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Opportunities in Mine Action for Mainstreaming of Environmental Protection and Conservation

Submission for the academic degree of Master of Science – Management of Conservation Areas

Carinthia University of Applied Sciences

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Affidavit

MASTER THESIS

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Submission for the academic degree of

Master of Science – Management of Conservation Areas

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STATUTORY DECLARATION

I hereby declare that:

- The Master thesis has been written by myself without any external unauthorised help and that it has not been submitted to any institution to achieve an academic grading.
- I have not used sources or means without citing them in the text; any thoughts from others or literal quotations are clearly marked.
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UK, 01/06/2023

With thanks to my supervisors, Michael Jungmeier and Francis Vorheis, to those who contributed to this research through interviews, and to the men and women around the world dedicating their days to making lands safe from the explosive remnants of war.

Abstract

This paper explores opportunities in the mine action sector for the mainstreaming of environmental protection and conservation. The paper presents an argument for evidence based environmental activities based on a holistic understanding of the environmental impacts of landmines and other explosive ordnance over time. Accordingly, a framework is drawn from the 'warfare ecology' field of study to structure an understanding of impacts as they occur throughout the entire lifecycle of war, incorporating the preparatory phase, wartime phase and post-war phase. Opportunities identified demonstrate the utility of moving beyond a 'do no harm' approach in order to adequately identify environmental impacts both within, and beyond minefield boundaries, and effectively address them by facilitating research and conservation efforts, accessing broader funding opportunities, and aligning mine action activities with the global biodiversity and development agendas.

Glossary of terms

AP: anti-personnel

AV: anti-vehicle

EIA: Environmental Impact Assessment

EO: Explosive Ordnance

EORE: Explosive Ordnance Risk Education

ERW: Explosive Remnants of War

GIS: Geographic Information System

ICBL: the International Campaign to Ban Landmines

IED: Improvised Explosive Device

IMAS: International Mine Action Standards

IUCN: International Union for Conservation of Nature

KAZA: Kavango–Zambezi Transfrontier Conservation Area

NTS: Non-Technical Survey

SDGs: Sustainable Development Goals

UXO: Unexploded Ordnance

VA: Victim Assistance

WWF: World Wide Fund for Nature

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1. Introduction

The impacts on livelihoods caused by mine laying activities and explosive remnants of war (ERW) go beyond the very real risk to life and limb posed by explosive ordnance (EO) contamination. Mine action organisations around the world work within the complex social and environmental fallout that results from conflict, mine laying and ERW contamination. When viewed through the broader lens of the warfare ecology field of study, the applicability of certain conservation and environmental activities to the core work of humanitarian mine clearance organisations can be understood, structured and prioritised. Post-war contamination by landmines, improvised explosive devices (IEDs) and other EO not only takes an enormous human toll, but can also directly exacerbate further ecosystem degradation through years of access denial that precludes restoration of damaged ecosystems, encourages illegal land use activities, and leads to unsustainable post-clearance land use.

Humanitarian mine action sits at an intersect between humanitarian and development agendas. The humanitarian priority of mine action is to prevent loss of life. However, the ultimate aim of mine action activities is the restoration of livelihoods, enabling social and economic development. Within a growing international acknowledgement of the inseparability of human wellbeing and the conservation of healthy eco-systems, a number of opportunities are presented for mine action organisations to engage with environmental and conservation activities. This approach aligns with the UN Decade on Ecosystem Restoration (2021-2030), built on the back of the 2030 Agenda for Sustainable Development, which specifically recognises the importance of cross-sectoral dialogues and collaboration on ecosystem restoration as a pathway to global sustainability goals[1].

'Mine action organisations' are referred to throughout this paper, and are understood as those organisations operating under the International Mine Action Standards (IMAS) to

[1] UNEP, 'Decade on Restoration'. Page 6.

conduct activities aiming to reduce the impacts of landmines and other types of explosive ordnance (including cluster munitions, IEDs and unexploded ordnance). The focus of this paper is on humanitarian mine action organisations, as opposed to military or commercially driven endeavours, although many of the themes discussed are applicable beyond the humanitarian sector.

The concept of 'conservation' is used throughout this paper in order to encompass broad themes of both environmental restoration and protection. Conservation is therefore understood here under the broad definition of: "actions that are intended to establish, improve or maintain good relations with nature"[2]. This definition facilitates an approach to conservation that is not constrained by sectoral boundaries, and recognises the applicability of conservation measures beyond legally protected or formally managed areas.

Taking the definition of mine action as "activities which aim to reduce the social, economic and environmental impact of mines, and ERW…"[3], it is proposed that facilitating the restoration of ecological damages caused at all stages of explosive ordnance contamination – pre, during and post conflict – falls well within the core remit of mine action organisations.

2. Summary

This paper offers a theoretical framework that situates landmine and other explosive ordnance contamination within a broader understanding of the taxonomy of war. It is structured in such a way to be accessible to those coming from conservation backgrounds with little exposure to mine action as a sector, and vice versa.

Chapter 4 provides a breakdown of the methodologies used to gather data and testimonies. In chapter 5 mine action activities are situated within the broader development agenda, and two fields of study are introduced from which the theoretical framework is developed: 'do

[2] Sandbrook, 'What is conservation?'. Page 565
[3] International Mine Action Standards, '04.10'.

no harm', and 'warfare ecology'. This framework is subsequently used to shape and present the research questions addressed throughout the paper.

Chapter 6 lays out a broad overview of the extent of global landmine contamination. The corresponding scale of potential environmental impacts is demonstrated, indicating that a comprehensive understanding must encompass regional and transboundary consequences. Chapter 7 details legal and moral imperatives for the identification and removal of landmines globally, and identifies how this furthers specific environment-focused UN Sustainable Development Goals. In chapter 8, an overview of environmental impacts across the lifecycle of war is presented, laying the groundwork for a detailed review of the environmental impacts of landmines, both direct and indirect, in chapter 9. Chapter 10 gives a summary of some common clearance methods in order to demonstrate how different approaches have different environmental consequences.

Chapters 11 and 12 place conservation and environmental activities within the '5 pillars' of mine action, and demonstrate how these activities may be better structured under the theoretical framework presented. Chapter 13 contains three individual case studies that demonstrate the diversity of contexts in which mine action occurs, and present a range of context-dependant practical opportunities for the mainstreaming of conservation activities. Chapters 14 and 15 develop methods for the integration of the theoretical framework presented into environmental assessments, standards and guidelines, as a means of adapting existing models to the context of mine action. In chapter 16, the role of local ownership and partnerships is highlighted, and put forward as a key component for sustainability of projects and long-term funding opportunities. Chapter 17 revisits the research questions posed, summarising the findings of this paper before the conclusion is given.

3. Methodology

The research content of this paper was gathered through desk-based research, expert interviews, and through the author's observations as a professional in the humanitarian mine action sector in 14 landmine-affected countries. Due to the sensitive nature of much of this information, where academic research was unavailable 'grey' literature, media sources and organisational reports were utilised to ensure that data presented was already in the public domain, and expert interviews have been anonymised. Opinions of the author and of expert interviewees are their own, and do not represent the viewpoint of any other organisation. Photographs are utilised throughout the paper to add context for those unfamiliar with the realities of minefield environments.

Of the case studies detailed below, two (Sri Lanka and Ukraine) were visited in person and the other (Somaliland) shared with permission of project staff. A total of nine expert interviews were conducted (in person or via video call, with one interview conducted via email exchange), under the condition of anonymity. Experts were chosen to represent a range of backgrounds and experiences. 6 respondents had experience working on projects in Ukraine post-February 2022, which allowed for a direct comparison of viewpoints in response to the same conflict:

- Interviewees 01, 02 and 03: Mine Action professionals working for international humanitarian mine clearance NGOs. Combined experience of over 25 years, spanning upward of 20 country contexts. Interviews included questions on the individuals' experiences in Ukraine post- February 2022, and on individual areas of expertise (including remote sensing technologies, clearance operations management and non-technical survey).
- Interviewees 04, and 05: Conservation professionals. One working for an international conservation organisation, currently focusing on Ukraine, one leading an environmental NGO in Ukraine.
- Interviewee 06: remote sensing specialist working on mine action projects in several countries globally.
- Interviewees 07 -09: Mine action professionals with backgrounds in different humanitarian response sectors (refugee support and environmental development

projects). Combined experience of 10 years in mine action, with combined experience working in 15 country contexts.

The expert interviews ran from 30 minutes to 120 minutes each, and focused on the individuals' specific areas of expertise. However, the following questions were broadly covered in each interview:

1. Do environmental considerations have a place/ are they appropriate alongside key humanitarian operations during a time of conflict/ immediately post-conflict?
2. Have you seen any concrete examples of humanitarian actors successfully engaging with conservation actors during a time of conflict, or immediately post-conflict? Please elaborate on these.
3. What is your understanding of how major state funding bodies perceive the role of the environment when it comes to giving out funding for humanitarian contracts at a time of conflict?
4. Do you have any ideas/ experience of collaboration between landmine/ explosive ordnance clearance organisations and environmental actors in the contexts you have worked in?

The theoretical basis outlined in the following chapter will look at how existing fields of study can form the basis for a holistic understanding of the wide-ranging environmental impacts of landmine contamination across both geographical space, and time.

4. Theoretical basis[4]

This chapter will situate mine-laying activities and subsequent mine action within the broader context of conflict and its long-term effects on ecosystem services[5]. It is

[4] A summary of the argument presented here has been submitted for publication (under review at time of writing): Chrystie, 'Environmental Mainstreaming in Mine Action: a case study of moving beyond 'do no harm''.

[5] Ecosystem services are understood here as the natural capital essential for human life and wellbeing provided by functioning ecosystems, such as water, clean air or pollination

demonstrated that in addressing the impacts of landmines on communities in post-conflict settings, a holistic understanding of the effect of mines across the entire lifecycle of the conflict (pre, during and post) is required. The research questions addressed in this paper will be drawn from the theoretical basis presented here, and are detailed at the end of this chapter.

In this chapter, two fields of study are introduced. These are the approaches of 'do no harm', and that of 'warfare ecology'. Together, they are presented as a theoretical basis for greater understanding of opportunities to engage with environmental protection and reconstruction within mine action.

Do No Harm

The established principle of 'do no harm'[6] forms the basis of an analytical framework commonly applied in the broader humanitarian sector. Originally derived from medical ethics[7], it entered the humanitarian field in the 1990s in recognition of the potential for well-meaning provision of aid to do harm, as well as good. Sequestration of aid supplies by warring parties was recognised to potentially undermine local business recovery, prolong and in some cases even enable conflicts[8], and new strategies for aid delivery in regions suffering from conflict began to be developed[9].

These changes complemented an overall shift in strategic direction within the aid sector, with the focus of aid delivery programs moving away from an 'emergency response' model, and toward a model of building long-term resilience in affected communities[10]. A focus on building resilience in affected communities saw a further shift towards a more holistic understanding of the causes and drivers of conflict and poverty, and the concept that 'fragile'

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[6] Anderson, *Do no harm*.
[7] International Federation of the Red Cross, 'Applying BPI: Do No Harm'.
[8] Nunn and Qian, 'US Food Aid and Civil Conflict'.
[9] Goodhand, 'Aiding violence or building peace? The role of international aid in Afghanistan'.
[10] Katie Harris, David Keen and Tom Mitchell, 'When disasters and conflicts collide: Improving links between disaster resilience and conflict prevention'.

human societies are at greater risk from both a human security and an environmental perspective.

Inextricably linked with climate vulnerability and the recognition of climate change as one potential driver of conflict, this approach posits security, climate change and resilience to climate induced disasters as key components of peacebuilding[11]. The recognition that the objectives of humanitarian interventions are inextricable from those of the sustainability agenda, and the established link between biodiversity conservation and the alleviation of poverty[12], have led to suggestions that sustainability is best understood within the framework of a 'conflict environment nexus'[13], or even within a 'conflict-environment-development' nexus[14].

A 'do no harm' approach has been put forward as directly applicable to environmental concerns within mine action[15], and the principle broadly reflects current best practice of mine action organisations to mitigating and minimising direct (negative) environmental impacts of mine clearance operations. This is reflected in the current International Mine Action Standard (IMAS) on Environmental Management[16], with its focus on avoiding environmental harm through the direct impacts of mine action activities, including through emissions, erosion, residual waste and direct harm to wildlife and vegetation. However, the broader context from which the 'do no harm' principle emerged, with a focus not only on impact at the point of delivery of a given service, but also on the long term changes and overall resilience of affected communities, is often overlooked when it comes to the environmental responsibilities of the mine action sector.

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[11] Dutta Gupta et al., *The Climate Security Inequality Nexus: A critical analysis of pathways and synergies*.
[12] Adams et al., 'Biodiversity conservation and the eradication of poverty'.
[13] Galgano, *The environment-conflict nexus*.
[14] Fisher and Rucki, 'Re-conceptualizing the Science of Sustainability: A Dynamical Systems Approach to Understanding the Nexus of Conflict, Development and the Environment'.
[15] Hofmann, Ursign and Rapillard, Pascal, 'Do no harm in mine action: Why the environment matters'.
[16] International Mine Action Standards, 'Environmental Management in Mine Action'.

The development agenda

The integration of emergency response activities into the broader development agenda has subsequently had observable effects in the field of mine action. Landmines have long been understood as posing a significant impediment to development, with mine action forming a vital step in post-conflict rehabilitation and reconstruction[17]. The contribution of mine action to economic development is demonstrable, with the presence of landmines often denying the implementation of planned projects[18], and affected states often situate mine action as a development priority, as well as humanitarian[19]. The integration of mine action into the development agenda has led to the suggestion that mine action is understood better not as a 'precursor' to development, but rather as an enabler and catalyst[20]. The linkages between the sustainable development goals and mine action have been recognised by the United Nations[21], further underlining the current understanding of mine action as inextricable from the broader development agenda.

Warfare ecology

To conceptualise the gaps in current practice within mine action in the context of conservation, it is useful to apply a theoretical framework that encompasses and expands upon the contextual elements of the 'do no harm' principle as it applies to environmental issues in the aftermath of conflict.

Introduced in 2008[22] [23], the 'warfare ecology' field of study was put forward to bridge the gaps in environmental research concerning ecological changes instigated by human conflict.

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[17] Hoffman, 'An Integrated Global Demining and Development Strategy'.
[18] Downs, 'Linking Mine Action and Economic Development'.
[19] Turcotte, 'Mine Action and Development' Page 42.
[20] Rasmussen, 'Whither HMA Policy: Linking HMA and Development Assistance' Page 8.
[21] Geneva International Centre for Humanitarian Demining and United Nations Development Programme, *Leaving No-One Behind*.
[22] Machlis and Hanson, 'Warfare Ecology'.
[23] Machlis, *Warfare ecology*.

This field of study takes into account both natural and social (human) consequences of conflict and their reverberations over time.

By adopting this approach, a more holistic understanding of the effects (both advantageous and detrimental) of conflict on ecosystems and their services is enabled[24], by structuring potential impacts into a broader taxonomy within which the biophysical and socioeconomic dimensions of war are considered interconnected. This taxonomy identifies three distinct stages of conflict: preparations; war; and post-war activities.

Within each phase, corresponding impacts are observable at different scales: landscape; regional; and global. Mine action activities, typically observed during the 'post-war' phase and at the 'landscape' level, can be understood as inextricably linked with the ecological consequences of the entire lifecycle of war. Whilst a 'do no harm' approach addresses specific impacts of landmine clearance at a landscape, post-war level, this approach allows for expansion of activities based on reverberations from 'preparations' and 'war' phases of conflict, expanding to regional and even global scales.

The expanding field of warfare ecology has found application in environmental analyses of multiple conflicts around the world[25] [26] [27] [28] [29]. This reflects a growing trend to consider social and natural consequences of conflict as inherently intertwined with the broader lifecycle of war. This approach has been used to advocate for the incorporation of biodiversity considerations into post-conflict recovery efforts[30].

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[24] Ecosystem services are the natural capital essential for human life and wellbeing provided by functioning ecosystems, such as water, clean air or pollination
[25] Baumann and Kuemmerle, 'The impacts of warfare and armed conflict on land systems'.
[26] Hanson et al., 'Warfare in biodiversity hotspots'.
[27] Lawrence et al., 'The effects of modern war and military activities on biodiversity and the environment'.
[28] Murillo-Sandoval et al., 'The end of gunpoint conservation: forest disturbance after the Colombian peace agreement'.
[29] van Butsic et al., 'Conservation and conflict in the Democratic Republic of Congo: The impacts of warfare, mining, and protected areas on deforestation'.
[30] Hanson, 'Biodiversity conservation and armed conflict: a warfare ecology perspective'.

As has been discussed elsewhere[31], the ecological consequences of human absence due to contamination of land with explosive hazards do not always translate to negative impacts on local biodiversity. The 'war zones and game sinks' dynamic[32], whereby wildlife havens exist in demilitarised zones, 'no man's land'[33] or buffer zones between warring parties is often quoted as an unintended benefit to the non-human world of human conflict (although the general consensus acknowledges that these benefits are outweighed by the cumulative negative environmental impacts of conflict).

