, hunger, and famine leading to mass starvation (Weldemichel, 2021).

The humanitarian crisis between 2020 and 2022 triggered a famine more catastrophic than those of 1958, 1973, and 1983–85 in Ethiopia (Oxford University Press, 1991) (Figure 1). The people of Tigray descended into a profound and largely unrecorded livelihood crisis (Annys et al., 2021; Nyssen, 2024; Verhoeven & Woldemariam, 2022).

Particularly, the war disrupted the socioeconomic system in Tembien districts in the central zone of Tigray. The impacts of the crisis have deepened the existing cycles of poverty and hardship in Tembien districts. The area recorded the highest poverty headcount in the Central Zone of Tigray, with 44.7% of its population living below the poverty line; it is well above the zonal average of 29.1% (Negash et al., 2018). In the Tembien lowlands, there has been a recurrence of rainfall. As a result, people were starved to death, and many farmers were displaced to other districts. The wars and drought-induced famine forced farmers to put pressure on vegetation in the exclosures (Meaza et al., 2025).

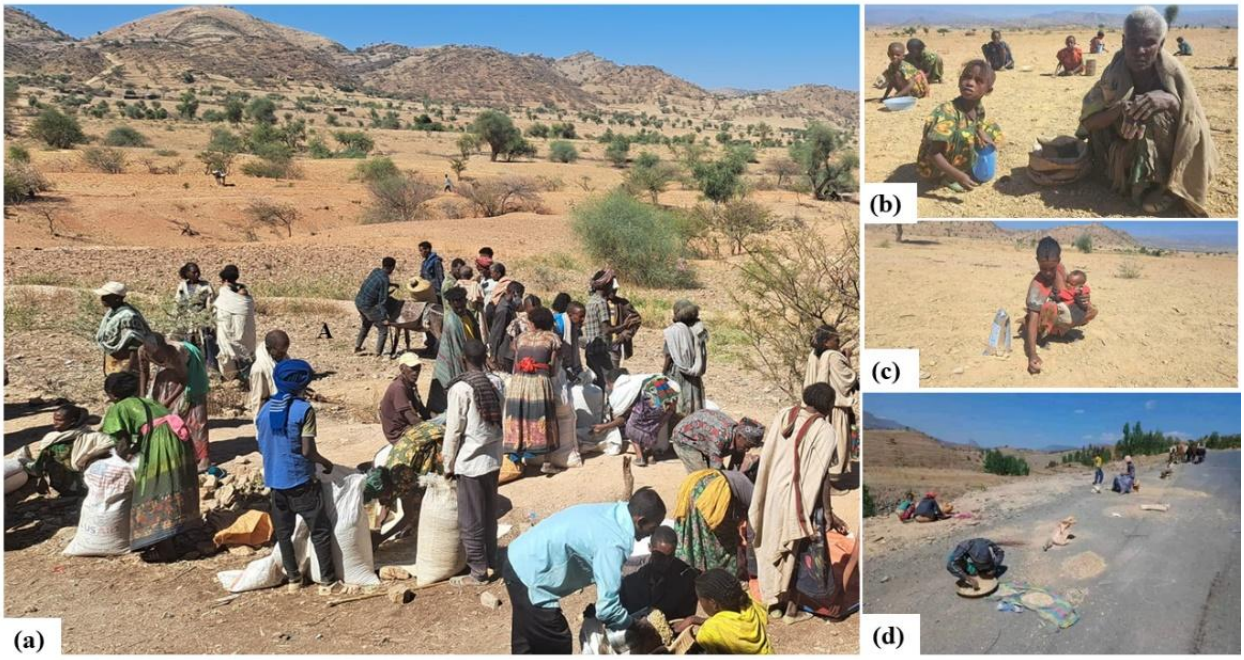


Figure 1: Humanitarian aid distribution in a war-affected area, Tembien: (a) shows wheat being distributed to vulnerable community members; (b–d) illustrate unregistered residents collecting leftover wheat from the ground after the official distribution concluded (Source: Social media).

Searching for alternative means of survival became imperative for the poor farmers (Ellis, 2000; Korf, 2003; Rockmore, 2012). In this context, a conceptual framework is provided in Figure 3. A critical question arises: how do communities of Tembien people resist, absorb, and adapt to the economic shocks caused by the war (2020-2022)? Based on the main research question, the specific objectives of this study were to (a) examine local farming and food innovations, (b) investigate the role of social capital in supporting the survival of the poor in conflict-affected areas, and (c) investigate the resilience of farmers throughout the conflict period.

## METHODS AND MATERIALS

### Description of the study area

Tembien is situated in the central highlands of the Tigray Regional State in northern Ethiopia (Figure 2). It is currently divided into five districts: Abergele Yechila, Dogua Tembien, Tanqua Milash, Kola Tembien, and Keyih Tekli. These districts are distinguished by diverse ecological, geological, and socio-cultural characteristics. Based on terrain analysis, the landscape of the study sites comprises rugged mountains (Figure 2), dissected plateaus, and deeply incised valleys, reflecting a complex and fragile terrain (Nyssen et al., 2023).

