Bonn Contact Group on Climate,
Peace and Security ahead of COP29

Report

# Land degradation: The 'double exposure' of ERW contamination and climate change

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## Report on the nexus between climate change and land contamination and degradation resulting from the remnants of armed conflict

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# Bonn Contact Group on Climate Peace and Security ahead of COP29

## About

The Bonn Contact Group on Climate Peace and Security ahead of COP29 brings together professionals, academics and civil society activists from across Europe and beyond who support the process of bringing to the COP29 process the agenda of peace.

The Group was established at the end of the Bonn Dialogue Meeting on Climate Peace and Security, held in Bonn on 3 May 2024. The landmark meeting brought together representatives of the COP28 and COP29 presidencies UAE and Azerbaijan), representatives of think tanks, civil society organisations and academics, and other stakeholders, for a dynamic exchange of views on how to build on the success of COP28 in Dubai, and particularly how to take forward the COP28 Declaration on Climate, Relief, Recovery and Peace. It was felt that what was achieved in Dubai should not be lost and that civil society needs to work with the Azerbaijani presidency of COP29 to consolidate the ideas and take them forward.

Given the vastness of the topic, and the limitation of time and resources, the BCG decided that in between now and November, it will focus on three sub-themes: Food Insecurity, water scarcity and Contamination by remnants of war.

The members of the Bonn Contact Group are organised in three task forces, dealing with the three sub themes. Their job is to prepare reports on the three sub-themes that will help inform discussions and decisions.

• To gather expertise on their topic of interest with a view to preparing, by September 2024, a report of a sufficiently robust level to feed into the discussions of the COP29 meeting.

• To engage with the COP Troika countries and other state and non-state parties on the theme in the run-up to the COP29 in Baku and beyond, and to support the holding of a day of peace within the context of COP29 in November in Baku.

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### Who is Who?

The work of the Bonn Contact Group is coordinated by LINKS Europe Stichting. The general coordinators of the Bonn Contact Group are Dr Dennis Sammut, Director of LINKS Europe; Leo Wigger from the Candid Foundation; and Isabelle McRae from Restart Initiative, are part of the core team. LINKS Europe provides the secretariat and logistical support for the initiative. Around 30 European and international experts have signed up for the contact group. They will be directly involved in the September workshops and in the preparation of the core recommendations on the themes of food insecurity, water scarcity and land contamination.

For more information about the Bonn Contact Group, please contact Maximiliaan van Lange at LINKS Europe. (maximiliaan@links-europe.eu).

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# Introduction

Many communities affected by ongoing conflict or coping with the legacies of conflict are also at the frontlines of the climate crisis. The effects of climate-related impacts and extreme events are compounded in conflict-affected areas. Deaths from natural hazards such as droughts and floods are 40 percent higher in regions marked by conflict (Marktanner, Mienie and Noiset, 2015). Yet these communities are consistently left out of climate adaptation funding and research (Muñoz et al., 2019; Reda et al., 2021; Sitati et al., 2021). The COP28 Declaration on Climate Relief, Recovery, and Peace highlights the need for "bolder climate action" that can respond to the specific needs of communities affected by fragility or conflict.

Among the many challenges facing communities enduring the legacies of conflict are the compounding effects of climate and contamination from explosive remnants of war (ERW). ERW includes landmines, unexploded ordnance such as cluster bombs that failed to detonate after dispersal, and abandoned ordnance, including sea-dumped munitions that are left behind and remain unused. Even decades after the end of a conflict, the presence of ERW continues to kill, maim, and threaten the physical security of communities. ERWs have a dramatic impact on the mental health of survivors, impede the resettlement of refugees and internally displaced persons, and impact food security and socioeconomic development of communities (Frost et al., 2017).

Both ERW and the impacts of climate hazards and climate change alter the relationship people and communities have with the land around them. They also impact environmental governance and the capacity of states to engage with international treaties. The cumulative effects of climate and ERW contamination contribute to land degradation. Land degradation is the loss of capacity of land to support biological production, ecological health, and value as a societal resource (IPCC 2019).

Land degradation can take many forms, including land abandonment, biodiversity degradation, soil degradation, and degradation of forests, rangelands, and freshwater systems. Land degradation affects people and ecosystems, significantly impacting many dimensions of well-being, food security, and water security of communities. The primary outcomes of land degradation include (Potts et al., 2018):

- Increased poverty and growing inequality among rural agricultural households (Muñoz et al., 2019)
- Increased food insecurity, especially among vulnerable social groups, particularly Indigenous peoples and rural communities;|
- Negative health outcomes, especially through increases in infectious diseases and contaminated drinking water;
- Increased water insecurity through the reduction of quantity and quality of freshwater;
- Threaten the cultural identity, spiritual well-being, and traditions of Indigenous peoples and local communities by damaging ecosystems that are central to their sense of self and cultural continuity.

Understanding the combined impacts of climate change and ERW contamination on land degradation is crucial, as these factors intensify challenges faced by communities enduring and recovering from conflict. The objectives of this report are to assess the current state of knowledge on how climate change and ERW contamination contribute to land degradation, identify knowledge gaps in understanding the combined impacts of climate and ERWs, and provide recommendations for actions that can support communities facing these challenges.

We would like to thank Linsey Cottrell, Environmental Policy Officer, Conflict and Environment Observatory (CEOBS) for her expert review and feedback on the report; We would also like to thank Zahraa Kapasi, consultant for SCRAP Weapons, SOAS, University of London SOAS for research support.

## The land-climate-ERW nexus

Communities affected by both climate change and land contamination do not experience these pressures on land independently. Understanding the nexus of climate change and ERW contamination requires understanding the complex drivers, processes, and feedback between land, climate, and contamination from ERW. In this sense, communities and ecosystems experience "double exposure" to climate and legacies of conflict (O'Brien and Leichenko, 2000). "Double exposure" describes how land degradation is driven by both climate change and ERW contamination, with "double" impacts on communities and ecosystems. To foster climate resilient peace, it is vital to understand the interactions between climate and ERW contamination and the cumulative effects on land degradation.

This report explores the processes and feedback across the land-climate-ERW nexus (Figure 1). Both climate change (section 1) and ERW contamination (section 2) independently contribute to land degradation. There are also feedbacks between ERW contamination and climate hazards and change (section 3). Finally, the double exposure of climate and ERW contamination has environmental and societal outcomes, affecting human security and ecosystems.