The Korean peninsula demilitarized zone, 4km wide and 250km long, heavily mined and restricted to human entry, has acted not only as a haven for wildlife but has been put forward as a proposed site for a border zone peace park[34] [35]. Whilst similar examples exist in fortified and contaminated zones around the world, it has been noted that the nature of modern warfare has made such examples increasingly rare in modern conflicts, and that demilitarised zones such as the DMZ should be viewed independently as qualitatively distinct from modern battlefields and armed political conflict[36]. Additionally, depending on the type of contamination, such areas are unlikely to be safe refuges for large animals capable of initiating the threat type present[37].

It is also worth highlighting here that whilst demilitarised zones such as these serve as reminders that areas denied to humans through the presence of mines and other EO can see ecosystem benefits, this is not grounds on which to argue for maintaining EO contamination as a crude form of 'fortress conservationism'. Notwithstanding the legal and moral imperatives of clearance, and the understudied negative environmental impacts of EO

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[31] McLean, 'Environmental Applications in Demining'.
[32] Martin and Szuter, 'War Zones and Game Sinks in Lewis and Clark's West'.
[33] Rotberg, *Pakistan and India's Siachen Glacier: No Man's Land for Conservation and Peace*.
[34] Kim, 'Korean DMZ Peace Park And The Landmine Problem'.
[35] Hall Healy, 'Korean Demilitarized Zone Peace and Nature Park'.
[36] Dudley et al., 'Effects of War and Civil Strife on Wildlife and Wildlife Habitats'.
[37] Although it should be noted that anti-vehicle mines, anti personnel, IEDs and tripwire activated devices have a range of operating pressures, and a blanket assumption that the threat to local fauna is equivalent to the threat to human populations should be avoided.

contamination (all explored in depth below), the focus of environmentalism in a post-conflict setting has long since moved on from a de facto fortress conservationism[38] that can in some contexts be provided by conflict related large-scale area denial[39]. Rather, the focus has moved to ensuring sustainable reintegration of human communities into a functioning ecosystem.[40]

Impracticalities aside of viewing forced human absence due to mine contamination as a useful tool for conservation, there exist overwhelming legal and moral imperatives for the complete global removal of landmines, summarised in chapter 7.

Justification and research question

In recent years, there has been a significant increase of interest in the mainstreaming of environmental issues in mine action. This can be observed in the formation of cross-sector working groups, the investigatory work of organisations such as the Conflict and Environment Observatory (CEOBS)[41] and heightened interest from donors to channel funding into environmental projects. Arguably, these developments are a predictable outcome of overwhelming scientific consensus on the increasingly mounting damage to global ecosystems caused by anthropogenic activity. Frequently viewed as a largely technical, practitioner based field[42], the mine action sector has made some progress in terms of developing conceptual and theoretical frameworks around the socioeconomic impacts of the sector. However, there remains a lack of understanding regarding environmental impacts, and by extension potential environmental opportunities.

This paper suggests that, whilst the widely discussed (although inconsistently applied) 'do no harm' approach remains appropriately suited for mitigating the direct environmental

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[38] Rai et al., 'Beyond fortress conservation: The long-term integration of natural and social science research for an inclusive conservation practice in India'.
[39] Dudley et al., 'Effects of War and Civil Strife on Wildlife and Wildlife Habitats'.
[40] Morin, 'Demining and the environment: A primer'.
[41] CEOBS, 'About - CEOBS'.
[42] Ikpe and Njeri, 'Landmine Clearance and Peacebuilding: Evidence from Somaliland'.

impacts of mine action activities and ought to be continuously applied, it is essential to recognise it as merely one aspect within a more holistic framework. This broader perspective is crucial if the sector is to take full advantage of the opportunity to engage with thorough research, mainstreaming of environmental concerns, and collaboration with conservation initiatives.

Mine action organisations, with their direct exposure to the immediate and legacy aftermath of conflict, and operational infrastructure in some of the most remote and ecologically vulnerable regions of the world, are in a position to contribute positively to developing research and practical knowledge of the realities of the relationship between conflict-caused environmental damage, and post-conflict ecosystem service restoration. Opportunities to address these impacts through environmental and conservation activities alongside local partners are widespread. This paper aims to further the mainstreaming of such activities in the mine action sector by posing the following research questions:

1. What can the ‘war ecology’ field of study add to a holistic analysis of the environmental impacts of landmines?
2. To what extent does current practice in the field of mine action contribute to or mitigate the environmental impact of mine contamination?
3. What are the main research gaps in the relationship between mine action and the environment?
4. What further opportunities are there to mainstream environmental conservation in mine action?

5. Scale of mine action and global landmine contamination

For the purposes of this paper, mine action is defined as per the International Mine Action Standard (IMAS) 04.10 as:

> “activities which aim to reduce the social, economic and environmental impact of mines, and ERW including unexploded sub-munitions… Mine action is not just about demining; it is also about people and societies, and how they are affected

by landmines and ERW contamination. The objective of mine action is to reduce the risk from landmines and ERW to a level where people can live safely; in which economic, social and health development can occur free from the constraints imposed by landmine and ERW contamination, and in which the victims' different needs can be addressed"[43].

Mine action activities

Landmine clearance activities are conducted by a range of actors, from civilians and military personnel to non-governmental or commercial organisations. For the purposes of this paper, the IMAS definition of 'mine action' given above is used. The key difference between military clearance and 'mine action' as it is understood here, is that military clearance tends to have a strategic purpose (for example, tactical movement of troops or opening of access), whereas mine action activities, regardless of the actor implementing them, are ultimately humanitarian endeavours with the wellbeing of civilians in mind.

Mine action activities are commonly broken down into five 'pillars'. These are[44]:

- Explosive Ordnance Risk Education (EORE): education activities that aim to reduce injury and death by raising awareness and instigating behavioural change.
- Clearance: this pillar includes survey of minefields through Non-Technical Survey (NTS), marking of hazardous areas and clearance activities (demining)
- Victim Assistance (VA): assistance to victims of mine accidents. This could include medical care and assistance in accessing available services, such as prosthetics and psychosocial support.
- Advocacy: advocating for states participation in the anti-personnel landmine ban treaty and Convention on Certain Conventional weapons.

[43] International Mine Action Standards, '04.10'. Page 29.
[44] Logan, 'IMAS_01.10_Ed.2_Am.10_02'.

- Stockpile destruction: supporting states in achieving destruction of AP mine stockpiles as per treaty obligations.

Engaging with all five pillars places mine action organisations in a favourable position for expanding outward from core activities in affected countries. Organisations require good liaison at all levels of local and national government; teams consisting predominantly of personnel hired from the local community who can work remotely conducting risk education sessions and surveying hazardous areas; Geographic Information Systems (GIS) and mapping capabilities (often including remote sensing capabilities); and the accompanying infrastructure of vehicles and accommodation to support teams on operational tasks that can be remote and difficult to access.

Scale of landmine contamination

This section will give a brief overview of global landmine contamination, and broadly situate it within the relevant environmental contexts. The data presented below focuses only on the geographical scale of contamination. The actual number of landmines that are currently laid are unknown, and any estimates are likely too unreliable to be considered useful.

Using available data[45], a breakdown by country is given below. It must be noted that these figures are estimates only, are and subject to significant change as new areas are discovered, land is cleared, or conflicts progress. These figures represent a very rough estimate of the current known extent of landmine contamination, and presenting them here is with the objective only of demonstrating the range of environments and terrestrial biomes in which contamination can be found. The figures given are caveated with the fact that as mine action activities progress, some previously mapped areas will be found not to contain a threat, and other previously unknown areas will be discovered.

[45] ICBL-CMC, 'Landmine Monitor 2022' The table is compiled from figures given in the narrative of the 2022 landmine monitor report, with an understanding that the figures are estimates only. Where the original data were separated by AP, AV and IED contamination, these figures have been combined to give an overall total.

Country	Estimated contamination (km²)
Abkhazia	0.05
Afghanistan	188.26
Angola	71.49
Bosnia and Herzegovina	922.37
Cambodia	715.9
Chad	78.33
Colombia	2.96
Croatia	204.4
Cyprus	1.24
Democratic Republic of Congo (DRC)	0.4
Ecuador	0.04
Eritrea (last reported in 2014)	33.5
Ethiopia	726.07
Georgia	2.29
Guinea-Bissau	1.09
Iraq	1736
Israel	90
Kosovo	1.8
Lebanon	17.87
Mauritania	14.93
Nagorno-Karabakh	6.75
Niger	0.18
Oman	0.68
Palestine	0.18
Peru	0.36
Senegal	0.49
Serbia	0.56
Somalia	161.8
Somaliland	5.43
South Sudan	7.4
Sri Lanka	11.89
Sudan	13.28
Tajikistan	11.82
Thailand	40
Turkey	140.59

Ukraine[46]	7,000
Western Sahara (East of the Berm)	212
Yemen (as of March 2017)	323
Zimbabwe	23.51
Total	12768.63

In the states above that have publicly declared, estimated declared contamination sits at 12,768.63km² - more than the combined size of Yellowstone and Yosemite National Parks. The actual extent of contamination is likely to be significantly higher, given the caveats above and additional contamination in the following states (for which no estimates are available): Algeria; Armenia; Cameroon; Central African Republic (CAR); China; Egypt; India; Kuwait; Kyrgyzstan; Libya; Mali; Morocco; Myanmar; Nicaragua; Nigeria; North Korea; Pakistan; Philippines; Russia; South Korea; Syria; Tunisia; Uzbekistan; Venezuela.

Contaminated areas therefore represent a significant quantity of land in over 60 states, often coinciding with communities who have already suffered from the effects of conflict, and many of whom are disproportionately vulnerable to climate change and to further degradation of the ecosystems they rely on.

The context-specific locations of landmines vary greatly between nation states, with the conflict history dictating where and how mines are laid. In many contexts, landmines are found widely (and often indiscriminately) laid across wide geographic areas as frontlines and parties to the conflict move (for example Cambodia, Ukraine), or in key strategic areas such as roads, mountaintops or watercourses. In other contexts, landmines will be predominantly

[46] These figures are as of 2018, and not inclusive of an additional 14,000km² estimated at the time to exist in areas under Russian military occupation. Extent of contamination has significantly increased since Russia's invasion in February 2022, but accurate estimates do not exist due to ongoing conflict at the time of writing. The Ukrainian example is revisited in more detail in chapter 13.

laid in specific areas such as along state borders (e.g. Zimbabwe, although in the case of Zimbabwe this still represents over 700 linear kilometres of contamination[47]).

Mountaintop minefield in Colombia. Photo courtesy of E. Chrystie

[47] Rupiah, 'A historical study of land-mines in Zimbabwe, 1963-1995'.

An uncleared minefield on the Zimbabwean border with Mozambique: minefields occur in most of the major terrestrial biomes on the planet. Photo courtesy of E. Chrystie

Given the broad range of contexts in which mine contamination exists, it is beyond the scope of this paper to cover in detail the environmental contexts of all known mine contamination. The following breakdown aims only to demonstrate the broad range of habitats in which landmine contamination exists. For this purpose, Olson *et* a*l's* 'Terrestrial Ecoregions of the World'[48] are utilised. Olson *et al* identify 14 key terrestrial biomes of the world, further broken down into 867 eco-regions. The examples below concentrate on biomes only, given the lack of detailed environmental data available on locations or environmental context of many countries' landmine contamination.

Broadly, it can be said that contamination is suspected to exist globally in 13 of the Olson *et al's* 14 'terrestrial biomes'. Examples of each are given below:

Biome	Example state(s) (not definitive)
1. Tropical and subtropical moist broadleaf forests	Sri Lanka; Thailand

[48] Olson et al., 'Terrestrial Ecoregions of the World: A New Map of Life on Earth'.

2. Tropical and subtropical dry broadleaf forests	Algeria; Eritrea; Ethiopia; Zimbabwe
3. Tropical and subtropical coniferous forests	Pakistan; Myanmar
4. Temperate broadleaf and mixed forests	Bosnia and Herzegovina; Croatia
5. Temperate coniferous forests	India
6. Boreal forests / Taiga	N/A
7. Tropical and subtropical grasslands, savannas, and shrublands	Cameroon; Colombia
8. Temperate grasslands, savannas, and shrublands	Ukraine
9. Flooded grasslands and savannas	Angola
10. Montane grasslands and shrublands	Tajikistan; Kyrgyzstan
11. Tundra	Russia
12. Mediterranean forests, woodlands and scrubs	Israel; Lebanon; Turkey
13. Deserts and xeric shrublands	Afghanistan; Iraq; Somalia
14. Mangroves	Sri Lanka; Cambodia

Scale of environmental impacts of contamination: the hidden picture

The previous section began to contextualise landmine contamination in terms of global scale and range. It is demonstrated below, however, that a broader understanding is required when conceptualising the scale of environmental impacts of landmine contamination, which can go far beyond minefield boundaries.

The main limitation of referencing the scale of 'impact' (as opposed to 'contamination') in terms of square kilometres when detailing the environmental impacts of landmines, is that this fails to take into account the interconnectedness of natural systems. The example below from Angola demonstrates why this is the case.

As noted above, Angola has declared a figure of 71.49 km^2 of landmine contaminated ground. This figure is likely to change somewhat as existing areas are refined, and new areas discovered[49].

A significant number of minefields in the South East of Angola fall within, or just outside, of the Kavango–Zambezi Transfrontier Conservation Area (KAZA). The KAZA is the largest transboundary conservation area in the world, spanning nearly 520,000km^2 across five countries in Southern Africa: Angola, Botswana, Namibia, Zambia, and Zimbabwe[50]. In Angola, the KAZA area includes the headwaters of the Okavango River Basin, feeding into the Okavango Delta, a UNESCO World Heritage Site. Landmine contamination in the headwaters of the Okavango watershed in Angola, including in the National Parks of Mavinga and Luengue- Luiana in Angola, fall within this transboundary protected area.

The following map details some of the known minefields in the central and southern parts of Angola, and their proximity to National Parks and the KAZA region:

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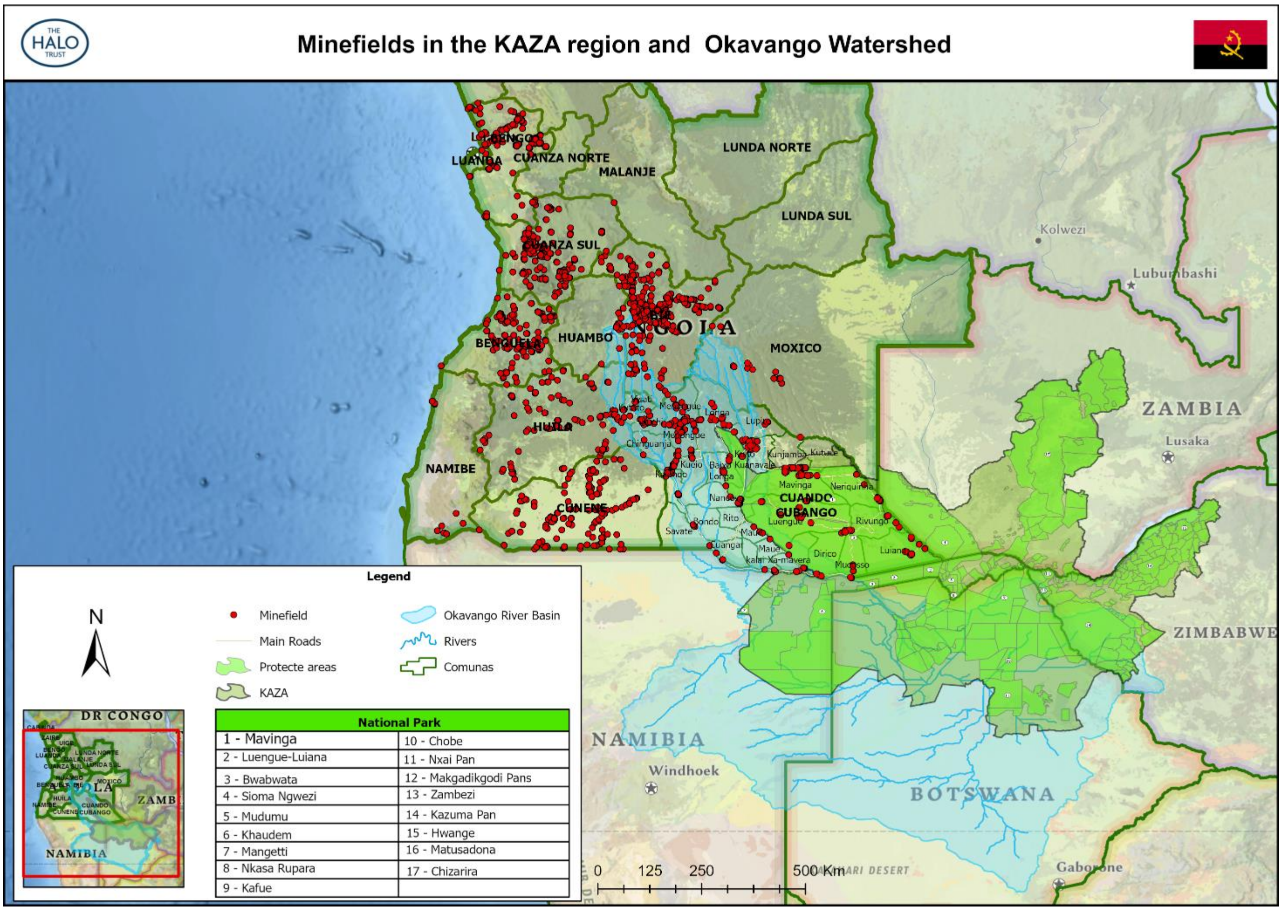
[49] Interviewee 3

[50] Stoldt et al., 'Transfrontier Conservation Areas and Human-Wildlife Conflict: The Case of the Namibian Component of the Kavango-Zambezi (KAZA) TFCA'.