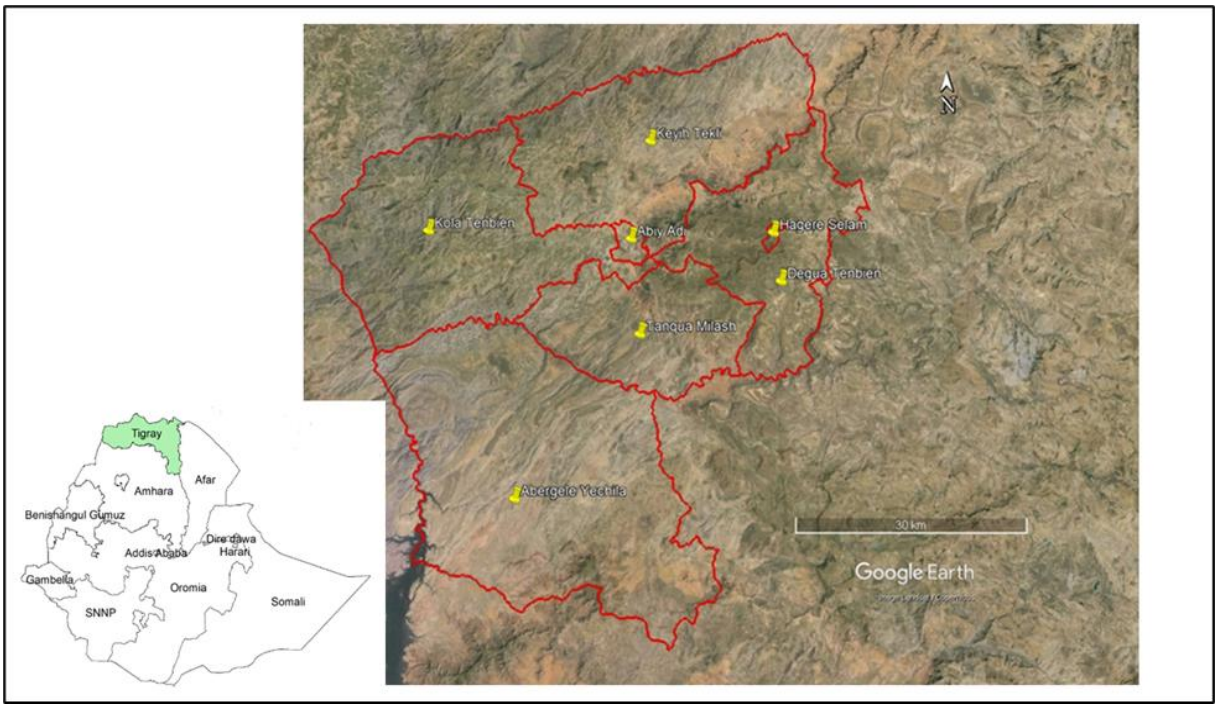


Figure 2: Location of the study area.

The study area lies within a transition zone ranging from semi-arid to sub-humid climates, with a distinct rainy season extending from June to September (Nyssen et al., 20219). Annual rainfall averages between 500 and 800 millimeters, with the highest amounts recorded in elevated districts such as Dogua Tembien and parts of Tanqua Milash. Temperature and moisture conditions vary markedly with elevation, with cooler, more temperate conditions in the highlands and hotter, drier conditions in lower-lying areas like Abergele Yechila.

Smallholder farming constitutes the backbone of rural livelihoods in the five districts (Meaza & Demssie, 2015). The agricultural system is predominantly rain-fed and subsistence-based, focusing on crops such as teff, barley, wheat, and sorghum. Livestock rearing is also a critical component of the local economy, supporting household food security and income (Demssie & Meaza, 2018).

Historically, Tembien has been both a cultural heartland and a contested frontier. Since the time of the Axumite civilization (Crummey, 2000), the area has experienced successive episodes of conflict, from the internal turmoil of the Zemene Mesafint (Era of Princes) to the Italian invasions in the 1930s, including the First and Second Battles of Tembien (Zewde, 2002). Many war events have also occurred during the Second Italo-Ethiopian War (1935-1941), the Derg-Tigray People's Liberation Front Conflict (1975-1991), and the Tigray War (2020-2022) in Tembien. The mountain chains, columnar ambas, deep gorges, valleys, rivers, and remote areas (Nyssen et al., 2023). Tembien sites were safe zones for the political leaders, combatants, and local farmers during wartime. Consequently, there were repeated spontaneous aerial and ground-based bombings.

Land degradation remains one of the most critical and enduring challenges in Tembien (Nyssen, 1997). The interplay of steep topography, deforestation, over-cultivation, and intense seasonal rainfall has led to widespread soil erosion and declining land productivity (Nyssen et al., 2004). These environmental stresses, combined with limited government intervention, have left the communities vulnerable to recurrent food insecurity and famine over the past several decades (Demissie & Meaza, 2018).