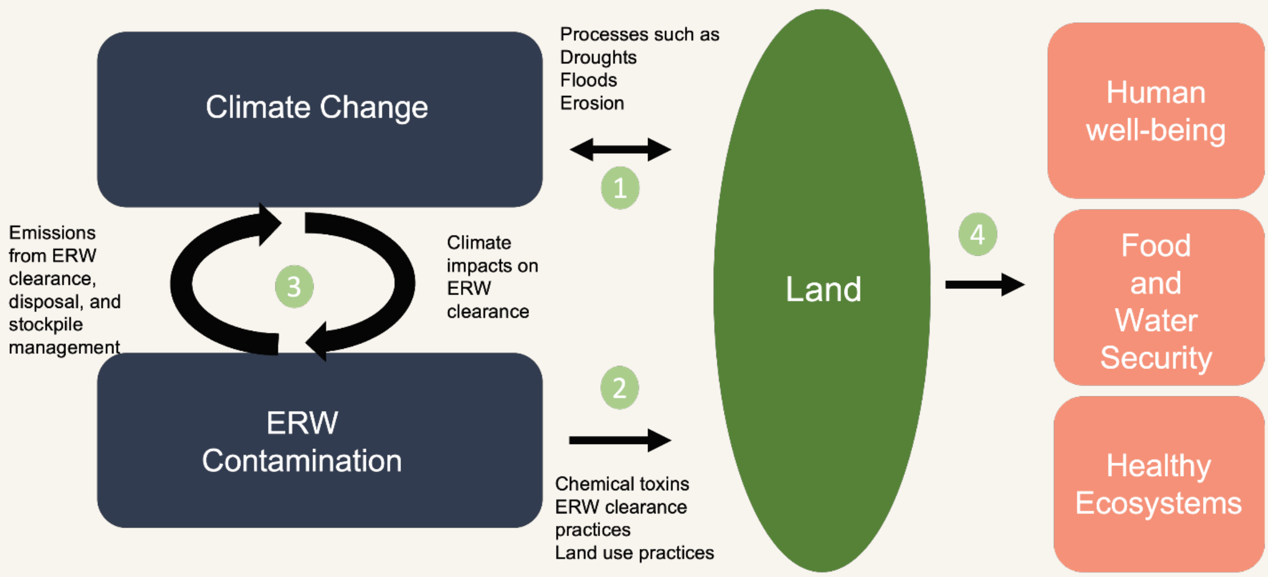


**Figure 1. Land Degradation from Exposure to Climate Change and ERW Contamination:** Drivers, processes, and feedback contributing to land degradation: 1) Climate contribution to land degradation, 2) ERW contamination contribution to land degradation, 3) Feedback between climate and ERW contamination, 4) Outcomes for ecosystems and human security from double exposure to climate and ERW contamination (adapted from Leichenko and O'Brien, 2008).

# 1. Climate Change and Land Degradation

Climate and land are intimately connected. Climate, through the variables of rainfall, temperature, and wind, shapes soils, freshwater, and biodiversity. Land also shapes climate, as soils and vegetation exchange $CO_2$ and other greenhouse gases with the atmosphere and affect climate patterns. Climate change alters the relationship between climate and land, intensifying land degradation processes, which can in turn contribute to climate change. Land degradation is driven by both natural factors and human factors such as deforestation and expansion of agricultural lands.

Land degradation processes such as rainfall, heat stress, droughts, and floods are increasing in frequency and magnitude due to climate change (IPBES, 2018; IPCC, 2019). For example, in Southern Africa, the increase in the frequency of droughts and land use changes since 1970 have amplified the severity and intensity of floods (Franchi et al., 2024). The interplay of droughts and floods in the region exacerbated population displacement, devastated crops and livestock, and heightened food and water insecurity. Climate change further impacts human land-use practices, indirectly accelerating land degradation. For instance, prolonged droughts often lead to increased irrigation and groundwater over-abstraction for agriculture, which can in turn cause soil salinization.

Land degradation processes and land use changes contribute to climate change by reducing carbon sinks, increasing greenhouse gas emissions, and altering regional and global climate patterns (IPCC 2019). Soils and vegetation are important carbon sinks and deforestation, soil degradation, and erosion release stored $CO_2$ back into the atmosphere. Wildfires can result in a sizeable release of $CO_2$. Non- $CO_2$ greenhouse gases are also released through agricultural land practices, and from over-fertilization.

| Major land degradation processes connected with climate change (Olsson et al 2019) |
| --- |
| Wind, water, and coastal erosion |
| Subsidence |
| Soil compaction and hardening |
| Nutrient depletion |
| Acidification/overfertilization of soils |
| Pollution |
| Decline of organic matter in soils |
| Metal toxicity |
| Salinization |
| Permafrost thawing |
| Waterlogging of dry systems |
| Flooding |
| Eutrophication of freshwater |
| Woody encroachment |
| Soil microbial and mesofaunal shifts |
| Biological soil crust destruction |
| Invasive species and pest outbreaks |
| Increased wildfires |

***Table 1.*** *Major land degradation processes connected with climate change (adapted from IPCC 2019)*

**Knowledge Gaps:**

The IPCC Special Report on Climate Change and Land identifies many knowledge gaps around land-climate interactions, land degradation drivers and processes, and outcomes on human security and well-being (IPCC 2019).

- Particularly relevant for this report is the need to understand how simultaneous stressors affect land degradation. Much of the knowledge on land degradation focuses on one stressor such as drought or erosion. There is a need to understand how multiple stressors interact, especially in the within conflict-affected areas.

- Research and policy on land degradation is dominated by the biophysical dimensions of land degradation and there is a need for greater integration with the human dimensions of drivers and outcomes of land degradation.

- The IPCC report also highlights the need for greater inclusion of the perspectives and lived experiences of land users affected by land degradation.

# 2. ERW Contamination and Land Degradation

It is difficult to clearly draw a link between the changing climate and an armed conflict, however, we can make direct links between ERW contamination which is an outcome of armed conflicts to land degradation as explained below.

## Armed conflict and land degradation

Armed conflict is a significant driver of land degradation, often surpassing the impact of urbanization and often understudied (Certini and Scalenghe, 2024). Warfare degrades land through contamination from chemicals, herbicides, and radiation, and the destruction of sensitive landscapes by military operations, such as the logging of primary rainforests by Myanmar's military junta (Darbyshire, 2021). In Cambodia, 35% of forests were devastated by conflict, while Vietnam lost nearly three million hectares of forest between 1976 and 1995 (Matthew, Brown and Jensen, 2009). Herbicides used in Vietnam also caused contamination of soil and water, soil erosion from the loss vegetation cover, altered faunal communities, and disrupted agricultural patterns, affecting the health of civilians (Padányi and Földi, 2014).