Map courtesy of the HALO Trust

The hydrological regime and water quality of the Okavango Delta are heavily influenced by occurrences up-stream, including in Angola[51]. A vital ecosystem for much of Southern Africa, this river system supports large-scale irrigation in neighbouring countries, the eco-system of the Okavango Delta, and subsequently the tourism revenue of national parks within the

[51] Kgathi et al., 'The Okavango; a river supporting its people, environment and economic development'.

KAZA conservation area[52]. With water demands on the Okavango increasing[53], this important eco-system supports communities, flora and fauna across five Southern African states.

An understanding of the impact of landmines in the upper parts of the Okavango River basin can therefore not be restricted to the contaminated land in which they were laid. Agricultural activities in the Okavango basin have been severely impacted by the presence of landmines[54], and by extension conservation initiatives[55]. An early external review of the KAZA conservation project notes that "[T]he presence of landmines in the Luiana Partial Reserve of southern Angola is seen as a major obstruction and limitation towards achieving integrated flow of wildlife and people in the TFCA [Trans-Frontier Conservation Area]."[56] The regional consequences of landmine contamination in the Angolan national parks affects the health of the entire Okavango river basin, and has a knock on effect on the Delta itself which spans 36 National Parks and is integral to the ecosystem of vast areas of Southern Africa.

The environmental impacts beyond minefield boundaries can also be observed in the effect on large migratory species. Angola's elephant population suffered greatly during the Angolan civil war, with ivory used by parties to the conflict to pay for arms and food[57]. Existing minefields prevent elephants from moving along migratory routes between Namibia, Botswana and Angola[58], thereby limiting recolonization in the region - an additional regional knock-on effect of landmine contamination that may appear by physical scale alone to affect only a relatively small area.

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52 Ibid.
53 Mbaiwa, 'Causes and possible solutions to water resource conflicts in the Okavango River Basin: The case of Angola, Namibia and Botswana'.
54 Mitchell, 'The status of wetlands, threats and the predicted effect of global climate change: the situation in Sub-Saharan Africa'.
55 Singh, 'Attempting palaeoenvironmental reconstructions in war-torn zones: the case of the Okavango source wetlands in Angola'.
56 Schuerholz, 'KAZA TFCA Project External Review'.
57 Chase and Griffin, 'Elephants of south-east Angola in war and peace: their decline, re-colonization and recent status'.
58 Unruh, 'The interaction between landmine clearance and land rights in Angola: A volatile outcome of non-integrated peacebuilding'.

This example demonstrates that in order to move beyond a limited understanding of mine action's environmental responsibility to 'do no harm', and take into account broader environmental impacts of landmines, we must look beyond the boundaries of minefields and the connectivity of natural systems at a regional, and even global scale.

A fragment of elephant bone found by mine clearance personnel on a minefield in Mavinga National Park, Angola. Photo courtesy of Dan Richards. Up to 15 elephants skeletons were observed by local communities on this minefield[59].

[59] Interviewee 3

6. The mine action imperative

This section presents a brief overview of the legal and moral imperatives for global landmine removal. As detailed above, the de facto 'fortress conservation' that can be found in some (increasingly rare) contexts due to reduced human activity in landmine contaminated areas should be recognised, and is of interest when ensuring that mine action operations 'do no harm' to existing ecosystems. However, this section presents the premise that the legal and moral imperatives for global landmine clearance are predominant, and that implementation of conservation measures will always require as their foundation the removal of landmines.

The legal imperative for mine action

The Ottawa treaty

The Ottawa Treaty[60], also known as "The Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on their Destruction" or the 'Mine Ban Treaty', is a legally binding international agreement banning the use, stockpiling, production and transfer of anti-personnel landmines. States Parties are required to clear mined areas on their territories, destroy any stockpiles of anti-personnel landmines, and provide assistance to victims of landmines on their territories. There are currently 164 States Parties to the treaty, with notable exceptions being China, India, Israel, Pakistan, Russia and the United States. Article V of the Treaty states: "Each State Party undertakes to destroy or ensure the destruction of all anti-personnel mines in mined areas under its jurisdiction or control, as soon as possible but not later than ten years after the entry into force of this Convention for that State Party."[61]

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[60] *Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on their Destruction*.
[61] Ibid. Article V.

Convention on certain Conventional Weapons

The Convention on Certain Conventional Weapons (CCW) is an international treaty that regulates the use of certain conventional weapons (including landmines). States Parties to the treaty are required to clear mined areas as soon as possible after the cessation of conflict. As of 2023, 126 states are party to the treaty, including Russia, China and the US.

Of note within the CCW is amended Protocol II (1996), which regulates (but does not prohibit) the use of mines and booby traps. States Parties are held to the legal obligation that: "Without delay after the cessation of active hostilities, all minefields, mined areas, mines, booby-traps and other devices shall be cleared, removed, destroyed or maintained in accordance with Article 3 and paragraph 2 of Article 5 of this Protocol" (article 10, amended protocol II[62].

Customary international law

Customary international law in the context of clearance of explosive remnants of war has developed from a combination of state practice, and the provisions of international treaties and other legal instruments. Given the broad international consensus on the imperative to regulate and remove victim-activated[63] devices such as landmines, it has been suggested that the duty to clear landmines after the cessation of hostilities, and the duty to take all feasible precautions to protect civilians during conflict, are obligated under customary international law even in the case that a state has not ratified specific treaties[64].

The moral imperative for mine action

The International Campaign to Ban Landmines (ICBL) campaigns on some key moral premises, including that landmines disproportionately affect civilian populations, hamper aid and relief efforts, threaten, injure and kill civilians indiscriminately, and continue to do so

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[62] *Ammended Protocol II*.
[63] Devices designed to be activated by presence, proximity, or contact of a person
[64] Kocse, 'Final detonation: How customary international law can trigger the end of landmines'.

indefinitely (until their removal)[65]. Advocacy for adoption of the Mine Ban Treaty in 1997 was largely conducted through moral arguments, due to the indiscriminate nature of victim-activated devices that do not distinguish between civilian and combatant, and cause prolonged fear and suffering long after hostilities have ended.

UN sustainable development goals

A further addition to the moral argument for complete clearance of landmine-affected areas comes from the Sustainable Development Goals (SDGs). Although grounded in international law, the SDGs are not legally binding in themselves. Nonetheless, they represent a pledge by all UN member states to enact "a universal call to action to end poverty, protect the planet and improve the lives and prospects of everyone, everywhere"[66]. Adopted in 2015, the SDGs include a target (16.1) that seeks to "significantly reduce all forms of violence and related death rates everywhere." A 2017 joint GICHD-UNDP report found Mine Action to have direct relevance to 12 of the SDGs[67].

SDGs with an environmental focus that are furthered by mine action activities are summarised below, and explored in detail in the following chapters:

SDG 6, Clean Water and Sanitation: Mine clearance can open up access to water sources that were previously unsafe to access. The presence of landmines in or near to water sources can cause contamination through the leaching of contaminants (see chapter 9). By removing these threats, mine action can contribute to improved water quality and sanitation.

SDG 12, Responsible Consumption and Production: safe access to resources is an essential first step in facilitating responsible management of them. The links between illegal resource extraction and landmine contamination are explored further in chapter 9.

[65] ICBL, 'International Campaign to Ban Landmines - Arguments for the Ban | Problem | ICBL'.
[66] 'THE 17 GOALS | Sustainable Development'.
[67] Hofman, U. and Juergensen, O., 'Leaving no one Behind: Mine Action and the Sustainable Development Goals'.

SDG 13, Climate Action: Mine clearance can facilitate reforestation and rehabilitation of degraded lands, which can act as carbon sinks and contribute to climate change mitigation. In addition, mine action can contribute to the resilience of communities to climate shocks through sustainable land release practices (see chapter 9).

SDG 14: Life Below Water: While this paper predominantly deals with landmines within terrestrial environments, unexploded ordnance from naval warfare, ammunition dumping and sea mines pose threats to marine ecosystems. In addition, contamination in coastal ecosystems can have negative impacts both on and offshore (see chapter 9).

SDG 15: Life on Land: Landmines and other explosive ordnance can cause significant harm to terrestrial ecosystems, killing wildlife and rendering habitats unusable. By removing these threats, mine action allows for the restoration of habitats and measures to improve and protect biodiversity (see chapter 9).

7. Environmental impacts of the lifecycle of war

As this paper seeks to apply the theoretical framework detailed above to identify pathways by which mine action organisations can move beyond a 'do no harm' approach and better integrate environmental and conservation activities alongside core operations, this section will situate the environmental impacts of landmines within a broader understanding of the environmental consequences of war.

War, understood here as defined by Machlis and Hanson in their 'warfare ecology' as incorporating pre-conflict preparations, conflict itself, and post-conflict activities, can have devastating effects not only on human societies, but on the natural world. In an analysis of 146 major conflicts between 1950 and 2020, it was found that over 90% occurred within countries that contained biodiversity hotspots, and more than 80% of conflicts took place directly within those hotspot areas[68].

Using the warfare ecology approach, it serves to analyse ecological impacts across the entire lifecycle of war. In preparation for conflict, resource extraction may be exacerbated in order to upscale industrial weapons production. For example, open forests in the Czech Republic saw increased deforestation in 1938, in preparation for the Second World War[69]. Training exercises deposit substances and metals such as arsenic, tungsten, lead and antimony into the environment[70], and training exercises can also replicate damages caused by active conflict, through live-fire exercises and movement of tanks and artillery.

The global size of military training areas (MTAs) has been estimated to be between 50-250 million hectares[71], and are generally unlikely to be managed according to conservation-based priorities. However, although access restrictions in such sites can limit the extent to which environmental monitoring or restoration efforts can be implemented[72], as with access denial for other reasons it has been noted that military training bases that are largely restricted to human access are likely to contain increased levels of biodiversity to that in the surrounding area[73].

Periods of conflict, recognised as direct and violent hostilities between humans, are where the destructive impact of war on the environment is at its most visible and severe. The social shock of conflict itself can lead to dramatic and rapid changes in land use that can remain in place well after the cessation of active hostilities[74]. Active hostilities are likely to preclude meaningful implementation of conservation activities, and the displacement of large

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68 Hanson et al., 'Warfare in biodiversity hotspots'.
69 Miklín and Čížek, 'Erasing a European biodiversity hot-spot: Open woodlands, veteran trees and mature forests succumb to forestry intensification, succession, and logging in a UNESCO Biosphere Reserve'.
70 Barker et al., 'Environmental impact of metals resulting from military training activities: A review'.
71 Zentelis et al., 'Principles for integrated environmental management of military training areas'.
72 *Geomodels as a key component of environmental impact assessments of military training ranges in Canada*.
73 Lawrence et al., 'The effects of modern war and military activities on biodiversity and the environment'.
74 Baumann and Kuemmerle, 'The impacts of warfare and armed conflict on land systems'.

numbers of people due to war can place huge pressures on natural area ecosystems[75]. The direct results of pollutants release from explosive ordnance, destruction of energy facilities, factories and other infrastructure, and the physical damages caused by bomb blasts, artillery strikes and land mine/ cluster munition detonations are all visible impacts in the immediacy of conflict. The destruction of ammunition storage areas is an additional cause of widespread contamination (although it should be noted that unplanned storage area explosions are also common outside of active conflict[76]).

Contamination resulting from an unplanned stockpile explosion at Primorsky, Abkhazia (South Caucasus) with a large range of damaged and partially burned EO visible (this site has since been cleared). Photo: E. Chrystie

It can often be in the post-conflict phase, which may continue for decades after cessation of hostilities, in which the full impact of war on ecosystems begins to manifest. The role of

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[75] Conteh, Gavin and McCarter, 'Assessing the impacts of war on perceived conservation capacity and threats to biodiversity'.
[76] Rutherford, K. and Williams, M., 'Unplanned Explosions of Munition Stockpiles'.

subsequent resource scarcity in contributing to conflict and to a self-fulfilling cycle of increased environmental degradation has long been debated[77], and a holistic approach necessitates an understanding of resource scarcity and ecosystem vulnerability as potential drivers of social conflict.

8. Applying the war ecology framework: Environmental impacts of landmines in the lifecycle of war

In applying a warfare ecology approach to identify pathways whereby mine action organisations can better integrate conservation and environmental activities alongside core operations, it is necessary to fully understand the environmental impacts of landmines across the lifecycle of conflict. A detailed overview of potential environmental impacts is presented in this section, however it is first useful to break down environmental impacts into the broader taxonomy of warfare as a method of identifying reverberating impacts at different spatial and temporal scales. Additionally, this is a necessary first step in order to conceptualise the links between humanitarian mine action activities, and longer-term development.

As an example, the table below uses the concept of warfare ecology to situate some potential impacts of landmines at different scales and phases of conflict:

	Scale			
		Landscape	**Regional**	**Global**
Phase	**Preparations**	Disruption/ resource extraction of local ecosystems due to enable landmine	Regional pollution and resource extraction for manufacturing landmines.	Global supply chains contribute to CO_2 emissions and other

[77] Homer-Dixon, Boutwell and Rathjens, 'Environmental Change and Violent Conflict'.

		manufacture and transport. Destruction of habitats during the installation of landmines (e.g. removal of flora, displacement of fauna).		forms of pollution.
	Active conflict	Direct destruction and fragmentation of habitats due to landmine detonations. Displacement of humans and wildlife. Changes in local flora and fauna due to reduced human activity in mined areas.	Widespread displacement of humans and wildlife due to accidents and fear of landmines. Suspension of conservation and research activities due to danger to life and limb. Regional disruption of agricultural systems and increased pressures on natural resources in safe areas.	Displacement of refugees due to fear of landmines. Potential contribution to climate change due to changes in land use.
	Post-conflict	Continued fragmentation and disruption of local ecosystems due to landmines that remain uncleared. Negative impacts on local community livelihoods due to inability to use land sustainably. Continued increased local pressures natural resources in safe areas. Inability to implement restoration activities due to continued threat of landmines.	Continued fear and displacement due to landmines. Continued disruption of regional systems (e.g. agricultural, economic, migratory). Ongoing difficulties in pursuing research and conservation activities due to danger to life and limb. Inability to implement regional, interconnected restoration activities due to continued threat of landmines in specific area.	Continued displacement of refugees. Global effects on biodiversity due to local and regional changes. Transboundary impacts where natural systems connect across state borders.

The manufacture and transport of landmines (broadly falling under the 'pre' conflict phase) has its own environmental impact in terms of emissions and resource extraction (as with the manufacture and transport of any weaponry). In the long term, this can be mitigated by states signing up to (and adhering to) the Ottawa Convention. However, this is a preventative approach whereas the focus here is on mitigation of impacts.

For mine action organisations looking to understand and address the environmental impacts of mines that have already been put to use, the 'preparations', 'war' and 'post-war' phases are of highest relevance when viewed at the landscape and regional scales. As detailed above in chapter 5, 'positive' environmental impacts of landmine contamination can result from denial of human access and activity. It is important to recognise this, however given that this paper rests on the premise of sustainable reintroduction of humans into a functioning eco-system being of key legal and moral concern, the focus here is on impacts that contribute (positively or negatively) to this objective.

The warfare ecology approach, when combined with an understanding of mine action as activities aimed at reducing the 'social, economic and environmental impact' of mines and explosive ordnance, offers a holistic approach that takes into account the interconnectedness of those social, economic and environmental factors.

Whilst a number of anecdotal reports of the direct environmental impacts of mines exist, the sector is lacking in informed scientific study into in this area. The summary below of known environmental impacts of landmines includes academic studies, reports from grey literature, and anecdotal evidence from professionals in the industry (referenced as such). For each impact detailed below, suggestions are given of opportunities for mine action organisations to engage in mitigation strategies.

Environmental impacts during the 'preparations', 'war' and 'post-war' phases include, but are not necessarily limited to:

Damage to ecosystems in preparation for laying minefields

At the stage of preparations, laying minefields may include removal of significant quantities of vegetation. In Sri Lanka, coastal mangroves were reportedly removed in the Northern Province in order to allow for the construction of minefields and other defensive works, and enable line of site for parties to the conflict[78]. These preparative actions are likely to go undocumented, however increasing availability of satellite imagery offers a valuable resource for observing this dynamic during contemporary conflicts.

Harmful components being released into the eco-system

Harmful components of landmines and other EO can be released into the environment in a number of ways, including through the breakdown of explosive fills, breakdown of casing material, residues from detonation, and residues from disposal method (including through detonation/ burning). The range of hazardous compounds found in EO will not be detailed in full here, but of note are heavy metal contaminates, and chemical contaminates. Two of the most commonly used high explosives, RDX and TNT, are proven contaminates posing risks both to human and ecosystem health[79], and have been widely used in landmines and other explosive ordnance globally since the First World War.

[78] Interviewee 7

[79] GICHD, 'Guide to Explosive Ordnance Pollution of the Environment'.

A degraded P4 anti-personnel mine. As the casing degrades over time, the explosive fill (tetryl) can leach out. Photo courtesy of E. Chrystie

In Libya, controlled studies of seed germination in soils collected at varying distances from the site on which a landmine had recently been detonated showed a considerable reduction in plant growth in soils taken up to 6m from the crater site[80]. However, whilst conventional munitions are known to contain components hazardous to both human and flora/ fauna[81], the effects of wider dispersal in terrestrial and marine ecosystems remain understudied[82].