## Research design and data collection

This study employed a qualitative case study approach to explore resilience and survival strategies of rural communities during the crisis. Despite the critical challenge during and after the crisis, I tried to collect qualitative data between November 2020 and November 2022, and the postwar recovery phase (2022-2023). The study design was guided by an interpretive framework grounded in resilience theory, social capital, and rural livelihoods (Figure 3).

During the crisis period, primary data were collected through ethnographic fieldwork in the war-affected areas of Tembien. I resided among the farming communities for five consecutive weeks during the peak of the war (November–December 2020). Moreover, I returned to the living conditions of the people in 2021 and 2023 to document changes and emerging recovery processes. Indeed, my physical immersion with the local communities enabled the researcher to observe, document, and experience firsthand the lived realities of conflict-affected farmers.

Elders, mothers, displaced persons from Western Tigray, and village leaders (n = 23) provided insights into their wartime livelihood adaptations, food sourcing strategies, and social support mechanisms. Of these participants, 18 of the respondents were males. These farmers were interviewed in situ, including those hiding in the caves, gorges, and mountain shelters during active bombardments. The observations, accompanied by informal interviews, facilitated the gathering of rich narrative data that reflected both material conditions and intangible cultural practices. In the five districts (Figure 2), informal interviews with agricultural experts (n = 26) were carried out in 2021 to highlight the valuable resources that could support postwar recovery and livelihood improvement during the postwar.

Numerous photos were taken during the active war to capture the livelihood conditions of farming practices, the status of homestead gardens, wild fruit harvesting, and community coping behaviors. Furthermore, government records and humanitarian agency reports also provided supplementary data on the agricultural input shortages, displacement, and food security indicators. In line with Zwijnenburg and Ballinger (2023), the social media platforms such as Twitter, Facebook, and YouTube were also reviewed to retrieve geo-tagged visual evidence and community narratives that validated field observations and added temporal depth to the findings.

## Data analysis

The collected qualitative data were analyzed based on the main objectives. Field notes, interview transcripts, and photographs were categorized under farmland preparation and cultivation, food system innovation, social networks, remittances, and environmental resources coping strategies. In addition, the visual data were analyzed as ethnographic evidence. Comparative references from literature on post-

conflict farming practices were also incorporated to situate the findings within a global framework of rural resilience.

## Conceptual framework

Standardizing relevant terms enhances both conceptual clarity and relevance. Farmers' experience differentiated vulnerability to shocks (Figure 3). Vulnerability refers to the degree to which individuals and households are exposed to risks and disturbances (Fussell, 2007). In response, coping strategies emerged as immediate mechanisms to reduce risk exposure (Ellis, 2000). These strategies included diversifying income sources, engaging in informal trade or barter, and seeking assistance through social support networks, such as gifts and loans from kin and neighbors (Rockmore, 2012).

The concept of livelihood resilience offers a broader view of how communities withstand, adapt to, and recover from shocks (FAO, 2019). Resilience entails persistence under stress, adaptive flexibility, and in some cases, transformative change. It acts as a buffer, enabling communities to minimize harm and bounce back more effectively (Mayer, 2019). In war-affected settings like Tigray, livelihood resilience is rooted in collective strengths. A key enabler of resilience is social capital, comprising social networks, trust, and community cohesion (Aldrich & Meyer, 2015). Cohesion facilitates solidarity and collective action, allowing for effective mobilization of resources and mutual aid (Ager et al., 2005). Besides, trust within communities enhances cooperation, reduces conflict, and supports coordinated relief efforts.

Social networks, both formal and informal, are essential conduits for the distribution of basic food, shelter, and healthcare (Labzaé, 2022). Family ties, friendships, neighborhood associations, and institutional affiliations reinforce both material and emotional resilience (Murphy et al., 2018). Strengthening these networks is therefore critical to both disaster preparedness and long-term recovery (Nassar et al., 2023).

Another critical layer is human agency. Local farmers demonstrated agency by reallocating labor, adopting new agricultural practices (Brown & Westaway, 2011). The community leaders played pivotal roles by organizing mutual aid and reinforcing local resilience (Verpoorten, 2009; Ellis, 2000). In addition, empowerment theories shed light on how communities reclaim control over their lives during conflict. For example, empowerment includes the rise of women in leadership roles, the use of indigenous knowledge and informal markets as adaptive tools (Korf, 2003; Goovaerts et al., 2005). These actions reflect individual and collective agency under siege.