The environmental impact of armed conflict varies with weaponry, terrain, tactics, and the sensitivity of the setting (Hupy, 2006). Damage occurs both directly, through chemical and explosive weapons contaminating soil and groundwater (Gaafar, 2021), and indirectly, through displacement. Refugee settlements often lead to deforestation and ecosystem loss, such as in Virunga National Park, where 36,000 million trees were cut within two years to supply Rwandese refugees with fuel (Oucho, 2007). Similarly, refugee camps in Bangladesh and Uganda caused deforestation and land degradation (Bernard et al., 2020; Darbyshire, 2021)

In Syria, conflict-driven deforestation in coastal regions has worsened soil erosion (Abdo, 2018). Karabakh and Ukraine have also suffered significant forest loss due to burning from military activity (UNEP, 2022). Afghanistan lost 33.8% of its forest cover, or around 442,000 hectares in total between 1990 and 2005 (World Rainforests, no date). In Iraq and Syria, farmland was intentionally burned during conflicts in 2019 and 2020 (Jaafar, Sujud and Woertz, 2022), further degrading soil and water quality.

ERWs exacerbate land degradation long after conflicts end. The use of Explosive Weapons and ERWs release chemicals into the environment, contaminating land and threatening biodiversity, water resources, human health and livelihoods (Berhe, 2007). As munitions and their casings corrode, munition components leak into the environment. Climate change can also affect how contaminants behave in the environment and may result in increased environmental risks and changes on exposure pathways.

ERW contamination drives land degradation directly in several ways:

- Direct impact of ERW contamination (these are effects, alterations and disruptions caused to the environment and/or its components now and specific location of the blast of an ordnance).
    - **Chemical contamination:** Through the release and exposure to hazardous toxic munition components; degradation in soil quality and contributes to migration and distribution of contaminants in soil and water.
    - **Physical disturbance of soil:** The explosion of bombs and other explosive munitions forms craters in soil, leading to changes in soil structures and composition.
    - **Impacts on vegetation and soil organisms:** Detonation of explosives and chemical contamination impact existing vegetation, agricultural production, and soil organisms (e.g. earthworms and microfauna).

- Direct Impact of the removal and disposal of ERW (efforts to address and remove ERW contamination cause damage to the soils' stability by destroying the soil structure, and causing local compaction, thereby increasing the susceptibility of soil to erosion and reducing soil productivity)
    - Vegetation removal and ground preparation for clearance damages vegetation and can affect ecosystem health.
    - Methods of disposal such as Open Burning and Open Detonation (OBOD) can cause the release of contaminants and damage to soils.
    - The mechanical impact of tilers and rollers which disrupt soil structure.
    - Worksite generation of waste and resource use.

## Direct Impact of ERW Contamination

### a) Chemical contamination of soil and water

ERWs can contain toxic explosives such as 2,4,6-trinitrotoluene (TNT), hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX or Cyclonite1) which are toxic and present risks to the environment (GICHD, 2021, p. 13). The casings and internal components include plastic and heavy metals such as lead, a component that is of grave concern. ERWs can also contain other toxic and radioactive components such as depleted uranium, cadmium, mercury, and PFAS (Berhe, 2007; Habib, 2007).

The primary and direct way in which toxic material is transferred into soil and water is upon open detonation where contamination is distributed by explosive ordnance and metal component casings. Another process is through open burning of explosive ordnances. Burnt debris falls on the ground and leaks into the soil or groundwater. Underwater munitions pollute when the explosives and metal casings corrode getting into the water ecosystem.

Left in-situ, ordnance corrodes and can leak explosive and metal components to soil and water, and become available for uptake by plants and animals. Evidence of such leaks can be found in and on the surrounding ground and plant life. This is caused by the aging of the casings of those buried in the ground which corrodes, leading to chemicals leaking into soil and groundwater. They release traces of the explosives' vapors into the surrounding soil such as TNT (trinitrotoluene), leading to soil degradation (Shemer et al., 2017). This release of hazardous chemicals into soil can take between 10-90 years to experience leakage, depending on factors such as soil condition, climate and type of munition (Mine Action Review 2021). This contributes to land degradation. However, some reports indicate that in places such as Ukraine's farmland, the pollution may be experienced sooner due to the types of mines that Russia is reported to have used and which are likely to corrode faster due to their age (Welsh et al., 2023).

This legacy of contamination can present long-term challenges of restoring degraded land and soil to achieve land degradation-neutrality, i.e. is remediation required to return land to safe and productive use and support functional ecosystems. This is because the evidence of the extent of degradation is not always immediately obvious.

### b) Physical disturbance of soil from ERW

Explosions from air-dropped bombs, propelled explosives, and landmines leads to a process called “bombturbation,” which includes the creation of craters on the soil surface and mixing of soils (Hupy and Schaetzl, 2006). The impacts of bombturbation are evident in Ukraine, although the full of impact on bombturbation on vegetation remains understudied (Solokha et al., 2023).

### c) Impact on vegetation and soil organisms from ERW

Explosions and explosive compounds from ERW affect vegetation and soil organisms. Explosive compounds affect the ability of plants to germinate, grow, and reproduce (Via and Zinnert, 2016). This leads to cumulative impacts on ecosystem health and agricultural production. Soil organisms such as soil microorganisms, nematodes, and earthworms play an essential role in soil health. There are limited studies on the effects of ERW on soil organisms, but initial studies in shooting ranges and warfare-impacted areas indicate that explosive chemicals impact soil microorganisms, microfauna, and mesofauna (Rodríguez-Seijo et al., 2024).

## Direct Impact of ERW detection, removal and disposal

Efforts to address the contamination cause damage to the soils’ stability by shattering the soil structure, and causing local compaction, thereby increasing the susceptibility of soil to erosion.

### a) Vegetation removal

Clearance of ERWs can be environmentally disruptive. To find and remove ERWs, it is sometimes necessary to prepare the territory by cutting the upper fertile layer of the earth; while the root system of trees is damaged or removed, low-growing plants (bushes, etc.) are destroyed to gain access to the likely location of explosive devices. Exposing the surface of the earth can lead to the thinning of the fertile layer and the possible formation of erosion. This removal of vegetation has the potential to damage habitat if the area is ecologically fragile.