Mine action organisations are well placed to play a key role in assisting with information collection, including direct participation in the collection of soil/ water samples, through community engagement and as a part of the non-technical survey process[83].

[80] Al-Traboulsi and Alaib, 'Phytotoxic effects of soil contaminated with explosive residues of landmines on germination and growth of Vicia faba L'.
[81] Johnson et al., *Wildlife toxicity assessments for chemicals of military concern*.
[82] Beck et al., 'Spread, Behavior, and Ecosystem Consequences of Conventional Munitions Compounds in Coastal Marine Waters'.
[83] Bach, McKosker and Cottrel, 'Environmental Soil Sampling and Analysis'.

A TM-62M anti-vehicle mine laid in shallow flowing river water near Mykolaiv, southern Ukraine. The heavy metal and explosive contaminants pose a risk of leaching into the river system. Heavy metals are toxic to both humans, and aquatic life[84]. Photo courtesy of E. Chrystie

Denial of access precluding conservation initiatives

The case study of the KAZA transboundary protected area in Angola detailed in chapter 6 provides a clear example of this in action. The presence of landmines precludes a number of core activities essential for designation or management of a protected area. These include: mapping; surveys; monitoring; and income generation through tourism or other means. In addition, any conservation action that requires human access to the designated area can be impeded by the presence, or fear, of landmines.

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[84] Sall et al., 'Toxic heavy metals: impact on the environment and human health, and treatment with conducting organic polymers, a review'.

When conducting clearance in protected areas, mine action organisations are well placed to offer support and develop partnerships with local stakeholders. An initial first step here would be integrating existing mapping practices with layers showing existing protected areas.

Direct damage to fauna through detonations (animal accidents)

This has been observed in a wide range of contexts. Interviewees specifically mentioned examples from Ukraine (hedgehogs activating tripwires)[85] Angola (large fauna activating anti-vehicle mines)[86] and the Horn of Africa (camels activating both AP and AV mines)[87]. The size of animal at risk will depend on the nature of the explosive hazard: activation pressures of different victim –activated devices can range from a few grams to over 100kg[88]. Whilst mine action organisations have little control over this pre-clearance, measures can be taken during the clearance process to ensure minimal further disruption to local fauna, for example working with local experts to ensure found explosive ordnance is destroyed at the least disruptive times (e.g. avoiding key nesting periods).

Mine action organisations can also play a key role in ensuring that evidence of animal accidents is documented and shared with relevant environmental authorities.

[85] Interviewee 4
[86] Interviewee 3
[87] Interviewee 1
[88] Gander, Terry and Cutshaw, Charles, *Jane's Ammunition Handbook*.

Camel skeleton in a Somali minefield. Photo courtesy of Dan Richards.

A monkey crosses marking sticks to enter a minefield in Sri Lanka. Photo courtesy of E. Chrystie.

Illegal re-purposing of landmines for use in poaching activities

During the civil war and in post-conflict Angola, it has been reported that local poachers re-purposed anti-vehicle mines to target elephant populations[89]. A another example comes from Sri Lanka, where one interviewee noted that AP landmines have been repurposed to act as traps for wild pigs[90]. When re-purposed, these weapons will remain indiscriminate and therefore pose the same threat to humans and wildlife as when tactically laid at a time of conflict. One method of repurposing involves wrapping the AP mine in fabric along with food bait, potentially causing severe injuries to any animal attempting to eat the bait.

There are opportunities here for mine action organisations to engage with local partners to support development of sustainable resource extraction activities that do not require the use of repurposed explosives.

Illegal re-purposing of landmines for use in fishing

The use of explosives for the purpose of fishing is common in many post-conflict communities globally[91]. In addition to being hazardous for those repurposing landmines and other explosive ordnance for this purpose, blast fishing is widely condemned globally as environmentally destructive. In Cambodia, there are documented cases of explosive ordnance having been repurposed for use in blast fishing, and of human accidents caused by attempts to dismantle explosive ordnance for this purpose[92]. Similar observations come from Laos[93], and from Sri Lanka, where damage to coastal ecosystems caused by illegal blast

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[89] Oppong and Kalipeni, 'The Geography of Landmines and Implications for Health and Disease in Africa: A Political Ecology Approach'.
[90] Interviewee 7
[91] Hampton-Smith, Bower and Mika, 'A review of the current global status of blast fishing: Causes, implications and solutions'.
[92] Moyes, Lloyd and McGrath, 'Explosive remnants of war: Unexploded ordnance and post-conflict communities'.
[93] Sims, 'Consolidating Post Conflict Development: Unexploded Ordnance and the Legacy of the Conflict in laos'.

fishing (often with explosive harvested from landmines or other explosive ordnance) can last for decades[94].

As with the example of poaching given above, there are opportunities here for mine action organisations to engage with local partners to support development of sustainable fishing methods that do not require the use of repurposed explosives.

Over-exploitation of resources by local populations due to supply chain disruption

Although harder to quantify than some other environmental impacts of landmine contamination, one interviewee[95] observed that in Mozambique (which has since been declared landmine free), there was an increase in local people who turned to hunting bush-meat out of necessity, when roads were so heavily mined that affected communities could not receive deliveries of farmed meat. This is related to the dynamic of over-exploitation of resources in safe areas (below), however it can also apply at a regional or even global scales as it pertains to the disruption of supply chains.

This impact will normally be mitigated through the existing clearance process, with minefields blocking crucial access routes for humanitarian supplies generally seen to be high priority.

Over-exploitation of resources in safe areas, in order to avoid unsafe areas

This has been observed due to displacement during and post-conflict. For example, deforestation and degradation of grasslands and wetlands, and deforestation around refugee camps whilst people are unable to return to their homes[96]. This impact is not

[94] Sosai, 'Illegal Fishing Activity – A New Threat in Mannar Island Coastal Area (Sri Lanka)'.
[95] Interviewee 1
[96] Bernard et al., 'The impact of refugee settlements on land use changes and vegetation degradation in West Nile Sub-region, Uganda'.

necessarily direct, as people are likely to have been displaced from their homes for a variety reasons and not solely due to landmine contamination. In post-conflict environments, however, the existence of landmines can become a lingering reason for people not to return to their homes.

There are opportunities here for mine action organisations to engage with local partners in order to support sustainable resource extraction in cleared (previously mined) areas, as people move back to the areas from which they have been displaced.

Illegal exploitation of resources by individuals with higher risk tolerance than local authorities

In Cambodia, illegal deforestation has continued in mined areas, with speculation that local authorities will not enter areas that illegal loggers will, due to landmine contamination[97]. The same dynamic has been observed in Angola, where poachers anecdotally have a higher risk tolerance for entering mined areas than the authorities[98]. An interviewee with experience working in Cambodia[99] described illegal loggers entering forests just hours after they had been cleared of landmines. This demonstrates the ability of illegal actors to exploit the delay between an area being made safe, and subsequently being officially handed over to state authorities, and subsequently to landowners/ legal land users.

There are opportunities here for mine action organisations to engage with state authorities and conservation officials, communicating clearance timeframes and sharing information on areas that are already safe to access.

[97] Interviewee 7
[98] Interviewee 3
[99] Interviewee 7

Damage to flora/ soil structure caused by detonations

The access-denying nature of landmines means that it is rare for significant numbers of detonations to occur outside of clearance activities or fires. Incidences of damage to vegetation and trees are nonetheless observed. As with chemical contamination, the impact of the detonation of an individual mine is likely to be minor, whilst multiple detonations or multiple corroded items have the potential to release larger amounts of harmful substances into the environment[100], or cause a greater degree of direct destruction to soil structure/ flora.

The opportunities for mine action to mitigate these affects are more relevant at the 'clearance' stage detailed below, when large numbers of mines are likely to be identified and require disposal.

Damage caused by minefield fires

Fires can occur due to detonations in minefields (accidental or deliberate), causing a fire to spread and burn out of control. Minefield fires can also be naturally occurring, or started accidentally by people. Fire-fighting attempts are understandably hindered should this occur. Fires have also been deliberately started by landowners/ land-users in an attempt to clear minefields, under the (mis)conception that a surface burn will counter the explosive threat (this had been observed in several cases in agricultural areas in Ukraine[101]). This technique is unlikely to leave the burnt area safe to access, as there is no guarantee that the fire will cause explosive hazards to ignite or detonate.

Mine action organisations play a key role here, especially during community risk education sessions, in ensuring local landowners and other stakeholders are aware of the risks involved

[100] GICHD, 'Guide to Explosive Ordnance Pollution of the Environment'.
[101] Interviewee 4

in deliberately starting minefield fires, and explaining the residual hazard that will remain even after an area has burnt.

Impacts of clearance activities

Types of clearance activities and their specific impacts are covered in detail in the following chapter. However, it is noted here that the positive environmental impacts of the clearance process are often overlooked. This is inevitable where an evidence-based understanding of the environmental impacts of landmine contamination is lacking, and whilst industry key performance indicators are focused on socioeconomic factors when post-clearance impact assessments are conducted. By making land safe and removing the explosive threat, the clearance process has the potential to mitigate many of the negative impacts of landmine contamination listed above.

The main negative direct environmental impacts of clearance activities are likely to be vegetation removal and some degree of soil disturbance. If these disturbances are not addressed at the point of clearance, then they can have negative knock-on effects. For example, a study in land changes induced by mechanical demining activities in Iraq found that in the aftermath of clearance, natural erosion processes (wind and rain) were enhanced, leading to accelerated soil erosion[102]. As noted above, the responsibility of clearance organisations to mitigate direct environmental impacts of the clearance process is already mandated in the IMAS standard on Environmental Management. Nonetheless, it remains important to develop a sector wide understanding of negative environmental consequences of the clearance process over time in order to ensure that, as a minimum, the principle of 'do no harm' is adhered to.

A general overview of some common clearance methods, and the degree of vegetation/ soil disturbance of each method, is given in the next chapter.

[102] Hamad, Kolo and Balzter, 'Land Cover Changes Induced by Demining Operations in Halgurd-Sakran National Park in the Kurdistan Region of Iraq'.

This section concludes that in developing a holistic understanding of the environmental impact of landmine contamination, we must take into account the entire conflict lifecycle. Doing so indicates that environmental impacts go far beyond observable damage to the natural environment caused by detonations or fragmentation. A holistic approach demonstrates knock-on effects on provision of ecosystem services[103], the depletion of which only intensifies the incidence of further environmental degradation as a stressor contributing to loss of livelihoods.

9. Overview of clearance activities

For readers unfamiliar with mine clearance methodology, this chapter gives a short description of some of the most commonly used methods and the degree to which they involve ground penetration and/ or vegetation removal. Guidelines for operators and national authorities on deploying these methods can be found in the International Mine Action Standards (IMAS)[104], the standard-setting body for mine action field operations worldwide.

Specific details on vegetation removal and ground disturbance are drawn from expert interviews and from the author's field observations of each of the described methods in minefields in a range of countries. In addition to giving greater context to the problem, this section will highlight the research gaps in fully understanding post-clearance recovery of land according to each method used. As pressure activated anti-personnel and anti-vehicle mines make up the bulk of global contamination, clearance methods directed at this specific threat are explored here. Multiple other methods exist for dealing with other types of victim-operated devices, including IEDs: this description is only meant to account for common methods applied in generalised settings.

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[103] Francis and Krishnamurthy, 'Human conflict and ecosystem services: finding the environmental price of warfare'.
[104] International Mine Action Standards, 'IMAS'.

Pressure-activated anti-personnel mines tend to be buried within a few centimetres of the surface of the ground (although they may move over time due to natural/ anthropogenic forces). The key to a successful clearance method is to identify the mine without applying pressure to the ground above it and safely remove it, either through a detection-based method or by completely removing the top layer of soil.

Typical AP mine laying: a 'betun' type AP mine found buried 3cm below the surface in Colombia. Photo courtesy of E. Chrystie

Common clearance methods generally include the same basic stages:

- Identification of area suspected to be hazardous through non-technical survey (no ground intrusive activity occurs at this stage).
- Mapping and marking of the suspected area.
- Preparation of the minefield or part of the minefield for clearance. This stage often requires cutting of vegetation in order to access the ground.

- Identification of mines and removal of the mine threat (through detonation, physical removal or neutralisation), through the application of clearance methodology.
- Quality control of cleared areas.
- Land release through national mine action authorities to the relevant stakeholders

The methodologies deployed for identification and removal of threats vary due to a range of factors. These factors include the type of threat; terrain conditions; ease of access; vegetation type; seasonal considerations (such as flooding, extremes of temperatures); available funding; and authorised methods (which may vary according to different national authorities). Therefore, it is not always the case that the techniques which would result in the lowest environmental impact are viable options. Some common methods are listed below:

Manual clearance (detector based). This method sees a deminer using a metal detector, ground penetrating radar detector, or combination, to search the ground ahead of them before advancing the marking of hazardous areas.

- This method tends to see vegetation other than trees cut down to ground level by using hand tools or mechanically, to facilitate detector sweeps. Trees and small saplings that are not suspected of covering hazardous items are generally left intact.
- This method has little direct impact on established trees, although a research gap that needs to be addressed is that of long-term effects of removal of understory vegetation, potentially altering the distribution of plant species in the area at the time of regrowth.
- Ground disturbance normally occurs only where sub-surface metal/ GPR signals are investigated by excavation (although in some areas, especially where there has been heavy conflict, these excavations can be numerous).

A deminer deploys manual clearance on the K5 mineline on the Cambodian-Thai border. She will remove all vegetation to allow for detector swings, leaving trees and saplings standing. The holes show where metal signals have been investigated. Photo courtesy of E. Chrystie

Manual clearance: full excavation (raking or full excavation tool). This method, normally reserved for areas in which a detector cannot be used due to mineralisation of soil, excessive metal contamination, or mine type/ depth, sees the deminer removing the top ~15cm (or more depending on the depth of the threat) of ground with a rake or other dedicated full excavation tool to search for mines.

- Similar to detector-based clearance, all vegetation is removed to ground level to facilitate soil removal, whilst trees are normally left behind. The exception to this is when fast growing trees are expected to have grown over mines since they were laid. In this case, trees are removed as the mines will pose a hazard for many years to come (especially if the tree is cut down for use as firewood).
- This method disturbs the ground more than detector-based methods as the entire top soil to the required depth is removed, and then replaced.

- The long-term effects of topsoil removal/ disturbance in different terrain types and to different depths are an avenue for future research.

A deminer rakes through sandy soil looking for AP mines. Photo courtesy of E. Chrystie

Mechanical clearance: excavation. This method sees the top layer of soil completely removed, processed to remove mines (through a variety of methods including screening, crushing or manual inspection by a deminer), then replaced in its original location.

- Mechanical methods tend to see the greatest amount of vegetation removal. Trees will be avoided where possible, although removed if their roots are expected to have grown over mine lines.

An area of mechanically excavated contaminated soil piled up and marked for follow on processing. Photo courtesy of E. Chrystie

A palmyra tree uprooted during clearance of a mine line on the Jaffna Peninsula, Sri Lanka. The roots of this fast growing tree can be seen to have grown around anti-personnel mines, requiring removal of trees to complete clearance. Photo courtesy of A. Vithoozen.

Mechanical clearance[105]: tilling/ flailing. Used either as a ground preparation technique or as stand-alone clearance, these methods see the ground tilled (ploughed) or flailed with chains/ hammers.

- This method causes a high degree of ground disturbance, and is often conducted remotely with a radio-controlled machine. This method will break through the topsoil and destroy any surface vegetation and root networks.

Mechanical clearance: raking: this method sees a metal rake pulled through the ground, normally to remove larger threats (anti-vehicle mines or large IEDs).

- This method disturbs the ground and removes vegetation, but does not remove the topsoil.

[105] Multiple other mechanical assets are used in mine clearance, some bespoke and others converted from agricultural equipment, however these go beyond the purposes of a brief introduction to common techniques. For more options see for example Maki K. Habib, *Mechanical Mine Clearance Technologies and Humanitarian Demining Applicability and Effectiveness*

Mechanical raking method in Iraq. The area to the left of the marking has been mechanically raked to remove ISIS laid IEDs. Raking overturns the top layer of soil and removes vegetation. Photo courtesy of E. Chrystie.

During mechanical clearance in desert environments the disturbed ground surface returns 'visually' to normal a few weeks after clearance[106]. However, further research is required to establish changes to soil structure that may not be immediately visible. Photo courtesy of E. Chrystie.

[106] Interviewee 9

Animal detection system: dog/ rat. These methods tend to be used as a survey tool or in order to conduct threat reduction of minimally contaminated areas.

- These methods cause minimum disturbance to ground and vegetation, although questions over their reliability mean their use as stand-alone clearance methods on densely contaminated minefields (or even sparsely contaminated minefields, by some operators) is still debated[107].

Disposal of landmines and other EO

Crater caused by a 120mm projectile detonation in Sri Lanka, Northern Province. Photo courtesy of E. Chrystie

[107] Roly, 'A Brief History of Mine Detection Dogs'.

Disposal methods vary between different contexts, and can include demolitions 'in situ' (without moving the ordnance), removal to a separate location for destruction, burning of the item or neutralisation.