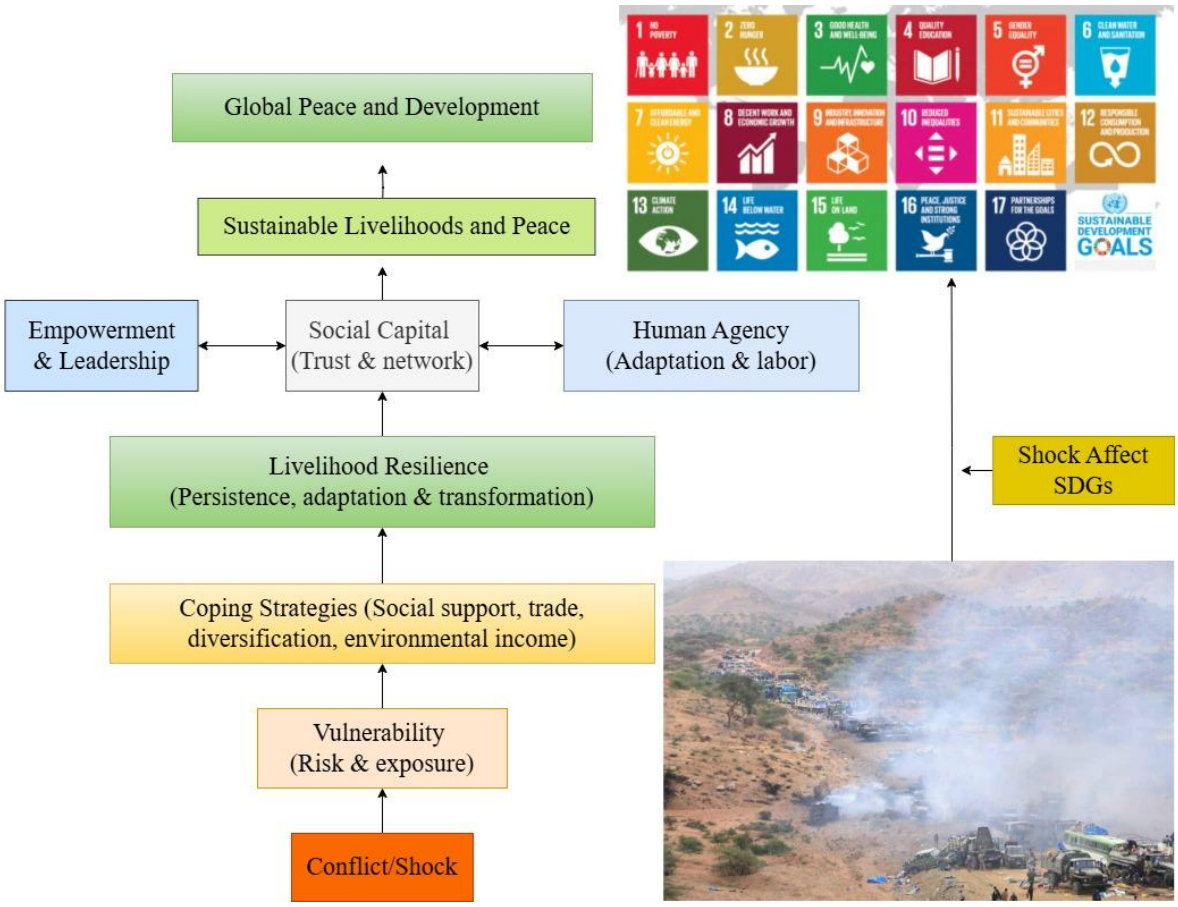


Figure 3: Conceptual framework for livelihood resilience during the war and siege.

In war-stricken zones, resilience is practiced through grassroots initiatives, local resourcefulness, and cohesive social fabrics (Roosevelt et al., 2023). Importantly, building sustainable peace maintains the livelihoods of the farmers (Figure 3). Given this, preventing relapse into armed conflict requires breaking the "war-poverty-war" cycle through inclusive sustainable livelihoods, peace operations, and institutional reform that goes with the global communities (Gregory, 1983; Beardsley & Beardsley, 2023). Thus, sowing the seeds of peace on the ground equates to securing sustainable livelihoods and thereby sustainable development.

## RESULTS

### Wartime farming and food innovations during wartime

### Crisis-driven farming innovation

The war started during the harvesting time, on the 4th of November 2020. The active war continued into the next season in 2021 (Table 1). The shortage of paired oxen led farmers to pair one ox with a donkey, or a cow, to till their lands during the rainy season.

Table 1: Crisis-driven problems, challenges, and coping strategies in wartime in Tembien.

| **Category** | Challenges | **Coping strategies and innovations** |
|---|---|---|
| Land preparation and labor | Shortage of paired oxen and labor for plowing due to displacement and war | Use of a single ox paired with a donkey, and planting less labor-intensive crops |
| Food insecurity | Widespread hunger due to the blockade | Backyard vegetable/fruit gardening; selling surplus produce locally |
| Agricultural inputs | Fertilizer shortage | Use of manure and crop residues; reliance on local resources |
| Crop protection | No access to herbicides and pesticides | Manual weeding and traditional pest control methods, such as killing pests by pests |
| Social solidarity & networks | Collapse of formal safety nets and inability to access aid in remote areas | Sharing of food within communities; religious and civic institutions provided basic food, and Mutual assistance |
| Begging and desperation | Lack of alternatives for the poor | Begging outside religious institutions or house-to-house, and borrowing from better-off relatives and friends |
| Remittances | Lack of access to financial support | Informal and black-market remittances sustained households |
| Nature-based survival | Severe food and medicine shortage | Consumption of wild fruits (e.g., *Ziziphus*, *Cordia*, *Balanites*) - Use of wild herbs and traditional medicine - Sale of cactus fruits, leaves, firewood, charcoal |
| Institutional Response | Yield gaps due to conflict | Development of farming guidelines (01/2014) to expand cultivation |

The war caused fragmentation within farming households. In this context, young people either joined with Tigray Defense Force or were displaced to urban areas to secure their lives. This resulted in a severe labor shortage during the rainy season when crop cultivation was crucial for the family. In response, the local farmers selected crops that required less labor for tilling, weeding, and fertilizing (Ghebreyohannes et al., 2022). Besides, the farming households with better labor availability assisted those with fewer members during farming.