### b) Disposal and detonation of ERWs

ERW disposal is sometimes done through remote detonation, generating a crater that displaces topsoil while compacting subsoil into the crater. When an ordnance detonates, it can cause soil degradation by shattering the soil structure and damaging soil stability, causing local compaction, and increasing the susceptibility of fertile topsoil to erosion. While this impact on the soil structure might be slow in the long term and with combination of other factors, the resultant loss of moisture, contributes to the erodibility and productivity of the land.

While the disposal methods may seem to be expedient and safest methods, beyond the damage caused on the soil structure and stability, the detonation of large quantities of explosives also releases toxic pollutants into soils and waterways, including from hazardous substances (Cottrell and Dupuy, 2020). For example, research on soil analysis around detonation sites in Cambodia following destruction in situ - indicated heavy metals in the soil (arsenic, cadmium & copper) increased by up to 30% following detonation in a one-meter radius around the detonation point (Mine Action Review, 2021). Similarly, studies on soil quality after mine clearance in Halgurd-Sakran National Park, Kurdistan, Iraq show evidence of the release of heavy metals into the soil following demining activities. The research identifies increased concentrations of heavy metals, which pose risks to local ecosystems and human health. These heavy metals, such as lead, cadmium, and arsenic, are released during the mine-clearing process and pose significant environmental risks. These elevated levels of heavy metals negatively impact soil health, can harm local ecosystems, and threaten human health through direct contact, inhalation of dust and ingestion, and potential contamination of water sources and food chains (Hamad, Balzter and Kolo, 2019).

**c) Method of clearance – Open Burning and Open Detonation**

Specific demining techniques may introduce toxic material into the soil. The destruction of ERWs can be logistically complex depending on the quantities involved. This means that sometimes the only option is the physical destruction techniques using the simple method of Open Burning and Open Detonation (OBOD). While this is banned in some countries and discouraged in others, it is cheaper and has been used particularly in developing and conflict-affected states, or where expedient destruction is needed for the disposal of unsafe items. However, this releases explosive residues into the environment such as TNT, which is a common explosive that, when absorbed into soil, slowly leaches and degrades to form degradation products such as 2,4-Dinitrotoluene (DNT), which has a higher toxicity than TNT itself (Cottrell and Dupuy, 2021).

**d) Mechanical Impact of tillers and rollers**

Large mechanical machinery equipped with flails, tillers, and rollers are often used in landmine clearance. These machines can disrupt soil structure, accelerate soil erosion, and disrupt water, carbon, and nutrient cycles. This occurs due to soil compaction caused by the movement of heavy machinery and vehicles. Soil compaction decreases soil porosity and hydraulic properties, thereby slowing the growth of crops reduce yields by up to 50% or more, depending on the amount and degree of soil compaction (Shaheb, Venkatesh and Shearer, 2021).

**e) Worksite generation of waste and resource use**

The establishment of worksites and temporary field camps to house deminers and other operational staff can lead to the overexploitation of local resources such as water, wood, or food and the generation of waste. These sites also impact the soil due to the repair, maintenance, and servicing of heavy ERW clearance equipment. If not properly managed, worksites can lead to lasting environmental degradation long after the camp has left.

## Impact of IEDs

A particular challenge is also exposed by improvised explosive devices that are used in places like Afghanistan, Nigeria, and Colombia, amongst other places. A study by Pedraza (2020) demonstrates the complexity of IEDs and their propensity to contribute to land degradation. This is mainly because most common raw materials used to make explosives are ammonium nitrate and potassium nitrate, chemical compounds predominantly used as fertilizers. However, these devices are also made from ordinary objects which are easily found, including plastic bottles, PVC tubes and syringes. Given their makeshift materiality, they are particularly prone to malfunction and decay. Unlike industrial landmines, which can be more resilient to climatic variables and regain their explosive capacity, seasonally improvised landmines are especially vulnerable to environmental conditions. Wind, heavy rain, or animals can easily damage detonators. Similarly, due to their unstable nature, they are normally destroyed in situ, which means that the ensuing contaminants including small volumes of plastics cannot be collected (or potentially recycled) during demining operations, contributing to land degradation.

### Knowledge gaps:

Data on the environmental impacts of detonation has not been widely examined or reported and studies are only just emerging. Therefore, the full extent of the impact is not fully understood, however, what is clear is that without mitigation, the detonation of ERW can affect soil fertility and water quality in heavily mined territories.

- Initial studies indicate pathways for ERW contribution to land degradation, but more research is needed to better understand the impacts of ERW contamination on soils, vegetation, and soil organism communities.

- There is a need for more long-term research on the impact of ERW contamination on agricultural production, specifically on possible reduction of crop yields or uptake of contaminants into crops.

- Preliminary research shows that explosive remnants of war (ERW) clearance and disposal methods may contribute to soil erosion and the release of harmful chemicals. More extensive long-term studies are required to assess the effects of these techniques on land degradation and to develop approaches that mitigate environmental damage.

# 3. Nexus of Climate and ERW

Climate events such as floods, landslides, and wildfires can worsen the threat posed by ERW by changing their location and affecting their stability. Climate events such as floods and extreme heat also present a significant challenge to efforts to ERW clearance operations. Climate change is altering the risks that ERW presents to communities as well as efforts to address ERW contamination. While remaining ERW contamination is not a significant driver of greenhouse gas emissions, it is also important to note that ERW clearance does play a role in contributing to climate change.

## Impact of flooding and landslides

### 1. Erosion and displacement of ERWs

Flooding can cause erosion of soil, potentially uncovering and carrying away previously buried ERWs, increasing the risk of contaminating new areas, or re-contaminating areas previously cleared. This dislodging of ERWs includes even those thought to be deeply buried, for example during the November-December 1999 flooding in central Vietnam, mines and UXO that were once 4-12 inches below the surface shifted during severe flooding (Wareham, 2000). Similarly, frequent mudslides and floods move mines to unpredictable locations in Tajikistan (IFRC, 2024), and in the fields north of Bahri along the road leading to the Nile River State in Sudan (Radio Tamazuj, 2024). The contamination of new areas and re-contamination of areas already cleared increases risk for both affected communities and relief workers. This has escalated vulnerabilities, especially among internally displaced people, and intensified urgent needs for shelter, health services, and food security.