One area of interest that there is an opportunity to further develop is in 'green' disposal methods. For example, commercially available alternatives such as MuniRem, which utilises sulphur reduction technology to degrade explosives into non-hazardous products[108]. The MuniRem solution has been proven in several case studies, including the neutralisation of ammunition from sunk civil war era warships in the US[109]. This approach negates the release of gases caused by burning or detonating explosives, and the physical damage to the environment caused by detonations. In some contexts, it is necessary to engage with local experts to understand how the demolitions process can be adjusted to minimise environmental impact. This will only be possible where safe to do so, and may include:

- Removing explosive ordnance for demolition elsewhere
- Considering which available method is most appropriate depending on proposed end use of the land
- Timing demolitions to be least disruptive (e.g. avoiding bird breeding seasons or fish spawning in the case of aquatic mining)

This chapter has presented a brief summary of some common clearance methods in order to identify research gaps, potential environmental impacts of activities and opportunities for landscape scale conservation activities in the clearance process. The following chapter moves beyond addressing the impacts of clearance, which can be understood as lying under the 'do no harm' framework, and explores opportunities for expanding mine action's

[108] National Academies of Sciences, Engineering, and Medicine et al., *Alternatives for the demilitarization of conventional munitions*.
[109] Nzengung, V. and Redmond, B., 'On-Site Neutralization of Civil War Munitions Recovered From an Underwater Environment'.

engagement with environmental activities to a broader understanding throughout the lifecycle of warfare.

10. Integration of conservation and environment with core mine action activities

The previous chapters have detailed a theoretical framework that uses a warfare ecology approach to structure thinking about the environmental impacts of landmines, and have outlined a range of direct and indirect impacts over geographic space and over time. Subsequent chapters will provide case study examples of the integration of environmental and conservation activities alongside core mine action operations, and detail practical tools and approaches for further formalisation of mine action's environmental engagement.

Building on the theoretical framework presented, this section aims to demonstrate the practical relevance of environmental mainstreaming to the established core work of mine action organisations, by situating various environmental activities within the five pillars of mine action introduced in chapter 6. Conservation activities, under the definition given above of "actions that are intended to establish, improve or maintain good relations with nature"[110], are considered from a broad understanding of conservation in a changing global landscape as that in which practitioners "implement approaches unconstrained by discipline and sectoral boundaries, geopolitical polarities, or technical problematisation"[111].

[110] Sandbrook, 'What is conservation?'. Page 565

[111] Colloff et al., 'Transforming conservation science and practice for a postnormal world'.

This section offers justification beyond the theoretical for further engagement by mine action organisations in environmental activities, by situating opportunities under existing core activities.

1. **Explosive Ordnance Risk Education (EORE):** ***education activities that aim to reduce injury and death by raising awareness and instigating behavioural change.***

EORE is defined by IMAS as "those actions which lessen the probability and/or severity of physical injury to people, property or the environment"[112]. There is scope within this definition to include educational content on activities that not only serve as a safety risk for those involved, but are also damaging to the environment – one example of this would be the deliberate starting of fires in an attempt to neutralise the explosive threat in contaminated areas. Several mine action organisations have already taken this a step further, and have trialled the integration of environmental and biodiversity awareness within mine risk education activities[113].

A further extension of this is provision of risk education to researchers and conservationists to facilitate safe conduct of their activities. With the sharing of data and research between mine action organisations and other stakeholders, the sector will be better placed to understand and communicate the long-term effects of landmine contamination at the land release stage, and support communities in continuing to address reverberating impacts.

2. **Clearance*****: this pillar includes survey and mapping of minefields, marking of hazardous areas and clearance activities (demining)***

It is under this pillar that the bulk of environmental activities lie. Addressing not only the risk to life and limb, but also the wider environmental fallout of landmine contamination requires

[112] International Mine Action Standards, 'IMAS'. 04.10, page 31
[113] Interviewee 8

integration of environmental awareness at every level of clearance activity. Activities relevant to maximising effective fulfilment of this pillar include conducting environmental assessments during survey and clearance activities; use of technology (such as GIS and remote sensing) for environmental monitoring in mine-affected areas; development and implementation of training programs on environmentally sensitive demining for mine action personnel; mitigation measures during all activities to avoid environmental harm; measures to directly address environmental impacts of landmines beyond disturbances at the time of clearance.

These activities can only occur within a context specific understanding of environmental impacts of contamination. The role of environmental assessments and partnerships with local organisations will be detailed in chapters 14-16.

3. **Victim Assistance (VA): assistance to victims of mine accidents. *This could include medical care, assistance in accessing available services, such as prosthetics and psychosocial support*.**

This pillar is predominantly focused on provision of care for direct victims of landmine related accidents. The environmental aspect will be relevant in so far as beneficiaries of VA will have increased opportunities to engage with projects, but in general this pillar has little direct relevance beyond the benefits derived by all beneficiaries from increased environmental engagement.

4. **Advocacy: advocating for states participation in the anti-personnel landmine ban treaty and Convention on Certain Conventional weapons.**

Advocacy in the context of mine action is defined in IMAS 04.10 as "public support, recommendation or positive publicity with the aim of removing, or at least reducing, the risk from, and the impact of, mines and ERW."[114] This pillar offers opportunities at a strategic

[114] International Mine Action Standards, 'IMAS' Page 7

level to increase awareness of the global landmine problem and to publicly situate the work of mine action organisations as key to broader environmental goals at state and international levels, with the ultimate benefit of furthering funding opportunities and state participation in the anti-personnel landmine ban treaty.

193 states have signed up for the sustainable development goals (SGDs)[115]. Promoting and proving the link between mine action and successfully achieving environmentally focused SDGs (see chapter 7 for specific examples) further demonstrates the role of mine action in supporting the broader sustainable development agenda.

5. **Stockpile destruction: supporting states in achieving destruction of AP mine stockpiles as per treaty obligations**

Ensuring safe and environmentally sensitive methods are available for use in the destruction of stockpiled landmines serves the dual purpose of preventing unnecessary environmental harm, whilst ensuring that disposal of stockpiles is not delayed due to environmental concerns. In 2021, for example, Greece (which is state party to, but remains in violation of, the Mine Ban Treaty) halted its planned destruction of stockpiled anti-personnel mines due to environmental concerns.[116]

11. Practical application of a war ecology framework to environmental mainstreaming in mine action

There are several documented examples that showcase the practical application of environmental mainstreaming at the 'clearance' stage of mine action operations. For

[115] United Nations Sustainable Development, '193 Member States Archives - United Nations Sustainable Development'.
[116] ICBL-CMC, 'Landmine Monitor 2022' Page 25.

example, in 2017, the UK government commissioned an Environmental Impact Assessment (EIA) in the context of mine clearance operations in the Falklands Islands. Data gathered during the assessment process allowed subsequent clearance to take into account the breeding seasons of local penguin colonies. As a result of this, where mines were suspected within 2m of an occupied burrow they were marked and left for extraction in the non-breeding season[117]. Environmentally fragile areas of sand dunes contaminated with landmines (Yorke Bay) were cleared with the results of the EIA in mind, allowing for projections relating to clearance timeframes and funding requirements to take environmental considerations into account[118].

Other documented 'best practice' examples exist in which mine action was able to take advantage of thorough EIAs to facilitate integration of environmental protection at the clearance stage. For example, during clearance in Skallingen, Denmark (falling within the Wadden Sea National Park and including a Natura 2000 site), extensive natural reconstruction efforts formed part of the clearance plan to avoid damage to fragile coastal zones[119].

Nonetheless, by its nature mine action often occurs in contexts that have seen the apparatus of the state collapse, ongoing conflict, and/ or the breakdown of law and order. In such contexts, mine action may not be able to count on the governance of state mandated environmental regulations. Even within existing protected areas, the legacy of conflict can cause a breakdown in management structures, the recovery of which may well be a lengthy process. In these contexts, where the state apparatus does not provide a framework under which mine action organisations can shape their environmental responsibilities and activities, a roadmap is required to guide appropriate and effective environmental management.

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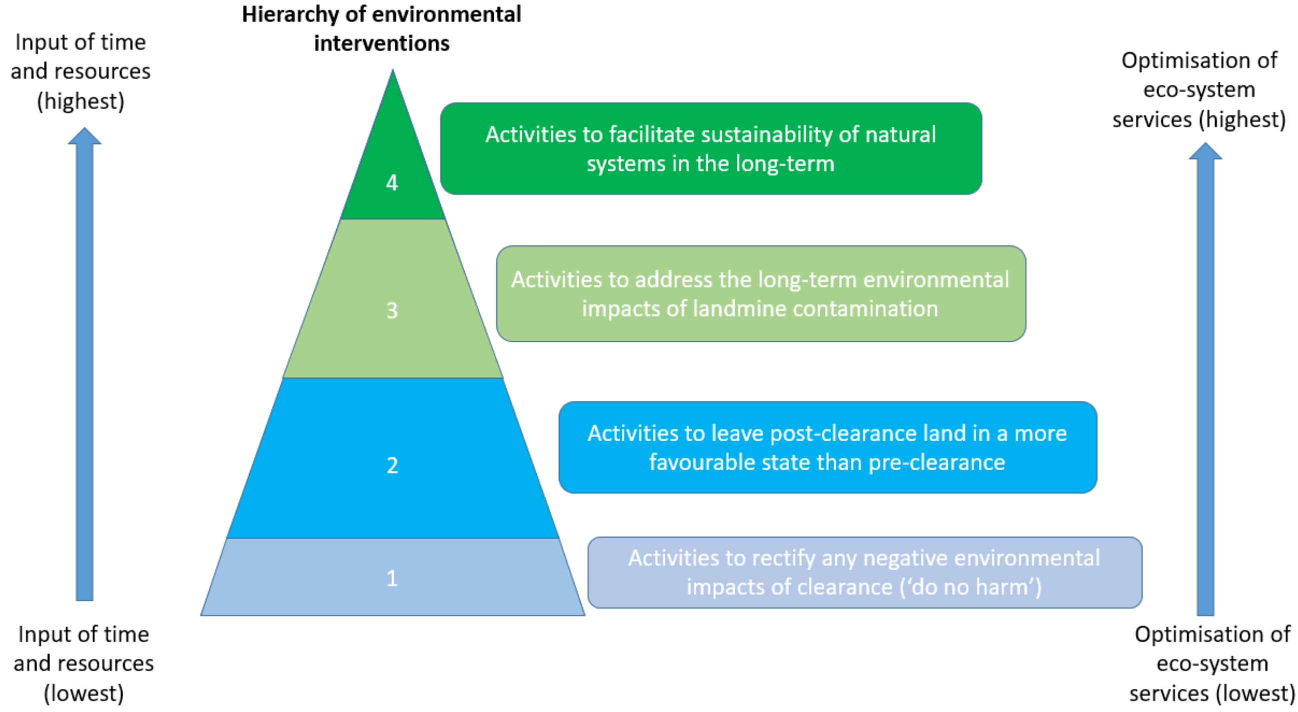
[117] APMBC, *APMBC Article 5 deadline Extension Request*.
[118] Ibid.
[119] Jebens, 'Protecting the Environment: Mine Clearance in Skallingen, Denmark'.

The current IMAS standard on Environmental Management (07.13) states that National Mine Action Authorities (NMAAs) have primary responsibility for assessing environmental impacts of mine action in their country and to develop accordingly an environmental management system, to be used by operators to understand their environmental responsibilities and under which to shape environmental management systems at an operational level[120]. However, a 2021 report by the Mine Action Review found that only 21% of NMAAs in states that are affected by landmines and are party to the Mine Ban Treaty have such a standard in place[121]. In states recovering from the wide ranging humanitarian and economic impacts of conflict, the use of existing frameworks or standards to shape national environmental mine action policy will minimise resources required to ensure that mine action is held to an appropriate national standard. As such, chapter 15 will examine how existing guidelines and standards can provide guidance as national standards are developed.

In advance of presenting a range of case studies, a basic hierarchy is suggested below, that builds and expands upon the concept of 'do no harm':

[120] International Mine Action Standards, 'Environmental Management in Mine Action' Page 2

[121] Mine Action Review, 'Mitigating the Environmental Impacts of Explosive Ordnance and Land Release' Page 14



In this diagram, the base (level one), represents the 'do no harm' approach of mitigating environmental damage caused by clearance operations. This approach forms the foundation of the hierarchy: it remains essential, but can be built on in subsequent interventions. Levels 2-4 are put forward as additional categories that address the impacts of landmines throughout the entire lifecycle of war. This requires an understanding of impacts beyond a 'landscape' based approach, towards a 'regional' understanding, and takes into account preparations, war and post-war phase impacts.

As noted, the input of time and resources required is likely to increase as the breadth of environmental engagement increases, with corresponding optimisation of benefits. In some cases however, environmental measures falling under the label of 'do no harm' can be significant in terms of resource inputs required. Depending on the threat type, terrain and nature of the ecosystem in which clearance occurs, mitigating negative environmental impacts can be a major undertaking requiring significant input of time and resources. An example of this is that of the Skallingen case study mentioned above, in which surface coastal vegetation in areas of sand dunes was removed during clearance and stored for later reconstruction. Beach and sand dune systems were mechanically re-established post-clearance, after the depth and nature of the landmine threat required invasive mechanical excavation techniques.[122]

In the diagram above, interventions at levels 1 to 3 can be justified as falling within the core remit of mine action organisations.

12. Case Studies

The following case studies were selected in order to demonstrate a range of opportunities in different operating environments. For each case study, a brief overview of the specific country context is given, followed by a selection of initiatives (both actioned, and proposed).

Case study 1: Somaliland

Somaliland, a self-declared independent state in the Horn of Africa, has experienced decades of conflict and minelaying, including during the Ogaden war from 1977-78, and the Somali Civil War in the late 20th century[123]. Minefields were laid to fulfil a broad range of tactical aims, including protection of military bases and refugee camps, along borders, to deny the use of tracks and roads, as well as indiscriminate use on agricultural fields and near resources such as waterholes[124].

The major livelihood in Somaliland is pastoralism, with pastoralists largely following seasonal migration patterns dependant on rainfall and availability of animal fodder. Somaliland is considered highly vulnerable to drought, in part due to its fragile environment and water

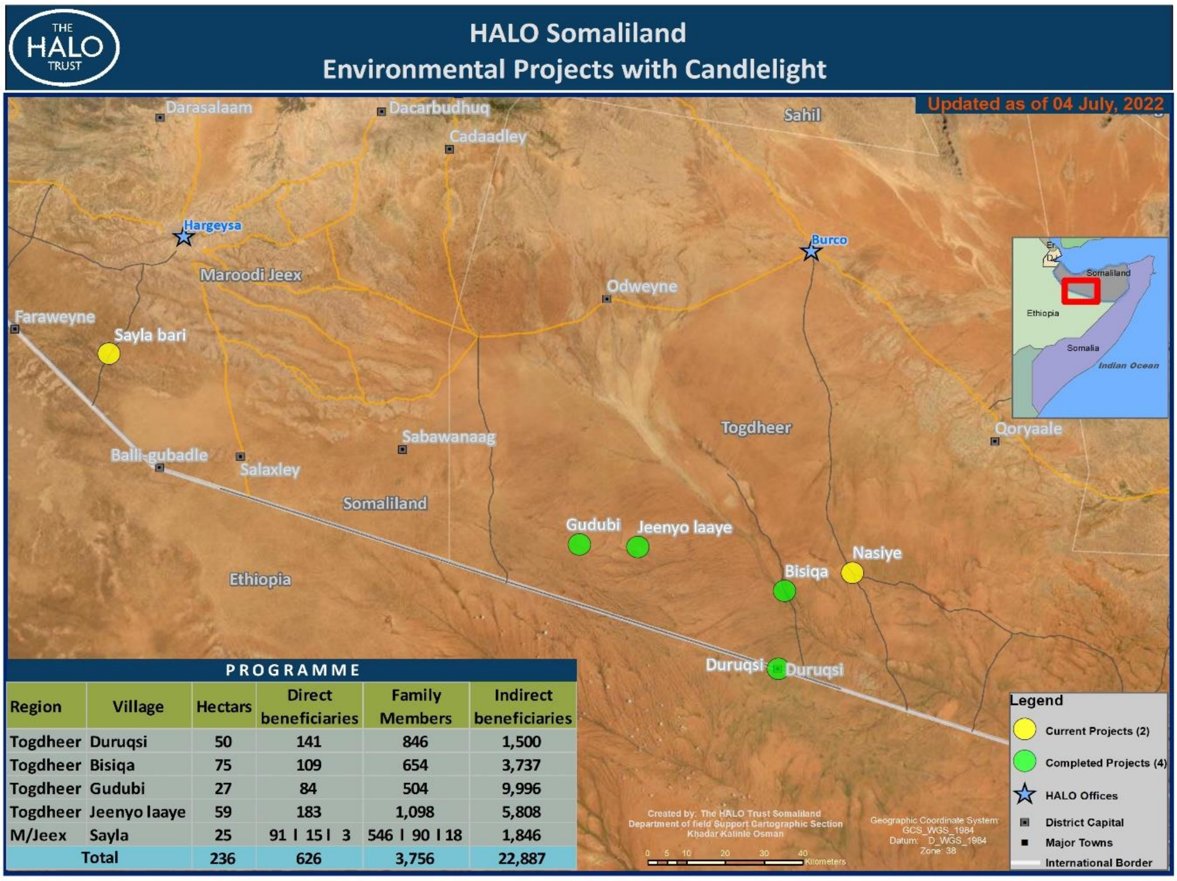
[122] Jebens, 'Protecting the Environment: Mine Clearance in Skallingen, Denmark'.
[123] Wertz, 'Somaliland country profile'.
[124] Ikpe and Njeri, 'Landmine Clearance and Peacebuilding: Evidence from Somaliland'.

scarcity[125]. Environmental degradation, driven by factors such as overgrazing, deforestation, and climate change, has added to the stressor of decades of conflict to exacerbate resource scarcity in the region.