Access to food sources was limited during the height of the fighting in 2021, and food prices soared in rural areas. As a positive coping strategy, the residents began cultivating vegetables and fruits in their backyards, transforming the free spaces into productive gardens (Hadush & Gebrekiros, 2024). This ensured basic self-sufficiency in food, and households were able to sell excess produce in the local

markets. Interestingly, the prices of these perishable and non-perishable products remained fair for non-growers due to the better market supply.

Figure 4: Farmers saw tef inside the exclosure (see the red arrows) at Enda Jewergs, Werkamba in 2021.

The complete siege restricted access to agricultural inputs during the active war. Analysis of secondary data indicates that 18% of the required 60,000 metric tons of fertilizer reached Tigray during the July-August 2022 rainy season (BoANR, 2022). In response, it was found that farmers turned to alternative sources such as animal manure, compost, and crop residues to maintain soil fertility. Moreover, the blockade led to a severe shortage of improved seeds. Only 1.4% of the required 49,000 metric tons of seeds were delivered to the region (BoANR, 2022). As a result, farmers relied on locally available seeds to continue cultivation. In line with findings by Arias et al. (2017), rural farmers shifted from planting high-yielding (maize, sorghum, millet, and finger millet) and long-cycle crops to low-yielding, short-cycle crops. To compensate for the lack of herbicides and pesticides, household members also manually weeded their croplands and used traditional pest control methods to protect their crops. Furthermore, the shortage of agricultural inputs led some farmers to lease or rent their croplands to wealthier farmers (Table 1). Grazing areas were also rented out to generate life-saving income during wartime.

Once relative peace had been restored in the 2022 rainy season, grassroots efforts brought available land into cultivation. Locally, survivors initiated that every space be cultivated to increase access to cropland. After this local initiation, new farming guidelines were developed by the regional government to address the yield gaps caused by the crisis. This initiative gave rise to new agricultural directives aimed at addressing post-conflict food shortages. A key guideline mandated that “every patch of land must be plowed and sown” to maximize output. In line with this, the regional executive government issued a

farming guideline (01/2014), which was promptly distributed to districts for immediate implementation. As part of this initiative, unused spaces, including green areas, school compounds and residential areas, were converted into agricultural land to boost crop production.

Part of the local initiative, hillsides were re-purposed into agricultural sites in order to increase yields. Many farmers also began cultivating part of the exclosures. For instance, the farmers at Enda Jewergs village near Werkamba town took advantage of part of the exclosures for farming (Figure 4). The farmers cleared trees, shrubs, and herbs, ploughed the land, and sowed tef. As a result, a significant increase in cultivated area was observed in 2022 in the freed spaces.

Woldearegay (2023) also noted that roadsides, empty construction sites, school and university spaces, and stream banks were made available for local farming. Hadush and Gebrekiros (2024) also reported that cultivation extended to roadsides, vacant construction sites, stream banks, and even university and school grounds. These adaptive strategies ensured food self-reliance. Gebreigziabher et al. (2025) further found that gardens near residences improved the availability and utilization of the food system. Case studies from South Sudan and Rwanda showed that shared farming cooperatives and support systems have enabled post-conflict recovery (Chelogam, 2022). These examples offer very valuable insights for designing sustainable interventions.

## Consumption of available fruits

Farmers had limited options for survival during the crisis. With the spherical siege, the residents were heavily dependent on the environmental resources. The multifunctional landscapes provided offered valuable livelihood opportunities (Figure 5).

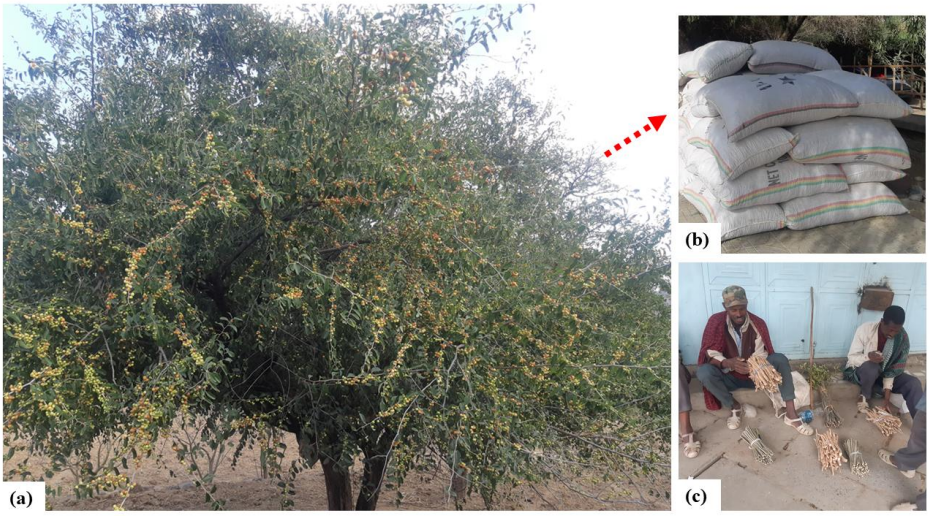


Figure 5: Mature *Ziziphus spina-christi* tree in Werkamba (a), as well as harvested fruits stored near a local market (b), and traditional use of the plant for teeth brushing transported to Mekelle City (c).