Floods have also caused contamination of ERWs in neighboring territories, for example, reports indicate that in 2021, mines planted along the Lebanese-Syrian border were washed into Lebanon following winter flooding, causing multiple accidents amongst many who were not familiar with these kind of objects (HOUSSARI, 2021; MINE ACTION REVIEW, 2023). Concerns have also been registered by the South Korean military because floods hitting the region can potentially dislodge North Korean mines into their territory (Kim, 2024). In early August 2010, there were similar concerns when North Korean landmines drifted along streams between North and South Korea due to heavy rainfall, causing the death of one man and injuring another after they picked up a mine on their way back from fishing (ICBL, 2010).

In Libya, gravitational mass movement caused by storm Daniel caused the shifting of an estimated 100,000 tonnes of ammunition that lay under the rubble in some parts of the country including Sirte, Tawergha, Derna and Benghazi were displaced. Similarly, floods also uncovered unexploded ERWs left behind from the country's war in cities such as Derna which were sites of armed conflict (Makhlouf, 2023).

The unpredictable threat of the undetected migration of ERWs also presents other challenges, for example disaster recovery is curtailed. Floods do not only cause the shifting of ERWs, they also damage infrastructure thus, humanitarian and emergency services are strained not only due to the danger from the displaced munitions but also due to infrastructure collapse, making humanitarian and disaster responses to ERW contaminated communities more complex. For example, the supply of aid to communities affected by the most recent floods (April – August 2024) in Yemen. Previously during the 2014 floods that hit Bosnia, Serbia and Croatia where such shifts and unpredictability on the location of displacement ERWs and made recovery dangerous (Trumble, 2021). Thus, populations have to deal with deaths, diseases and lack of food and shelter, they also face the additional hardship of trying to avoid mines and providing care for ERW survivors.

Similarly, contamination can block access to maintenance of infrastructure such as waterways and this can cause flooding. For instance, in the western Balkans, presence of ERWs along waterways on the banks of the Drava, Kupa, and Sava rivers, challenge the maintenance of drainage canals, which causes intermittent flooding (Baselt et al., 2023).

**2. Impact on the stability of ERWs**

Explosive ordnance that is moved by water can sometimes become more sensitive to movement and is easier for it to detonate if it's been handled afterward (Frey, 2024). Some become sensitive to the slightest touch, others are designed to explode upon impact with a hard surface, and many explosives will not detonate.

With more climate-related events like heavy rainfall and wetter soil conditions, there is a potential to accelerate the corroding process of explosive ordnances and degradation of ERWs (this can take between 10-90 years depending on factors such assoil condition, climate and type of munition). Such degradation may cause leakage, from corroded casing leading to chemical leaking into soil and groundwater. However, there is not much research on the effect of climate conditions on the stability of ERWs.

## Impact of High Temperatures and Extreme heat on ERWS

High temperature may also have an adverse impact on munitions, as intense heat can weaken munitions' structural integrity, cause the thermal expansion of explosive chemicals, and damage protective shields. Many countries especially post-conflict countries, have poor stockpile management practices and weapons experts warn that due to climate-related events such as increased temperatures, unplanned explosions at munitions sites (UEMS) have been on the increase. An analysis of data from Small Arms Survey, an arms-monitoring project based in Geneva, suggests that UEMS are roughly 60 percent more likely between late April and mid-September (Schwartzstein, 2019). In 2018-2019 six different munition sites exploded across Iraq (Mine Action Review, 2021). According to evidence by experts, the explosions happened during the scorching Iraqi summers, when temperatures routinely topped 45 degrees Celsius (113 degrees Fahrenheit) (Schwartzstein, 2019).

In Jordan, heatwaves have been blamed for similar arms dump explosion in 2020 (Durham, Waller and Pizzino, 2023). Investigations by the Jordanian army indicated that the intense heat had caused the "thermal expansion of mortar shells" in the old and obsolete mortars stored in an arms depot in the eastern outskirts of Zarqa, the second largest city in Jordan.

## Wildfires

Drought, increasing aridity, and extreme heat contribute to the increase of wildfires under climate change. Wildfires represent an important agent of land degradation in temperate ecosystems, such as those in the southern European Mediterranean countries (Esteves et al., 2012), Wildfires can have an impact on soil quality and contribute to soil erosion. The frequency of wildfire disturbance means that the degradation is accelerated, a phenomena that has increased substantially in the Mediterranean.

ERWs can inhibit the capacity of communities and local government to address the spread of wildfires. During the most recent wildfires in Bulgaria, and Greece, reports indicate that firefighters had to stop fighting a wildfire in the Slavyanka mountains near the Greek border after landmines dating back to the Cold War era began exploding (Moutafis and Sekularac, 2024).

In 2022, fire crews in the UK could not enter Salisbury Plain to tackle several fires due to the risk of ERWs (Brimstone UXO, 2023).

In Bosnia, forested areas contaminated with ERWs have also become susceptible to wildfires as the presence of landmines prevents forest thinning, and important forest management tool in preventing wildfires. The presence of ERWS further makes it impossible to create fire corridors or even send in fire trucks to combat the fires from the ground (Stelstra, 2023).

## Climate Impacts on ERW clearance operations

Climate hazards, such as heatwaves, tropical cyclones, dust storms or heavy rainfall, have a tangible impact on the conduct of mine action operations. Climate hazards present additional challenges, in terms of both how many mine action operations are carried out, and how ERW contaminated areas and communities will be affected.

### a) Contamination of new areas due to flooding and landslides

There is greater uncertainty over the location of ERWs as they would shift in the flowing water, moving downstream following gravity. Flooding increased the associated risks and threats of ERWs as 1) markings of mined areas are swept away or destroyed 2) rain and flooding may expose buried mines 3) mines may shift in the floodwaters and end up in areas previously considered clear and safe. Tracking the location of displaced mines also becomes a formidable challenge: operational plans and data on known mined areas become obsolete, setting back clearance plans several months, if not longer, as new surveys become necessary. Any gains from humanitarian demining are lost. There is also the need to re-educate or provide mine risk education to different communities depending on where the ERWs have been deposited.

There are many examples where storms and floods led to the displacement of ERWs. In Mozambique following Cyclone Eline in late February 2000 and Cyclone Hudah in mid-April 2000, the violent storms swept the ERWs to unknown locations and rendered maps of contaminated land obsolete (Wareham, 2000). As the mines in Mozambique were made of plastic, they floated and were easily displaced (Schlosser and Saulnier, 2000).