The example given here is taken from the work of the HALO Trust, a mine action organisation whose post-clearance conservation initiatives in Somaliland have seen a relationship built with a local partner to spearhead locally led environmental projects. The project presented here was implemented on formerly mined land, with the aim of leaving it in a more favourable state than it had been in pre-clearance. The activities detailed below could therefore be understood as sitting at level '2' of the hierarchy of interventions detailed above.

At a more regional level, the project itself was initiated on the understanding that historical contamination of land in the area with mines had further increased pressure on remaining green areas, thereby exacerbating existing problems of resource scarcity. This link presents an interesting line of enquiry for future research initiatives in the region, which remain lacking at the time of writing.

[125] Abdulkadir, 'Assessment of Drought Recurrence in Somaliland: Causes, Impacts and Mitigations'.

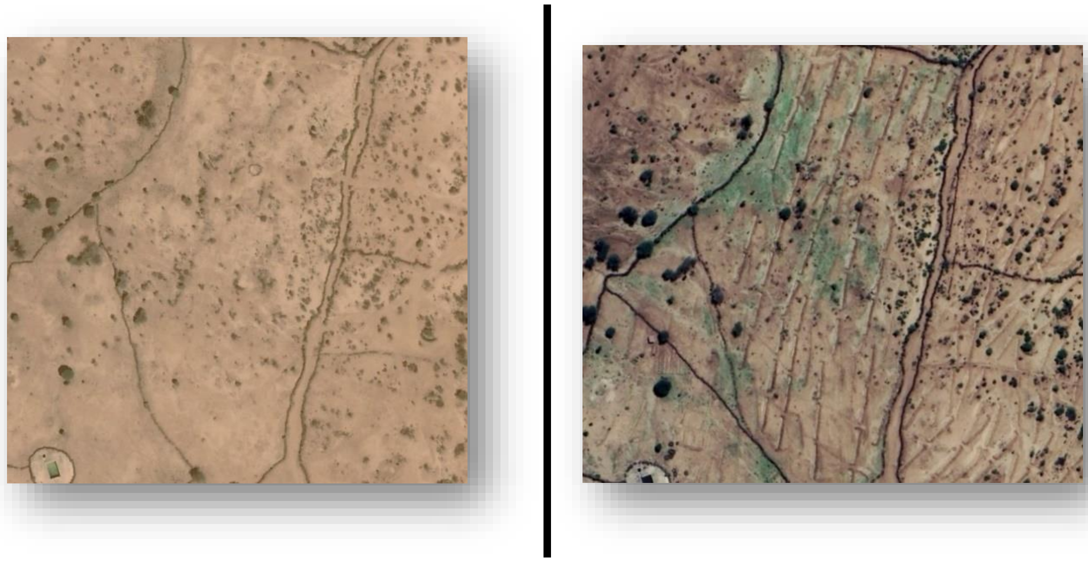


Region	Village	Hectars	Direct beneficiaries	Family Members	Indirect beneficiaries
Togdheer	Duruqsi	50	141	846	1,500
Togdheer	Bisiqa	75	109	654	3,737
Togdheer	Gudubi	27	84	504	9,996
Togdheer	Jeenyo laaye	59	183	1,098	5,808
M/Jeex	Sayla	25	91 I 15 I 3	546 I 90 I 18	1,846
Total		236	626	3,756	22,887

The HALO Trust's project sites in Somaliland. Map courtesy of the HALO Trust.

In 2022, 25 hectares of cleared (formerly mined) land in Sayla Bari village, near Somaliland's Southern border with Ethiopia, formed part of a regeneration project that saw the construction of 300 soil bunds under the direction of Candlelight, a local environmental NGO. These bunds are designed to maximise water retention and minimise surface erosion and run off during times of rainfall. In addition, the project saw an area of one hectare fenced off with permission from local land users, to act as a tree nursery for plantation of saplings. In order to support these initiatives, a water storage site ('berkad') was rehabilitated and left under the guardianship of the local community.

Environmental awareness training was delivered through the local partner to the 85 workers who were paid to construct the soil bunds, sharing information about the goals of the project, the relevance of the trees for the rehabilitation of the area, and the role of soil bunds in regreening, thereby providing a model for the local community should similar re-greening opportunities be pursued in the future.



Sayla project site pre (left) and post (right) intervention. Photos courtesy of the HALO Trust.

The long-term success of this project will be demonstrated through ongoing monitoring and evaluation, and an upcoming report from an external research company that has been contracted to review the project. Of interest here is the successful implementation of the project alongside core mine action activities, and opportunities presented for replication of this model in other contexts. Key aspects specific to core mine action activities that were identified by project staff as facilitating implementation were:

- The HALO Trust's longstanding presence in the country (since 1999).
- Relationships forged through being the third largest employer in the country.
- A network of staff from local communities and good countrywide contacts promoting collaboration among diverse stakeholders, including local land users, governmental stakeholders, and local NGOs.
- Existing operational infrastructure (vehicles, staff, local liaison, security assessments).

- Knowledge of and ability to access remote parts of the country.
- Existing skills of HALO Trust employees (including remote aerial mapping and GIS) to support and complement the work of the local partner

Given the multiple factors contributing to resource scarcity in the region, the link between environmental degradation and historical landmine contamination is not as direct as in some other examples given in this paper. The extent of the link between environmental degradation and conflict remains academically controversial. In some circumstances, resource scarcity can be a driver of conflict in addition to a range of other factors[126], and a majority of studies concur that a combination of increasing demand and decreasing supply is likely to exacerbate existing frictions in a society[127]. However, it has also been suggested that in the Somali region resource scarcity has an often overlooked potential to foster cooperation between ethnic groups[128].

For the purposes of situating mine action's environmental responsibilities within a theoretical framework, it is not necessarily useful to remain constrained by the concept of 'breaking free' from the cycle of conflict through environmental regeneration (whether human or climate change induced), as this approach can oversimplify the vast range of factors that contribute to situations of conflict[129]. It is more useful, when the responsibility of mine action initiatives is understood as supporting the sustainable reintroduction of humans into a functioning ecosystem, to maintain a basis in the humanitarian mandate of supporting livelihoods and resilient societies. This approach is more compatible with the warfare ecology framework presented here in that it allows for a focus on the impacts, rather than the drivers, of conflict.

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[126] Le Billon, 'The political ecology of war: natural resources and armed conflicts'.
[127] Mildner, Lauster and Wodni, 'Scarcity and Abundance Revisited: A Literature Review on Natural Resources and Conflict'.
[128] Bogale and Korf, 'To share or not to share? (non-)violence, scarcity and resource access in Somali Region, Ethiopia'.
[129] Salehyan, 'From Climate Change to Conflict? No Consensus Yet'.

Within the hierarchy of environmental interventions presented above, this approach can be understood to sit at the second level, as an activity to leave post-clearance land in a more favourable state than pre-clearance. The local ownership of the project, facilitated through partnerships with local stakeholders, integrates the fourth level of the hierarchy as an activity to facilitate sustainability of natural systems in the long-term.

Case study 2: mangrove restoration, Sri Lanka[130]

Sri Lanka's Northern Province saw extensive use of minelaying by both sides during the Sri Lankan Civil War (1983-2009), resulting in dense, complex minefields containing both conventional and improvised mines[131]. Clearance efforts are still underway by a number of different operators in the Northern Province, with large numbers of mines destroyed on an annual basis. Throughout 2021 alone, mine clearance organisations reported the destruction of a total of 26,804 landmines in the Northern Province[132].

The legacy of Sri Lanka's landmine contamination has had long-term environmental impacts, some of which can be traced back to the 'pre-war' or preparations phase, with long stretches of coastal vegetation including mangroves removed in order to set up defensive works, including minefields, along coastal defensive positions[133].

In 2021, The HALO Trust partnered with a local organisation to implement an environmental restoration project that would see approximately 4,000 mangrove saplings planted in previously mined areas of the Jaffna Peninsula's lagoons and coastlines. Known as Sri Lanka's 'dry zone', this fragile ecosystem has come under increased ecological pressure[134] due to the

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[130] A summary of this chapter has been submitted for publication (under review at time of writing): Chrystie, 'Environmental Mainstreaming in Mine Action: a case study of moving beyond 'do no harm''.
[131] Dathan, 'The effects of ERW contamination in Sri Lanka'.
[132] ICBL-CMC, 'Landmine Monitor 2022'.
[133] Interviewee 7
[134] Gopalakrishnan and Kumar, 'Linking Long-Term Changes in Soil Salinity to Paddy Land Abandonment in Jaffna Peninsula, Sri Lanka'.

combined pressures of the reverberating effect of conflict, and changes to weather patterns and sea levels resulting from climatic changes. The largest minefield on the peninsula, Muhumalai, saw dense minelaying activities by both the Sri Lankan Army (SLA) and the Liberation Tigers of Tamil Eelam (LTTE) for over a decade, until the culmination of the war in 2009[135].

A manually cleared breach lane through mangrove trees on the edge of Maruthenkerny Lagoon: yellow marking sticks indicate the position of mines that have been found and removed, and red sticks indicate the boundary between safe and unsafe land. Photo courtesy of E. Chrystie

As minefields on the peninsula are made safe from explosive ordnance and people are able to return to their pre-war lands, reverberating effects of the conflict continue to affect local livelihoods. One of the significant challenges in the Northern Province is that of changes to

135 Interviewee 7

soil salinity, leading to abandonment of previously fertile paddy lands that can no longer support rice crop cultivation.[136] A key driver of these changes in the region is salt-water intrusion, the migration of seawater onto landmasses. Research analysing salinity changes in agricultural wells on the peninsula from 1999- 2020 found that groundwater salinity levels had increased by 1.6-fold over that timeframe[137], a problem that has been found to affect 45% of the peninsula[138].

The over salination of previously fertile paddy fields, a direct outcome of saltwater intrusion, has been exacerbated by both sea level rises in the region, and through the war time destruction of coastal mangrove systems for construction of minefields and other defensive works. In addition, the area suffered from wartime destruction of human made bunds and barrages that were designed to mitigate saltwater intrusion[139].

A 65-year-old participant of community orientation session on Jaffna Peninsula recalled: *"'we were [always] catching prawns under the roots of mangroves on our beach. We then cooked the prawns and enjoyed eating them on the beach too. Those mangrove forests were totally destroyed by the war."*[140]

Coastal vegetation is an effective, low cost bio-shield that can mitigate the occurrence of salt-water intrusion on the peninsula through dissipation of storm surges and prevention of erosion[141]. In addition to the war-time degradation, the safe clearance of complex mine-lines

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[136] Gopalakrishnan and Kumar, 'Linking Long-Term Changes in Soil Salinity to Paddy Land Abandonment in Jaffna Peninsula, Sri Lanka'.
[137] Gopalakrishnan, Kumar and Mikunthan, 'Assessment of Spatial and Temporal Trend of Groundwater Salinity in Jaffna Peninsula and Its Link to Paddy Land Abandonment'.
[138] Gopalakrishnan and Kumar, 'Modeling and Mapping of Soil Salinity and its Impact on Paddy Lands in Jaffna Peninsula, Sri Lanka'.
[139] Interviewee 7
[140] Provided by project staff
[141] Gopalakrishnan, Kumar and Mikunthan, 'Assessment of Spatial and Temporal Trend of Groundwater Salinity in Jaffna Peninsula and Its Link to Paddy Land Abandonment'.

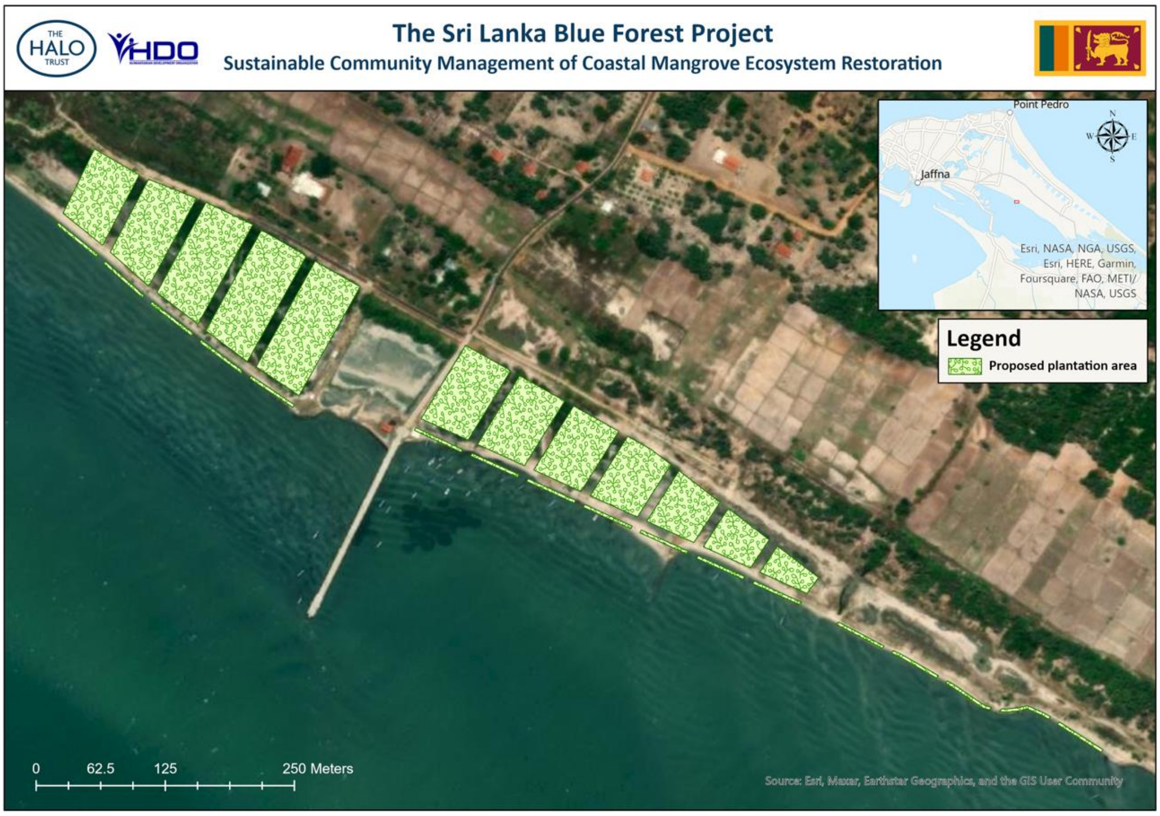
in the region has necessitated removal of significant areas of vegetation[142], further depleting the eco-system and its bio-shied effect.

In this context, applying a 'do no harm' model necessitates the mitigation of further damage to coastal ecosystems that may be caused by mine clearance activities. This includes restoration of any areas damaged where, for example, ground conditions and safety concerns preclude the use of manual clearance and mechanical techniques are required, or where mangrove trees have grown directly over landmines and their root systems must be removed to facilitate safe clearance. This project, in addition to addressing damage caused at the point of clearance, moves beyond a 'do no harm' approach by encompassing a broader understanding of the impacts of decades of EO contamination and addressing the reverberating effects of long-term mine contamination. This was approached by structuring restoration efforts around an understanding of the pre-war ecosystem, rather than a more limited assessment of only pre-clearance ground conditions and flora.

Project summary

The project, initiated on the ground in June 2022 and due for completion in 2023, was implemented through a partnership developed with a local NGO, Humanitarian Development Organisation (HDO). A local ecologist with expertise in mangrove conservation was contracted through HDO to assess proposed project sites as to their suitability for mangrove restoration, with the resultant report independently reviewed by three other mangrove conservation experts. HALO's direct input included using existing GIS and survey capabilities to identify and map proposed plantation sites and previously mined areas, and assisting in conducting stakeholder meetings to gather input from local fishermen, nearby landowners and government officials.

[142] Interviewee 7



Map showing mangrove plantation site in Kilali. HALO completed clearance of this area in 2011, safely destroying 266 items of EO including AP blast mines and UXO. Although forming part of a mangrove forest pre-war, very few trees remained at the time of clearance. Map courtesy of The HALO Trust.

HALO Trust staff accompanied by a mangrove expert conduct DGPS mapping pre-planting in the Kilali coastal area. Photo courtesy of The HALO Trust.

HALO and HDO have since coordinated a number of community orientation meetings in local villages, with the involvement of other local grassroots organisations such as the Rural Development Society, Fisheries Society, and local youth clubs and religious committees.

At the time of writing, the project has overseen plantation of 3000 mangroves planted across and area of 6,000sqm. The long term impact of this project on the local ecosystem and communities who rely on it will take longer to establish, however the model of using expert mine action personnel; GIS, community liaison and survey, alongside partnerships with local NGOs and local environmental experts proved successful.

HALO Staff conduct aerial mapping of a proposed restoration site. Photo courtesy of E. Chrystie

The problems identified above were recognised organically throughout HALO's long-standing work on the ground in Sri Lanka, counting on a large number of staff from the region who themselves have lived experience of ecosystem changes over the lifecycle of the conflict. Ideally, issues such as these will increasingly be recognised early on in the land release process through formalised environmental impact assessments, facilitating donor engagement, identification of local partners and environmental experts, and accurate budget forecasting. This will require structured pre-clearance environmental assessments to become the norm across the mine action sector (discussed further in chapter 14).