Communities harvested edible fruits, roots, and leaves to sustain themselves. Importantly, Ziziphus spina-christi (locally called “Geba”) was either consumed or sold during the war (Figure 5a-b). Moreover, the mature fruits of Cordia Africana (“Awuhi”) were also vital to the poor, both for food and income

generation. These edible fruits became a crucial source of sustenance during crisis (Meaza & Demissie, 2015). Other studies also showed that edible fruits played a key role in bridging the food gap (Addis et al., 2005; Wilson, 2023).

The farmers utilized traditional medicine to treat the wounded civilians during the war. Due to the siege and a lack of money to purchase pharmaceuticals, roots, leaves, and seeds of indigenous trees and shrubs were used to treat injuries and other diseases. Importantly, traditional toothbrushes were used by the vast majority of people who could not afford to buy the commercial toothbrush and toothpaste during the crisis (Figure 5c). Similarly, Gebrekirstos and Birhane (2023) also reported that the population had to rely on wild fruits and leaves to survive during the crisis. The study found that smallholder farmers value native forests for timber, firewood, medicine, and micro-climate regulation (Bulonvu et al., 2025).

Figure 6: Mature *Cordia africana* tree with fruits ready for harvest in Dembela.

Following the de-electrification during the crisis, biomass such as wood, charcoal, and timber became highly demanded in the towns and cities. This led thousands of residents to enter the "charcoal business" as a survival strategy. However, these survival practices could contribute to the degradation of natural resources. Ponta et al. (2021) also noted that severe hunger drove people into protected areas to gather resources. Excessive forest extraction could lead to the loss of valuable ecological gains.

## Social networks as coping mechanisms

The food aid was limited both in space and quantity. With time, the international NGOs tried to reach out to some areas. Part of this, each person received 15 kg of grain, 1.5 kg of pulses, and 450 ml of cooking oil (Figure 1a). However, the life-saving handouts were far from sufficient to meet the needs of the households. Food gaps remained substantial in hard-to-reach areas in Kola Tembien. As a response, the residents were collecting the leftover wheat from the ground after the official distribution concluded at

Yechila district (Figure 1b-c). Thus, sharing food during the crisis became a critical strategy for saving lives.

Social cohesion played a vital role in supporting each other. Similar to a form of insurance, social networks became essential for survival. The mutual relationships among farmers enabled them to share available food, offering a lifeline for survival for the farmers (Table 1). Notably, cultural institutions such as churches and mosques, along with private charities, provided basic food to the needy local people and displaced individuals. Moreover, local civic societies and more affluent households extended support to the poorer residents in the study area.

Begging emerged as a desperate survival strategy for poor farmers, children, women, and disabled individuals during the siege and blockade. As a negative coping mechanism, begging became a response to the lack of basic food. The farmers gathered in significant numbers outside local churches, mosques, and in the streets, moving from house to house, or borrowing from relatives and friends. As an additional coping strategy, some youngsters were also gathering money from different NGOs or individuals using go-fund or other means at the local level.

Many rural farmers had nothing left to offer to the needy. Households that had once provided food for others were now also forced to beg. In this context, one interviewed household shared, “In autumn in 2020, we used to give up to 10 poor people. But in the rainy season in 2021, we had nothing to offer, not even food for ourselves.”

Remittances became a crucial livelihood strategy for many residents amid the crisis. The money, often sent via informal channels, sustained the livelihoods of the residents. In agreement with Gebregziabher et al. (2023), rural residents received financial support through the black-market cash transfer system. As the blockade reduced over time, the remittances played an even more significant role in supporting the community in 2022.

In a nutshell, social networks, cultural institutions, and remittances were essential to community survival during the crisis. It is inferred that the role of communal, family, and social networks was massive during wartime.

### Evolution of livelihood adaptation status during the crisis

Farmers demonstrated remarkable resilience in the face of critical shocks. They were engaged with every possible means of survival for over two years. The principle of “local innovations for local problems” was evident throughout the sites (Table 1). There was a noticeable shift in livelihood strategies during the crisis time. Regarding this, the households used up their available crops, and the residents began borrowing grains and cash from those with more stable family economies. As the crisis deepened, the families started selling household utensils and farm equipment to survive. Then, they sold their sheep and goats to secure basic food, followed by the sale of oxen and cows. As a last resort, mothers sold their jewelry to cope with food shortages.