During floods any ongoing clearance operations are constrained and or delayed. In Mozambique, demining activities were postponed until the flooding ceased, and mine awareness campaigns became even more important in some places (Schlosser and Saulnier, 2000). Flooding has also delayed clearance in South Sudan and poses significant challenges in accessing remote areas contaminated by explosive ordnance and responding to emergencies (Takpiny, 2022). Flooding and landslides have halted or affected activities contamination mitigation activities in other places such as Angola, Iraq, the Lao People's Democratic Republic (LPDR), Sudan and Zimbabwe. Following severe tropical storms and flooding in 2018 clearance activities were halted in Laos, the world's most heavily contaminated country by cluster munitions. Flooding had caused explosive items to move, requiring areas previously cleared to be re-cleared (Ferrie, 2018). In places where infrastructure such as roads have been damaged due to floods, the direct impact on demining efforts includes restricting access by limiting the use of machinery and impacts on mine-detection dogs, which are unable to work in wet conditions.

### b) Danger from Higher Temperatures and Extreme heat

Increasing temperatures present a danger for mine action workers, especially deminers, as such temperatures can create heat stress and have severe consequences on their well-being. This results in the need to limit the working time for deminers and mine detection dogs. Similarly, in places where there is drought due to extreme heat, it can mean that soils can harden and more difficult to work and demine (Mine Action Review 2021).

Clearance teams play a role in securing safety storage for munitions storage also known as physical security and stockpile management (PSSM) in many countries where they work. Those working near such sites have an increased risk of injury due to detonation given the deterioration and instability of ERW generally and under extreme weather variables such as heat waves. This is because extreme heat and increased temperatures are linked to unplanned explosions at munitions sites as highlighted previously. For example, a DanChurchAid deminer was killed by a mine whilst working in a neighbourhood of such a detonation in Dafniya, 12 miles from Misrata in Libya in 2012. The detonation had spread ERWs across the neighbourhood (Docherty and Crowe, 2013).

## Emissions from ERW clearance

It is important to highlight that as with every sector, organizations such as national mine action authorities, and other partner organizations within the mine action sector working on efforts to address contamination also directly contribute to global warming, and thus climate change. This is through emitting GHG in the atmosphere during operations and also through the use of resources (Mine Action Review, 2021). As highlighted, addressing the challenges of ERWs especially clearance operations, operators do sometimes remove vegetation or trees to allow detectors to get close enough to the ground in order to detect and remove explosive ordnance. Consequently, this may sometimes cause soil compaction, thereby increasing the risk of soil erosion degrading the quality and or disturbing the ecosystems. This includes removing carbon sinks (that is, capturing carbon dioxide from the atmosphere). This amounts to the removal of the environmental protection that naturally prevents or limits the extent to which climate-related hazards may occur. Collectively this has an impact of exacerbating climate change.

It is worth highlighting that there are efforts within the humanitarian mine action sector that are working towards delivering positive action to address these challenges. For example the Norwegian People's Aid (NPA), one of the largest ERW clearance organizations, has been working with local partners such as Zero Waste Laos (ZWL) to mitigate their environmental footprint.

## Knowledge Gaps:

There is a persistent lack of data that specifically covers the impact of climate-related incidents such as heat-related detonations; this is partly because they happen in areas of deemed as high security and may often kill any nearby witnesses destroying evidence that could explain what triggers such an event.

Similarly, there are lack of studies that explore the extent to which each of the climate-related incidents including flooding impacts on stability of ERWs.

# 4. Outcomes of double exposure to ERW contamination and climate

The double exposure of ERW contamination and climate has environmental and societal outcomes, affecting human security and ecosystems.

### Indirect or Secondary Impact of Land degradation from the presence of ERW contamination

The indirect impact of ERW contamination on land degradation is that which occurs at times and locations other than the original location or detonation of the device. This is as a result of the human interactions with contamination, which generates fear, whether this is real or imagined. This has indirect impact of land degradation as it is often accompanied by the population's movement to new locations leading to competition over limited resources. The manifestation of this is through land use restrictions; agriculture practices due to pressure on uncontaminated land. Consequently this has societal implications such as the heightened risk of conflict and higher levels of food insecurity as highlighted by a number of scholars on post-conflict contexts such as Afghanistan (Unruh and Shalaby, 2012); Angola (Unruh, 2012); Mozambique (Unruh, Heynen and Hossler, 2003) and Cambodia (Lin, 2024).

#### 1. Land use restrictions

The presence of ERWs alters land use practices and limits the ability of communities to access natural resources. ERW contamination has a large impact on rural households who rely on land access for agriculture, forestry, grazing, and other essential activities for livelihoods. The impact of contamination therefore inevitably leads to decreased agricultural outputs. It is particularly relevant because of the salience of dependency on land for livelihoods.

Land restrictions through ERW contamination contribute to changes in land use, such as converting non-agricultural land, like forestry, to agriculture (Lambin et al., 2018). Population pressure on un-contaminated land can lead to deforestation due the increase of the intensity of available uncontaminated land, inevitably exacerbating the risk of increasing the degradation of soil due to cropping. This results in a loss of the productive potential of the land. Those who are dependent on such lands are then pushed to use or abuse marginal resources or move into refugee camps or urban centers. This often leads to forest loss, the degradation of soil and water quality, and it impacts biodiversity and ecological resilience. Such movements, including rural-urban migration, not only hinder development, but inevitably lead to food insecurity. For example, in Mozambique, small-scale landholders put significant pressure on land that was free from ERWs due to the abandonment of large tracts of land where ERWs were believed to exist (Unruh, Heynen and Hossler, 2003).

Due to the fear of the presence of ERWs, the population moves as a rule to urban and suburban areas leading to the abandonment of arable land (Hamad et al., 2019). The area of arable land and pastures decreases, and as a result, the quantity and quality of food products decrease too. This often leads to the further depletion and overburden of natural resources in new areas when populations are forced to migrate, creating further environmental strain.