This project represents an initiative that addresses not only the environmental impacts of clearance activities, but in addition the consequences of landmine contamination throughout the entire taxonomy of warfare. In this example, the role of the mine action organisation was that of facilitating and supporting the work of a largely local initiative. In the hierarchy of environmental interventions presented above, this project fulfils the first three levels. With a foundation based in rectifying any negative impacts of clearance, a secondary aim of leaving post-clearance land in a more favourable state than pre-clearance, and tertiary of addressing the long-term environmental impacts of landmines. The local ownership approach along with continued support where required sits at the top of the hierarchy, in facilitating the sustainability of natural systems in the long-term.

Case study 3: potential future projects, Ukraine

Whilst the example from Sri Lanka given above demonstrates how mine action organisations may address the long-term environmental implications of conflict by supporting local partners in the implementation of restoration or conservation projects, this next example aims to demonstrate opportunities for engaging at the stage of immediate intervention where the humanitarian mandate for core clearance activities is high. As above, the success of positive contribution to a broader environmental agenda is dependent on locally led partnerships.

Mine action activities take place in a range of different conflict contexts, and this section explores opportunities for environmental activities in a rapidly changing conflict situation. This contrasts with the previous two examples, which focus on activities applicable to more stable, post-conflict environments. By their nature, mine action organisations are often working close to areas in which conflict is ongoing, in order to maximise the lifesaving humanitarian mandate of initiating mine clearance as soon as possible after frontlines have moved.

This example from Ukraine is focused on potential, with many of the ideas given below suggested by Ukrainian conservation experts with knowledge of the current (2023) context.

The WWF estimates that since Russia's invasion in February 2022, at least 30% of all protected areas in Ukraine have been directly affected by military action, including shelling, bombing and manoeuvres. Issues such as suspension of conservation activities, influx of displaced persons, the absence of park management personnel and suspension of management training schemes have affected other protected areas[143]. There is further concern that rare species endemic to Ukraine's remaining areas of steppe habitat in the south and east may disappear entirely[144].

The extent of landmine contamination in Ukraine is currently unknown, with survey and mapping ongoing in liberated areas, and little to no accurate information from occupied areas. Ukrainian national authorities report that, as of February 2023, over 305,000 mines and explosive devices laid since the 2022 invasion had been identified and removed, with humanitarian demining efforts already underway in many regions[145].

The principle of 'do no harm' is widely applicable to all clearance scenarios, however applying the principle adequately in terms of environmental impacts requires liaison with local experts if the particular vulnerabilities of a given area are to be taken into account. Whilst some incidences of mitigating environmental harm are relatively easily identifiable to a non-expert - such as the riverbank example given below - others will require expert input. An example raised by one interviewee is the ecological importance in Ukraine of narrow tree lines found in-between agricultural fields[146], which are commonly contaminated with

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[143] WWF, 'Assessing the environmental impacts of the war in Ukraine'.
[144] Pearce, 'Collateral Damage: The Environmental Cost of the Ukraine War'.
[145] GICHD, 'Our news'.
[146] Interviewee 4

tripwire activated fragmentation mines and can be badly affected by both detonations, and mechanical clearance techniques.

A marked TM62p anti-vehicle landmine in a tributary of the Dnipro in Mykolaiv Oblast. Conservationists from the region are concerned about the effects of detonations in aquatic ecosystems, especially in free-flowing sections where rare species are found[147]. Photo courtesy of E. Chrystie.

[147] Interviewee 4

A cleared minefield in Mykolaiv Oblast, Ukraine. The yellow sticks mark where anti-vehicle mines have been found. In this case, the mines were safely removed to be destroyed elsewhere. Demolitions in-situ would have caused significant damage to the riverbank. Photo courtesy of E. Chrystie

Moving beyond 'do no harm' in the context of emergency humanitarian response, it is first important to highlight that, as with the other examples presented, there is no suggestion that environmental activities should be initiated at the expense of personnel safety, or at the expense of core humanitarian activities. It is therefore suggested here that the most appropriate environmental activities that mine action organisations can engage with in ongoing conflict situations are low-resource, and integrate with core operational activities to make use of existing infrastructures and systems. The most appropriate activities will be those that focus on supporting and facilitating the existing work of local environmental organisations and researchers and contributing to laying the groundwork for rapid post-conflict implementation of restoration projects.

As an example, whilst environmental restoration activities will not be possible until an area has been made safe from explosive threats, there are a number of monitoring, reporting and remote sensing opportunities to be taken advantage of. Mine action organisations are often present immediately post-conflict in areas in which there has been considerable conflict related environmental damage. Sharing this knowledge with organisations such as state environmental authorities or NGOs will support environmental baseline assessments at a time in which access remains challenging. Similarly, the growing use of remote sensing technologies in the industry presents the opportunity to collect and share remote imagery.

Two interviewees suggested the addition of sensors during drone flights (e.g. multi-spectral) would enable an analysis of vegetation health were that information to be shared with interested parties[148]. In addition, it was highlighted that real-time information on safe access routes, or the location and nature of conflict related environmental damage, would be valuable for environmental actors planning interventions in similar areas to those in which demining activities occur. There is a corresponding potential for remote vegetation analysis to provide information on explosives contamination to improve the efficiency of initial surveys, and thereby maximise clearance efforts, with ongoing research and development showing initial success in the use of hyperspectral image analysis for assessing explosive induced stress in vegetation[149].

The initial surveys conducted by mine action organisations have the objective of identifying and prioritising contaminated areas for clearance operations. This process includes discussions with all relevant stakeholders such landowners (when present) and national authorities. Early information sharing with conservation industry professionals not only gives them valuable information on areas at threat, but also provides mine action personnel with additional information to inform clearance planning and prioritisation (for example, the locations of fragile eco-systems or vulnerable species). As noted above, these cannot take precedence over operations in areas of high humanitarian priority, but would provide additional information to enable mitigation of potential negative impacts.

[148] Interviewees 4 and 6
[149] Manley et al., 'Remote Sensing of Explosives-Induced Stress in Plants: Hyperspectral Imaging Analysis for Remote Detection of Unexploded Threats'.

The collection of information on conflict related pollution alongside initial survey activities conducted by mine action organisations has already been identified as an opportunity in the Ukrainian context[150]. The collection of data such as chemical contamination, debris and pollutant spills could be integrated into existing procedures for data collection on the location of suspected or confirmed hazardous areas. This would support the open source information gathering of other NGOs whose ground based work is likely to be limited in the immediate aftermath of conflict, and assist in establishing a base-line for post conflict environmental reconstruction.

Debris in Kharkiv Oblast, Ukraine. Mine action organisations are often well placed to contribute to databases documenting the location of conflict contamination. Photo courtesy of E. Chrystie

Participatory citizen science has been put forward as a potentially useful tool in conflict situations, not only providing key data for remote monitoring, but also in identifying

[150] CEOBS, 'Integrating conflict pollution data collection into mine action'.

ecological risks during conflict[151]. Furthermore, this approach can empower affected communities, making way for the inclusion of local knowledge. Weir *et al* identify a number of means by which citizen science initiatives can provide useful environmental data, including through monitoring of land degradation, and monitoring of conflict related oil pollution through direct participation in sampling activities[152]. In the context of Ukraine, a citizen science approach would allow mine action personnel to engage in data collection with little training or prior environmental knowledge.

Explosive ordnance contamination in Kyiv Oblast, Ukraine. This poses both a threat to life and limb, and an ecological hazard. Photo courtesy of E. Chrystie

It is further expected in Ukraine that landmine contamination will be identified in formally protected areas. In some cases, park management personnel have undergone mine risk education to enable them to recognise threats and avoid unsafe actions.[153] Integration of

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[151] Weir, McQuillan and Francis, 'Civilian science: the potential of participatory environmental monitoring in areas affected by armed conflicts'.
[152] Ibid.
[153] Interviewee 5

protected area locations into operational map layers would be an additional way to identify where existing protected areas coincide with areas of suspected or known contamination, and streamline the process of identifying protected area management plans and personnel.

Mine action and conservation professionals interviewed for this chapter expressed a range of ideas as to how, without diverting resources from life-saving work, mine action organisations can engage with existing conservation projects and mitigate any further environmental damages caused by landmine contamination. To summarise, examples of collaboration include:

- Contribution to conflict contamination databases to assist in developing a bassline that identifies post-conflict environmental damages/ risks.
- Integration of protected area locations into existing operational mapping to facilitate awareness and direct risk education or inform the need to seek expert advice.
- Collaboration on ensuring safe access to areas critical for environmental clean-up (through survey and/ or clearance).
- Where relevant, integration of environmental objectives into existing remote sensing operations (e.g. by sharing of aerial imagery of mine contaminated areas with researchers).
- Sharing of information on fish spawning times and locations, and bird nesting/ breeding times and locations.
- Sharing of information on key riverbank areas for recommendations of where destroying mines 'in-situ' (i.e. destroying them where they are found as opposed to safely moving them elsewhere).
- Direct participation in sampling activities by collecting soil or water samples to share with relevant researchers.
- Facilitating access for researchers through risk education and communication of known safe access/ escorts to allow researchers to safely access and observe or take samples from contaminated areas.

13. Integrating warfare ecology into environmental assessments

The examples given above demonstrate the broad range of opportunities for mine action organisations to implement environmental activities alongside core work. Whilst many examples exist of these opportunities being taken advantage of, there is currently little formalised methodology at a sector level for identifying where such projects are required and / or appropriate. The resulting projects therefore tend to be driven by certain project staff or by funding opportunities, as opposed to emerging from systematic analyses of environmental impacts of landmines over time[154]. This is especially noticeable in operating contexts in which state authorities are not in a position to ensure mine action goals align with national environmental policy or standards[155], or in which thorough Environmental Impact Assessments (EIAs) have not been conducted for mine action activities.

In order to formalise and develop the process of identifying opportunities to address the environmental consequences of landmines over time, it is first necessary to develop a thorough understanding of the environmental context of any given area of operations.

For this purpose, Environmental Impact Assessments (EIAs) are often required by donors or by host governmental authorities. The completion of comprehensive Environmental Impact Assessments (EIAs) would likely be resource heavy for mine action organisations that do not count on existing qualified personnel to conduct them. However, some organisations have developed simplified assessments specifically designed to be completed by field staff with minimal training. One such example is the 'Nexus Environmental Assessment tool' (NEAT+),

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[154] Interviewee 2
[155] Interviewee 6

developed by the UNEP/OCHA Joint Environment Unit alongside other partners (including WWF and IUCN)[156]. This open source assessment tool, designed for rapid initial screening at a project level, additionally allows users to adapt content to suit specific contexts or organisational guidelines. A tool such as this can be modified to include risks and mitigations specific to mine action, whilst requiring a minimum of environmental training. Ideally, these environmental assessments will be used to inform projections as to duration of clearance activities and identify early on any additional funding required.

In this section, the utility of integrating a warfare ecology framework into existing environmental assessment methodologies is examined, as a tool to assist operators and national authorities in situating the environmental impacts of landmines into the wider historical and spatial context of war. This approach allows for environmental assessments (at a project level or larger generalised EIAs) to account for the specific environmental impacts of landmines that may not be immediately obvious.

In order to conceptualise the environmental impacts of landmines within a warfare ecology framework, impacts and potential impacts can be broken down into their relevant phases (preparations, war and post-war) and scales (landscape, regional, global). An example of this exercise is presented below, using a generalised version of the framework presented in chapter 9 (specific impacts will vary considerably depending on the context). This exercise is presented as a simple first step to facilitate the structuring of environmental interventions. In this table, green text indicates those impacts that mine action activities, at a project level, can consider addressing. Other impacts, at a regional and global level of preparations, are understood to be ultimately addressed under the 'advocacy' pillar of mine action but are possibly beyond addressing at the environmental level.

[156] Environmental Emergencies Centre, 'The Nexus Environmental Assessment Tool (NEAT+) - Resources'.

	Scale			
		Landscape	**Regional**	**Global**
Phase	**Preparations**	Landscape alterations in preparation for minelaying activities	Resource extraction/ pollutant emissions in the case that landmines are manufactured or transported	Resource extraction/ pollutant emissions in the case that landmines are manufactured or transported
	Active conflict	Direct impact of landmine use (e.g. detonations, access denial)	Impacts beyond minefield boundaries (e.g. through human displacement, eco-system disruption)	Indirect impacts felt at a global level (e.g. through human displacement, disruption of supply change, climate impacts)
	Post-conflict	Continuation of 'active conflict' phase impacts. Additional impacts caused by clearance activities.	Impacts beyond minefield boundaries (e.g. through human displacement, eco-system disruption). Disruption to restoration efforts due to mine contamination.	Indirect impacts felt at a global level (e.g. through human displacement, disruption of supply change, climate impacts)

To further develop this concept, a project specific example is given below that uses the case study from Sri Lanka presented in chapter 13. This offers a way to conceptualise the extent to which the project engages with the reverberating impacts of landmines across the entire taxonomy of war. Impacts that can be understood as addressed to some degree by this project are summarised below within their respective phase and scale using a warfare ecology approach:

Environmental impacts of landmines in Sri Lanka's northern coastal habitats

		Scale		
		Landscape	**Regional**	**Global**
Phase	**Preparations**	Removal of coastal vegetation in preparation for defensive works including minefields	*NA*	*NA*
	Active conflict	Direct destruction and fragmentation of coastal habitats due to explosive detonations. Displacement of humans and wildlife.	Increase in paddy field salination levels due to salt water intrusion. Regional displacement of communities.	Global displacement of refugees due to fear of landmines. Disruption to exports (especially rice due to lower yields).
	Post-conflict	Negative impacts on local community livelihoods due to inability to use land sustainably. Inability to implement restoration activities due to continued threat of landmines. Further degradation caused by landmine clearance activities.	Continued increase in paddy field salination levels due to salt water intrusion. Increased vulnerability to climate induced sea level rises. Ongoing difficulties in pursuing research and conservation activities due to danger to life and limb.	Continued displacement of refugees. Global effects on biodiversity due to local and regional changes.

The above table represents a simplified method for contextualising environmental impacts specific to mine contamination into a broader taxonomy of warfare that takes into account different phases of conflict, as well as different spatial scales. This methodology aims to clearly and simply identify reverberating impacts in order to inform clearance, land release and relevant conservation efforts.

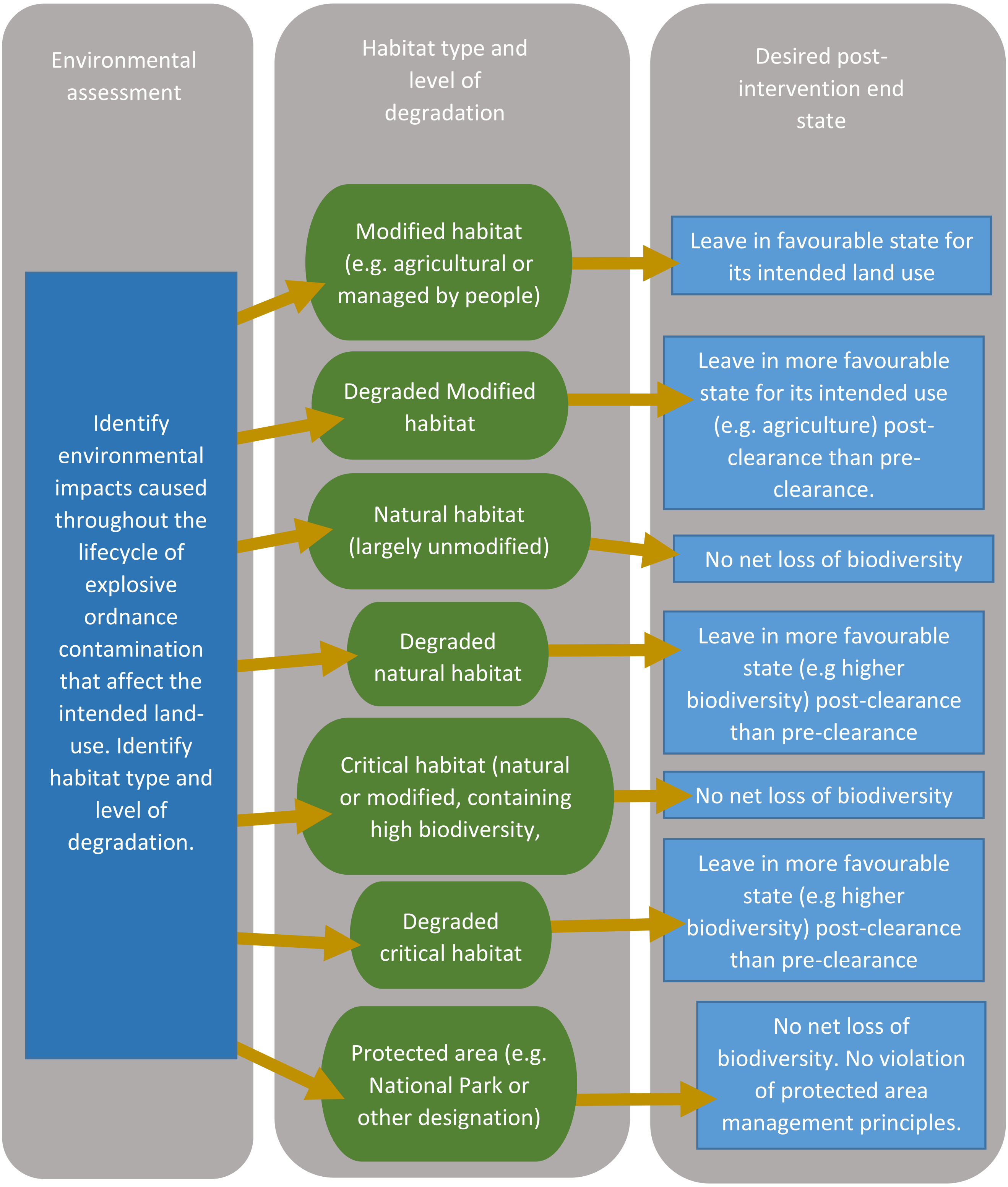
14. Integrating warfare ecology into standards and guidelines

Mine action organisations generally conduct operations under organisational Standard Operating Procedures, developed in compliance with National Mine Action Standards, which in principle are themselves compliant with the IMAS, which are developed in compliance with ISO standards. Standards play a key role in the sector in encouraging best practice. The existing IMAS standard on environmental management, around which national authorities and subsequently mine action operators base their procedures, is predominantly focused on the 'do no harm' principle of humanitarian operations.