The residents were forced to adjust their food consumption patterns. Initially, they reduced the size and number of meals per day. Later, they turned to less preferred foods, cheaper, less desirable foods,

limiting the variety of foods consumed and reducing portion sizes to make do during the crisis (Sassi, 2021; Maxwell, 2017). In eastern Tigray (Table 2), farmers shifted to cheaper foods as a first-phase coping strategy (Weldegebriel et al., 2023). The second phase coping strategies were also asking for remittance and borrowing money, grain/injera (Table 3).

Table 2: Coping strategies employed by households (N = 42) facing food and financial insecurity in eastern Tigray (Source: adapted from Weldegebriel et al., 2023).

| First phase coping strategies | Response | | Second phase coping strategies | Response | |
|---|---|---|---|---|---|
| | N | % | | N | % |
| Shift to cheaper foods | 23 | 54.8 | Reducing food portion size | 5 | 11.9 |
| Consumption of similar food | 25 | 59.5 | Priority for children | 1 | 2.4 |
| Reducing portion size of food | 6 | 14.3 | Borrow money, grain/injera | 6 | 14.3 |
| Remittance to purchase food | 9 | 21.4 | Reduce the frequency of eating | 3 | 7.1 |
| Selling assets to buy food | 2 | 4.8 | Reduction of food portion size | 3 | 7.1 |
| Working daily labor | 2 | 4.8 | Asking for remittance | 15 | 35.7 |
| Borrowing money or grain | 1 | 2.4 | Maternal buffering | 1 | 2.4 |

The availability of coping strategies and the degree of resilience varied across different areas. However, the coping capacity and resilience of farmers diminished over time. In agreement with Kuol (2014), these coping strategies became exhausted, leaving families unable to access even basic daily food supplies in the study sites.

## Potential strategies for post-conflict agricultural and economic resilience in Tembien

In the immediate postwar period, a critical priority is rehabilitating basic agricultural assets (Table 3). Many farming households lost oxen, seeds, and farming tools due to displacement, conflict-related losses, and distress sales (Table 1). Backyard gardening, which emerged as a vital adaptive strategy, was scaled up to meet food and nutrition needs through targeted extension services and promotion of low-input technologies (Goovaerts et al., 2005).

Table 3: Perceived strategies and timeframes for building livelihood resilience of the survivors.

| Component | Immediate (0–12 months) | 1–3 Years (medium-term) | 3+ Years (long-term) |
|---|---|---|---|
| Restoring agricultural livelihoods & food security | - Rehabilitate oxen, seeds, and tools<br>- Expand backyard and homestead gardening<br>- Promote manure, compost, and local seeds | - Introduce drought-tolerant, low-labor crop varieties<br>- Expand small-scale irrigation (solar/gravity)<br>- Promote crop diversification | - Transition to climate-smart agriculture<br>- Reforest hillsides and restore exclosures |
| Reviving social institutions | - Reinforce informal support networks and remittance channels<br>- Strengthen religious and civic safety nets | - Revitalize village development committees and cooperatives<br>- Engage diaspora in recovery initiatives | - Institutionalize community savings and credit systems<br>- Embed resilience in governance structures |
| Sustainable natural resource enterprises | - Assess and protect forests and exclosures<br>- Promote sustainable charcoal and firewood alternatives | - Regulate gold, sand, and wild plant harvesting through community cooperatives<br>- - Support beekeeping in enclosures | - Promote eco-cultural tourism (rock-hewn churches, war heritage)<br>- Develop value chains for forest products |
| Infrastructure and market recovery | - Restore feeder roads, bridges, and rural market access<br>- Reconnect essential services | - - Build storage facilities and small-scale processing units<br>- - Promote market digitization | - Strengthen market linkages<br>- Upgrade infrastructure to support tourism |
| Youth empowerment | - Launch cash-for-work schemes<br>- Provide emergency support | - Deliver training and entrepreneurship programs<br>- Promote youth-led eco-tourism & beekeeping | - Ensure inclusive land rights<br>- Promote youth participation in decision-making |
| Environmental peacebuilding & governance | - Collaborate on unexploded ordnance mapping and decontamination | - Implement integrated watershed restoration<br>- Formalize land tenure rights | - Establish land-use planning systems<br>- Embed environmental governance |

The diverse topography and natural endowments of Tembien offer substantial opportunities for building resilient livelihoods for the residents. The Tembien Gherealta semi-chain mountains are hydrologically rich, feeding numerous intermittent and perennial rivers, which are well suited for small-scale and large-scale irrigation schemes using either solar-powered or gravity-fed systems. The development of range of dams can stabilize production and reduce dependency on erratic rainfall.

Tembien possesses considerable large areas of exclosures and forest patches which are ideal for sustainable beekeeping enterprises. These ecological assets can enhance rural incomes and biodiversity restoration in the areas (Rey Benayas & Bullock, 2012). Moreover, terracing, agroforestry, and area closures could contribute to long-term environmental and economic recovery (Table 3). Capacity-building programs should also equip farmers with skills in conservation agriculture and climate-adaptive practices, which could diversify livelihoods post-crisis (Prayoga et al., 2024).