#### 2. Agriculture production practices - due to pressure to produce more food on limited land

The war between Russia and Ukraine potentially brings to fore the reverberating impact of conflict on food security due to the nature of the globalized agricultural markets. Both countries are considered ‘global breadbaskets’ due to their importance as producers and exporters of essential agricultural commodities (Ben Hassen and El Bilali, 2022). Beyond this, it can be anticipated that in the event that the war comes to an end, it is unlikely that agricultural production will resume to pre-war levels in both countries partly due to the impact of the degradation of land due to soil contamination. This view is supported by evidence from past events such as the battle of Verdun in France that left the once-fertile farmland contaminated. This land remains uninhabitable, over a century later, due to the threat from unexploded ordnances. The military operations and extensive deployment of heavy military equipment accompanied by combustion of munitions, explosions and the use of chemicals are affecting soil quality and fertility leading to heavy metal contamination potentially harming agriculture through reduced yields, as well as loss of food quality and safety (Shaforost et al., 2024). Reclamation and rehabilitation of the soil will take a long time. It can be anticipated that to mitigate global food insecurity, there will be pressure for other agricultural production countries which can lead to land degradation and the associated loss in soil productivity in said regions.

Evidence from other contexts demonstrates that upon clearance, land may suffer from combined pressures for agricultural production and livestock production, thereby leading to degradation as a result of desperate attempts to boost yields from fewer amounts of accessible land. There is already pressure in countries in Europe to postpone the transition to greener agriculture to increase agricultural output in response to threatened food security (Abnett, Blenkinsop and Abnett, 2022). Thus, as in other contexts, more intensive agricultural production systems will be deployed that are heavily reliant on the application of mechanical, chemical or biological supplements for production on safe land (Berhe 2007). Similarly, intensive management of agricultural land and higher use of N-fertilizers and GHG emissions leads to the loss of soil function, negatively impacting on the many ecosystem services provided by soils. Degradation of agricultural land, then results in a negative cycle of natural land being converted to agricultural land to sustain production levels.

### 3. Deforestation due to population pressure on uncontaminated land

The most cited and common way in which land degradation manifests is through deforestation. It is also the most common environmental outcome of armed conflict (Meaza et al., 2024). The 2018 Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services report states that human-caused land degradation, including deforestation, is now responsible for land abandonment, loss of soil and water resources, and declining populations of terrestrial organisms (IPBES, 2018). While land use restrictions due to the presence of ERW causes degradation from pressure on uncontaminated land, the clearance of ERWs can also have the unintended impact of improving access to forests and therefore potentially increasing deforestation rates. For example internal migration, increased settlement and greater demand for agricultural land have accelerated rates of deforestation close to the Cambodian–Thai border and K5 mine belt.

## Risk of Conflict

Land plays a key role in conflict in many contexts with ERW contamination. While it is not always the sole cause of conflict, it can be a contributing factor. In turn, conflict worsens the damage done by climate change as it limits people’s ability to respond or cope with climate shocks. Insecurity can find mobilization around land issues which can become the object of dispute and can lead to the escalation of localized conflict. Thus, diminishing or limited access to land and other natural resources due to degradation and contamination has the potential to trigger competition for scarce natural resources, due to the perceived threats to livelihoods and well-being, potentially leading to conflict.

In 2005, the Millenium Ecosystem Assessment report singled out land degradation as among the world's greatest environmental challenges, responsible for reducing environmental security, destabilizing societies, endangering food security, and increasing poverty around the world (Berhe, 2022). Resource scarcity and demand pressures from population growth or shifting mobility patterns are another important dimension in creating disputes over the use of land and related resources. Land degradation can also amplify a communities livelihood vulnerability and depletion of assets, sometimes forcing communities to resort to risky or maladaptive behaviors such as food theft, land grabbing, and illegal fishing resulting in more conflict. Collectively, ERW contamination exacerbates and or contributes to these shifts thereby exacerbating levels of community vulnerability to conflict.

Findings by conflict studies scholars indicate that post conflict societies are most likely to experience its reoccurrence. While climate-related challenges are not the single motivating cause for this reoccurrence, it is believed that these do interact with other social, economic and political factors to heighten the risk of return to conflict especially due to political instability at crucial post-conflict moments. For example, ERW contamination forced populations in two provinces of Mozambique's provinces of Nampula and Zambezia to relocate. These were the country's breadbasket, and therefore this had impact on food security for the country as they had historically been responsible for a large portion of Mozambican agricultural productivity. This combined with takeover of large tracts of land by other actors, and the absence of effective local to national institutions to regulate and arbitrate land rights, contributed to decreasing food security at the state level. Besides, food insecurity and dislocation due to changing social conditions and unstable land tenure regimes in some cases resulted in instability as small holders migrated to other locations, contributing to land conflicts in the destination areas. Thus, for many post-conflict and conflict communities, the vulnerability to conflict is directly linked to issues over land, and therefore ERWs contamination and climate-related hazards increase and heightens the society's vulnerability.

### Food insecurity

For communities that rely on agriculture, complexities and vulnerabilities are more dire because the majority largely depend on agriculture and/or livestock for livelihood; therefore, their resilience is weakened as food security is threatened thereby aggravating the humanitarian conditions. Thus, in contexts where communities are impacted by challenges such as drought, ERWs contamination adds to the complexities of the existing conditions for such communities compromising their resilience.

The outcome of land degradation impacts communities in specific localities especially where livelihoods are based on the land for their survival and well-being. This then impacts on agricultural and crop productivity leading to food insecurity and quality. For example, Colombia's alarming deforestation has resulted in continued extraction and deforestation eroding society's ability to address environmental challenges. The ensuing damage and loss of biodiversity has led to an increasing threat to food security, increased pests and diseases for traditional crops, water scarcity and the destruction of streams and rivers that lead to increased poverty and hunger (Quiroga et al., 2024). In the case of Sri Lanka, as contaminated land on the Jaffna peninsula was cleared of explosive hazards and families returned to their pre-war lands, the changes of soil salinity levels, as a result of, among other factors, the destruction of coastal mangrove systems, due to contamination and consequently due to clearance, led to abandonment of previously fertile paddy lands. The absence of the mangroves has resulted in salt-water intrusion limiting the extent to which the land can support rice crops (Chrystie, 2023).

This adverse impact of this is felt by the many communities that have double exposure to climate and ERW contamination. The land becomes less productive, and the diversity of plants is also reduced, and this equates to the loss of societal income, with consequences for regional policy, economic growth, and rural population welfare (Berhe, 2019). Angola is rebuilding its country after years of war, and ERW contamination has a drastic effect on access to agricultural land, which in turn affects the livelihoods and food security in the communities. While communities have benefitted from increase in arable land from clearance recent drought has reduced the variety of cultivated crops (Ikpe and Njeri, 2024). In Afghanistan, agriculture is the second largest sector of the economy. Agricultural labor is critical for livelihoods however, through degradation and abandonment (due to ERW contamination among other reasons) there has been an annual decline of agricultural production over time leading to food insecurity. In the past decades, the area of agricultural and pasture lands has drastically been decreasing. Pastureland, especially those located on the lower slopes of the valleys and steppes have been heavily degraded by soil erosion and partial contamination with ERWs. Some pastures are either abandoned or are extremely dangerous to use. As a result, the loss of this pasture has severely affected the lives of hundreds of thousands of nomads and semi-nomads that rely on it.

Desertification has affected more than 75 percent of the total land area in the Afghanistan's northern, western and southern regions, reducing vegetation cover for pasture, accelerating land degradation and affecting crop farming in the last four decades (Borthakur, 2024). This has resulted in communities such as those in Hakimabad village, Laghman Province, to struggle due to 'reduced incomes, as farming is no longer feasible due to recurrent drought, drying land, severe flooding, deforestation, desertification, and excessive use of farmland and pasture (OCHA, 2023). Severe food insecurity and competition over scarce resources, particularly water, then gives rise to new conflicts in the region (Borthakur 2024).

### Knowledge gaps:

- Little is known about how local people's inability to cope with multiple interacting stressors undermines their capacity to improve their food security status, including the barriers and opportunities associated with fishing and farming livelihoods where food security programs are required to account for differential vulnerability to compounding risks.

- There are no in-depth case studies or comparative studies that examine the compounding impacts of climate and ERW contamination on land degradation.

# 5. Conclusions and Recommendations

Conflicts and climate-related events are becoming more frequent, intense, complex, and longer lasting. Together, they accelerate land degradation, a process that can take centuries to recover from, with even more time needed to restore land fertility. Similarly, climate-related events add an additional layer of complexity to the already challenging task of mitigating the risks posed by ERWs. These linkages are also bi-directional. **Therefore to address the climate needs of communities facing conflict and fragility and to foster climate-resilient peace, there is a need to address the complexity of the outcomes of climate and ERW contamination and their cumulative impacts on human well-being, food security, and ecosystems.** This call is urgent and critical.

Evidence gathered for this report highlights how contamination on the front lines of wars in the previous centuries continues to shape the well-being of people and ecosystems long after the cessation of hostilities. The ERWs from these conflicts are still shown to impact today's disaster recovery. They pose a lose-lose situation because they will cause land degradation whether they are left in the ground or detonated. The climate crisis, as demonstrated, leaves societies with no option than to address this problem, including those previously considered safely located and marked. **The evidence demonstrates that climate-related hazards are exposing communities including those in contexts that are now considered peaceful, to new hazards, vulnerabilities and new risks.** Thus, given the delayed impacts and the longevity of the impact from contamination, there is a need for a better understanding of how climate change is affecting areas and territories especially those that have previously endured armed warfare.

Similarly, **climate hazards are not confined to national boundaries,** as demonstrated by the ongoing flooding in central Europe caused by storm Boris. Territories bordering those that have endured armed conflicts are at much risk of ERW contamination and the concomitant implications as those that have never had conflict or contamination. There is need for recognition that countries share common ecosystems and vulnerabilities, and face common challenges from climate change. This calls for stronger efforts to promote solidarity, shared understanding, and support. **Greater focus is needed on coordinated, cross-border efforts to tackle ERW contamination.** This includes working towards finding innovative and comprehensive solutions that foreground communities' resilience in the face of these challenges. It also requires resources to avert, minimize and address technical, policy, institutional and resource gaps, national, regional and international levels.

Beyond this, comprehensive solutions on the climate action will require practitioners, academics, and community members to work across siloes in more integrated partnerships. As stated in the COP28 Declaration on Climate Relief, Recovery, and Peace, **there is a need for "bolder climate action" to respond to the needs of communities living on the frontlines of conflict and climate change.** Addressing ERW contamination requires an approach that incorporates responses and considerations that extend beyond conflict, to include mitigation and adaptation toward climate change risks. While there are attempts by practitioners and researchers towards understanding conflict dynamics in the vulnerable context that ERW contamination occurs, there is a gap in policy, practice and academic research that explores how these issues intersect and critically how they interlink with and impact societal challenges and outcomes.

## Recommendations

**1. Invest in the restoration and rehabilitation of land affected by fragility and conflict.** Land degradation outcomes from ERW contamination and climate change are long-lasting, with significant impacts on ecosystem services, well-being, food security, and agricultural livelihoods. Land restoration, climate action, and ERW contamination should not be addressed in isolation. Investment in land restoration and rehabilitation in conflict-affected areas requires an integrated approach that connects measures to mitigate the impacts of ERW, including removal and clearance of ERW, with land outcomes such as improved rural livelihoods, increased food security, and ecosystem health.

**2. Integrate land degradation considerations into mine action activities.** Research covered in this report highlights the potential for ERW detection, removal, and disposal to contribute to land degradation. Except for a few initial studies, there is a lack of knowledge on the long-term environmental impacts of mine action. There is a need for a comprehensive environmental impact assessment of mine action activities and the development of best practices to mediate land degradation outcomes.

**3. Develop and strengthen existing funding to address land degradation for communities affected by fragility and conflict.** Innovative funding mechanisms are needed to address the dual challenges of climate change and ERW, both of which contribute to land degradation. While acknowledging that the various actors (researchers, policymakers, and practitioners) are working in the context of competing needs, there is a need for funding that bridges traditional divides between humanitarian, peacebuilding, development, and climate funding. Such an approach includes delineating climate financing to fund research that addresses peacebuilding and conflict mitigation outcomes in contexts of climate change fragility and vice versa. This should be done, whilst also prioritizing activities and research that foregrounds positive societal outcomes for communities living and impacted by these complex climate-related outcomes.

**4. Build a knowledge community to create evidence-based practices and programs that address land degradation from climate change and ERW.** There is a need for land management solutions that are tailored to the needs of communities in fragile and conflict-affected contexts. Academic research that includes climate and land science as well as social, political, and conflict research should partner with humanitarian and development organizations to develop evidence-based land management and ERW clearance practices responsive to land degradation. It is critical that the expertise and needs of community members whose lives are affected by climate change and ERW contamination are included in the knowledge community.

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