Tembien is rich in underutilized rock economy. Particularly, the mineral wealth, such as Sandstone, basalt, gold Sapphire, and limestone could empower the marginalized people.

Multipurpose indigenous trees, shrubs, and herbs in the area offer potential for value-added products such as traditional medicine, firewood, and edible fruits (Meaza & Demissie, 2015). Importantly, sustainable timber and non-timber tree products such as *Ziziphus spina-christi*, *Cordia Africana, and Boswellia papyrifera*, could improve the livelihoods of the poor communities.

The geo-tourism potential is remarkable yet untapped in Tembien (Table 3). Its rock-hewn churches perched along the mesa and amba mountains, scenic chains of highland landscapes, and the historic Italian military tombs (Nyssen et al., 2019), where over 10,000 Italians were buried, could serve as pillars of eco-cultural tourism. Investing in this sector would generate employment for youth and women, and link to environmental conservation. Labor-based restoration programs and vocational training could also reduce migration pressures.

Tembien is endowed with vast rangeland and abundant livestock resources (Nyssen et al., 2019). The wide grazing areas and diverse browse species make it a center of livestock production. Hence, this rich livestock–rangeland base underpins rural livelihoods and offers great potential for sustainable development. Social capital should be reinforced through revitalization of community governance institutions (Table 3). Savings and credit groups should be embedded within resilience frameworks to support local investment and reduce external dependency (Aboushala & Haj Ismail, 2022; Liaga & Wielenga, 2020). Thus, tapping into the Tembien diaspora, many of whom live abroad, can mobilize remittances and expertise for socioeconomic recovery.

Infrastructure repair remains essential for economic recovery after the war ends. In line with Meaza et al. (2024), restoring rural bridges and market access points reconnect isolated areas to services and markets, stimulate trade, and reduce post-harvest losses. Similar to the suggestion by Amosha et al. (2024), digital inclusion initiatives must also be scaled to strengthen local economies and remittance flows.

In line with Sommer and Fassbender (2024), environmental peacebuilding is critical for long-term resilience in Tembien. Through an inclusive and resource-aware approach, thus, Tembien communities can move from a war-ravaged landscape to a resilient and sustainable rural economy (Beardsley & Beardsley, 2023).

### Limitations of the study

This study provides valuable insights into local innovations and coping mechanisms during the war-led crisis in Tembien. However, some limitations must be acknowledged. Although efforts were made to include participants of various age groups, gender, and social status, the study did not systematically disaggregate the sample by category: the exact number of elderly people, women, or youth involved in the interviews was not consistently recorded due to the absence of research fund. While key informants and community members were randomly selected from across different parts of Tembien, the sampling did not guarantee proportional representation from all five newly delineated districts.

Although the region spans highland and lowland sites with varying access to resources such as edible wild fruits, gold, and sand, the results and discussion sections did not differentiate coping strategies based on these ecological contexts. While expert interviews contributed to triangulating local narratives, the process of expert selection and representation in the districts and agroecological zones was limited.

## CONCLUSION AND POLICY ACTIONS

The main findings reveal how farmers exhibited a remarkable adaptive capacity through grassroots innovations. These included creative land preparation methods, substitution of inputs, conversion of non-agricultural spaces into croplands, and expansion of cultivation into hillsides and exclosures. Also, communities relied on the multifunctionality of the landscape and the value of traditional ecological knowledge in times of crisis. Notably, wild fruits were among the best solutions during the shortage of food in the war-led crisis. Furthermore, community reciprocity, cultural institutions, informal remittances, and mutual aid mechanisms replaced formal safety nets. However, the local livelihood strategies had trade-offs with environmental degradation through deforestation. The study concludes that while farmers showed remarkable resilience during the war through local innovations and social solidarity, the prolonged crisis weakened their livelihood sources. Postwar recovery strategies must go beyond restoring basic agricultural inputs. Hence, sustainable use of abundant yet underutilized resources such as rivers, livestock, forests, gold, limestone, and multipurpose plants should also be prioritized to bring back the survivors better. Therefore, Tembien holds strong potential to transform from a war-ravaged area into a resilient, inclusive, and economically vibrant rural geographical zone in Ethiopia.

## ETHICAL STATEMENT

Ethical approval is not applicable to this manuscript.

### Abbreviations and acronyms

Open Researcher and Contributor ID; NTD:-Neural tube defects; SPSS:-Statistical Package for the Social Scienc-es; ETV:-endoscopic third ventriculostomy; EVD:-External ven-tricular drainage; VPS:-ventricular peritoneal Shunt; CT:-com-puted tomography; MRI:-magnetic resonance imaging; ACHS:-Ayder Comprehensive Specialized Hospital; ODK:-Open Da-ta Kit; COVID:-corona virus disease;

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## Authors Contribution

Hailemariam Meaza: Prepared the paper

## Data availability statement

The data that support the findings of this study are included in the paper.

## Declaration of the use of AI

The authors declare that no AI-assisted technologies were used during any stage in the preparation of this article.

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The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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