The adoption of a holistic approach to environmental management within mine action is likely to occur at different levels of governance depending on the country context, and prior existence of national laws, regulations and assessments. Where existing legislature does not provide sufficient guidance, there are other existing international standards that can be adapted to the context of mine action.

One such example is the International Finance Corporation (IFC) Standard on Biodiversity Conservation and Sustainable Natural Resource Management (IFC Performance Standard 6), the main objectives of which are to protect and conserve biodiversity, and to promote the sustainable management and use of natural resources. This standard's focus on site level operations makes it a useful starting point from which to better understand what a standardised approach to the land release environment could look like.

As an example, the flow chart below details how findings of an environmental assessment, structured to take into account the lifecycle of landmine contamination as described in the previous section, can ultimately inform the desired post-intervention state of released land. Using the habitat categories of the IFC Performance standards of 'modified', 'natural', 'critical' and 'protected area', an additional category of 'degraded' has been added for each relevant habitat type to take into account operations occurring where direct and/ or indirect environmental impacts of landmines have been identified. The category of 'degraded' may also be applied where the land release process has itself caused environmental degradation.



15. Ensuring sustainable interventions: partnerships and funding

Sustainable Land release

As detailed in chapter 7, there is sector-wide acknowledgement of the proven links between mine action and sustainable development goals. Although operating under a humanitarian mandate, mine action can be understood as sitting at the intersect between humanitarian and development agendas. The priority of mine action activities is to prevent loss of life and limb. However, the ultimate aim of mine action activities is to enable social and economic development, and restore livelihoods through land release activities.

The land release process in general aims to leave released land in a state that supports its intended use. Land release processes should be participatory, with the inclusion throughout of end-users of land and of affected communities[157]. An approach that takes into account wide ranging environmental impacts of contamination is likely to encourage the inclusion of a wider range of stakeholders. This will facilitate both community participation in the land release process, and government engagement, where sustainable use of released land is understood to have relevance to achieving state level environmental and sustainability goals.

A focus on developing partnerships and enabling the sustainability of post-clearance ecosystems has the participation and ownership of local stakeholders at its core. Mine action organisations, often counting on local staff who are also stakeholders in the very land they are working to make safe, are well placed to take existing principles of participatory land release, and apply them to participatory environmental engagement.

[157] International Mine Action Standards, '07.11'.

Partnerships and funding

In the examples given throughout this paper, the key to successful implementation of environmental activities is ensuring that projects are driven by local partners and communities. Stakeholders' participation needs to start at the stage of pre-intervention assessments, and sustainability of any conservation measures undertaken will depend on local ownership. Local partners, with mine action supporting and facilitating where necessary, should help inform measures taken to 'do no harm', and should drive conservation activities that move beyond 'do no harm'. In order to support this, mine action organisations can play a vital role in using their platforms to raise awareness about the environmental challenges and opportunities related to mine action, in search of increased public support, policy change, and funding opportunities.

In their 2022 report, the Mine Action Monitor observe that international funding for mine action activities has decreased every year from 2017 ($696.3 million) to 2021 ($543.5 million).[158] Engagement with, and communication of, conservation activities is an opportunity for the mine action sector to diversify funding streams and appeal to funding bodies that do not traditionally provide support to mine action activities. As previously noted, mine action operations often take place amongst remote and economically vulnerable communities. Mine action operations are traditionally funded in the knowledge that mine action activities are finite, with cessation of funding largely expected at completion of state-wide operations. Whilst other funding mechanisms exist that can be utilised for continuation of environmental activities, key to successful implementation will be identifying initiatives that allow integrated conservation activities to be self-sustaining.

There is increasing understanding amongst donors that the livelihoods aspects of mine clearance operations require engagement at the environmental level, which necessarily will

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[158] ICBL-CMC, 'Landmine Monitor 2022'.

require targeted funding opportunities[159]. There is also an increasing recognition amongst conservationists as to the environmental impact of explosive ordnance, especially in light of high profile and well-documented cases in Ukraine[160]. However, funding opportunities from large state donors remain limited, and there is an imperative for 'traditional' mine action donors (state funding bodies) to recognise that additional funding is required to ensure funds are not diverted from core mine action activities, when mine action services are provided by non-profit organisations. Additionally, in contexts in which funding opportunities are limited and declining international funds are necessarily directed towards core clearance operations, a more innovative approach may be required.

In this case, it is useful to consider adopting a business model concept of ecosystem services that understands the economic sector as 'ally' to ecosystem conservation[161], and takes into account the interrelated nature of human development and ecosystem health. This approach aligns well with global trends, with the goals of the UN Decade for Ecosystem Restoration (2021-2030), emphasising the need to identify economic returns from eco-system restoration globally, and encouraging holistic approaches to do so.[162] Furthermore, the Global Biodiversity Framework adopted at the 2022 Biodiversity Conference in Montreal included the adoption of the following clause by participating states:

> "Ensure that the management and use of wild species are sustainable, thereby providing social, economic and environmental benefits for people, especially those in vulnerable situations and those most dependent on biodiversity, including through sustainable biodiversity-based activities, products and services

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[159] Interviewee 01
[160] Interviewees 04 and 05
[161] Bishop et al., 'New Business Models for Biodiversity Conservation'.
[162] UNEP, 'Decade on Restoration' Page 6.

that enhance biodiversity, and protecting and encouraging customary sustainable use by indigenous peoples and local communities"[163].

A focus on economic benefits of conservation not only makes investment more appealing to wider range of potential donors[164], but ultimately ensures the sustainability of interventions where local communities have economic incentives to take ownership of sustainable land management.

Economic opportunities will vary greatly according to the specific context, as demonstrated by the diverse case studies outlined in the previous chapters. To take the example given above from Sri Lanka, the restoration of coastal mangroves can be quantified in a number of ways, including carbon sequestration, revenue increase for fisheries and eco-tourism, avoidance of losses through storm damage, and avoidance of losses through saltwater intrusion into freshwater reserves and agricultural lands[165].

Increased agricultural productivity as previously mined lands are put back to use is another clear economic advantage of the clearance process, along with opportunities for carbon credit schemes alongside the restoration of previously mined areas. Other economic potentials directly related to environmental and conservation activities can be found in the example of clearance taking place in protected areas, on access routes to protected areas, or even in areas the clearance of which will open up conservation opportunities in a much wider region (e.g., in the case study presented from Angola in chapter 6). In these examples, there are associated potential economic benefits resulting from opportunities for eco-tourism and sustainable resource extraction. In short, any intervention that leaves the eco-system (and by extension eco-system services) in a more favourable state can be understood

[163] UNEP, 'CBD/COP/DEC/15/4'. Target 9, Page 10.
[164] Athanas, A., Vorhies, F., Ghersi, F., Shadie, P., Shultis, J., & Phillips, A, *Guidelines for financing protected areas in East Asia*.
[165] Flint et al., *Increasing success and effectiveness of mangrove conservation investments : a guide for project developers, donors and investors*.

in terms of its economic value for the affected community. The most successful interventions, and those most appealing to potential donors, are likely to be those that become sustainable due to this economic feedback mechanism.

16. Discussion

The context-specific examples outlined in the previous chapters (including those of Angola, Sri Lanka, Somaliland and Ukraine) offer an overview of the breadth of opportunity available to mine action organisations in terms of understanding and directly addressing the environmental impacts of landmine contamination.

In this chapter, the research questions presented in chapter 5 are revisited and assessed against the findings of this paper.

1. **What can the 'warfare ecology' field of study add to a holistic analysis of the environmental impacts of landmines?**

The warfare ecology field of study has been applied throughout this paper to develop a framework under which the environmental impacts of landmines can be better understood. This framework allows for an analysis that takes into account the lifecycle of war at different geographic scales. This is especially useful when analysing environmental impacts of landmines, given the interconnectedness of natural systems across space, and the incremental changes over time.

2. **To what extent does current practice in the field of mine action contribute to or mitigate the environmental impact of mine contamination?**

Throughout this paper, some 'best practice' examples have been presented of environmental mitigation and conservation measures being conducted alongside core mine action activities. However, the industry lacks a standardised approach to addressing environmental management, and existing standards adopt a reductionist approach of 'do no harm' that provides little guidance on addressing broader environmental impacts of landmine contamination. The examples presented throughout this paper demonstrate that the environmental impacts of landmine contamination go beyond those that may be caused at the phase of clearance activities, and that a holistic approach is required if those wider impacts are to be understood and addressed.

3. What are the main research gaps in the relationship between mine action and the environment?

A number of research gaps have been identified throughout the course of this paper. Potential areas for future study are summarised below:

- The direct impacts of landmines on ecosystems, including dispersal of explosive and heavy metal contaminants throughout an ecosystem and direct effects on flora and fauna.
- Long term effects on agricultural systems, including the migration of contaminants into food chains.
- Before and after analyses of different stages of clearance, for example removal of understory vegetation, to develop an evidence based understanding of the environmental impacts of different clearance methods.
- Economic valuation mechanisms that quantify the impact of landmines and landmines clearance on ecosystems, and by extension ecosystem services.
- New technologies that have the potential of lowering the environmental impact of clearance processes (e.g. low impact disposal methods).
- Comparative analyses of different impacts of existing disposal methods to better inform mine action decision making, and potential requirement for alternatives.
- An understanding of the role and effectiveness of environmental education and awareness in mine action.
- Context specific analyses in areas affected by landmines that seek to map the environmental impacts of mines across the phases and scales of conflict.

4. What further opportunities are there to mainstream environmental conservation in mine action?

For simplicity, specific action points that have been discussed throughout this paper are summarised below along with their underlying assumptions, outputs, and projected outcomes and impacts. This is by no means a definitive list, and the range of contexts in which mine action occurs means that the following activities will not be relevant to every operational context:

Assumptions	Activities	Outputs	Outcomes	Impacts
Safety, efficiency and effectiveness of operations are not adversely affected. Availability of funding. Availability of trained personnel. Availability and interest of local partners. Favourable security context.	Develop and conduct regional/ national level Environmental Impact Assessments (EIAs).	EIAs are completed and analysed.	Long-term environmental impacts of landmines are identified. Demining activities avoid or mitigate harm to the environment.	Reduction in environmental degradation.
	Develop and conduct project level Environmental Assessments that take into account the lifecycle of conflict and its environmental impacts in the region.	Field based environmental assessments are completed and analysed.	Development of demining strategies that take into account past, present, and future environmental impacts in the aftermath of conflict.	Reduction in environmental degradation and increased resilience of local ecosystems.
	Where safe and effective, implement demining practices with minimal negative environmental impacts.	Environmental impacts are taken into consideration when developing clearance plans.	Reduction in negative environmental impacts of demining activities.	Increased area of land returned to productive use, benefiting local ecosystems

				and communities.
	Integrate environmental rehabilitation into post-clearance land release through local partnerships.	Local ownership of environmental interventions. Restoration activities are initiated on cleared land.	Cleared lands are more effectively rehabilitated and reintegrated into local ecosystems. Long-term environmental impacts of mine contamination are addressed.	Enhanced biodiversity, improved ecological resilience. Long-term sustainability of conservation activities.
	Provide environmental education and awareness programs in target communities alongside outreach and explosive ordnance risk education.	Increased community awareness about the environment and landmines.	Local communities are more widely empowered to participate in environmental conservation.	Sustainable land use, improved livelihoods, increased resilience to climate change.
	Advocate for the integration of environmental considerations in national and international mine action standards and policies.	Policies and standards incorporate environmental considerations.	Environmentally sustainable practices are adopted in mine action at a systemic level. Funding proposals take into account additional resources required.	Long-term sustainability of environmental considerations within mine action.
	Facilitate safe access and research opportunities for	Increased research and conservation activities in	Greater understanding of the local environment and its	More effective and targeted environmental conservation alongside mine

	researchers and conservationists.	mine-affected areas.	relationship with landmine contamination. Greater understanding of the environmental impacts of landmines and clearance processes.	action strategies.
	Build local partnerships for information sharing (such as remote aerial mapping, location of areas that have suffered environmental damage).	Creation of local information sharing networks and increased availability of high-quality data.	Improved access to information for partners, and mine action organisations, facilitating conservation activities and prioritisation.	Sustainable land use, improved livelihoods, increased resilience to climate change.
	Develop and implement training programs on for mine action personnel on mitigating the environmental impacts of the clearance process.	Increased number of mine action personnel trained in environmentally sensitive demining practices.	Enhanced capacity of mine action organisations to conduct demining in an environmentally sensitive manner.	Reduction in environmental degradation caused by mine clearance activities.
	Implement community-based habitat restoration projects in cleared areas.	Communities spearhead projects in cleared areas.	Biodiversity and ecosystem health is improved in cleared areas.	Enhanced biodiversity, improved ecological resilience, economic opportunities and carbon sequestration.
	Integrate community led livelihood	Community led sustainable livelihood	Improved socio-economic conditions and	Sustainable land use, improved

	development programs into mine action, focusing on sustainable livelihoods.	programs are launched in mine-affected communities.	environmental stewardship in mine-affected communities.	livelihoods, increased resilience to climate change.

17. Conclusion

As the field of mine action has evolved over time, it has broadened its scope from one of immediate humanitarian response, to one integrated with the core aspects of human development. A parallel shift has occurred in the broader humanitarian and development sector, with humanitarian endeavours increasingly understood as inextricable from themes of human security, conflict, and the environment. In the emerging field of environmental mainstreaming within mine action, there is an opportunity for mine action to align itself with the global development agenda, which increasingly recognises the interconnectedness of human wellbeing and environmental security. Working under the IMAS definition of mine action as addressing the "social, economic and environmental impact of mines, and ERW" lends itself to a holistic approach. Engaging fully with environmental opportunities will entail an in-depth understanding within the sector of the environmental impacts of contamination over time and how they interact with social and economic factors. The approach presented in this paper offers a holistic framework under which environmental impacts can be better understood, and opportunities identified.

The systematic integration of conservation principles into the planning and implementation of mine action operations and alignment with industry standards that promote biodiversity conservation also contributes to wider conservation and development goals and with the broader global narrative of sustainable development, thereby facilitating further research and funding opportunities. Doing so requires a holistic understanding of the impacts of landmines and other explosive ordnance on ecosystem health throughout the entire lifecycle of conflict.

The case studies detailed in this paper demonstrate that integration of environmental and conservation activities within mine action can provide both direct and indirect environmental benefits. Directly, it can help restore ecosystems, conserve biodiversity, and promote sustainable reintegration of communities into previously contaminated lands. Indirectly, it can support the long-term sustainability of communities and economies by facilitating access to natural resources, maintaining ecosystem services, and promoting economic recovery.

18. Bibliography

Abdulkadir, G. 'Assessment of Drought Recurrence in Somaliland: Causes, Impacts and Mitigations'. *Journal of Climatology & Weather Forecasting* 05, no. 02 (2017).

Adams, William M., Ros Aveling, Dan Brockington, Barney Dickson, Jo Elliott, Jon Hutton, Dilys Roe, Bhaskar Vira, and William Wolmer. 'Biodiversity conservation and the eradication of poverty'. *Science* 306, no. 5699 (2004): 1146–1149.

Al-Traboulsi, Manal, and Mohamed A. Alaib. 'Phytotoxic effects of soil contaminated with explosive residues of landmines on germination and growth of Vicia faba L'. *Geology, Ecology, and Landscapes* (2021): 1–11.

Ammended Protocol II. 1996. https://treaties.un.org/doc/Treaties/1996/05/19960503%2001-38%20AM/Ch_XXVI_02_bp.pdf (accessed February 20, 2023).

Anderson, Mary B. *Do no harm: How aid can support peace--or war*. Boulder, Colo., London: Lynne Rienner Publishers, 1999.

APMBC, ed. *APMBC Article 5 deadline Extension Request: United Kingdom's Extension Request Process*. 2018. https://www.apminebanconvention.org/en/membership/united-kingdom/united-kingdoms-extension-request-process/ (accessed May 20, 2023).

Athanas, A., Vorhies, F., Ghersi, F., Shadie, P., Shultis, J., & Phillips, A. *Guidelines for financing protected areas in East Asia*. 2001. https://portals.iucn.org/library/efiles/documents/paps-009.pdf.

Bach, Doan B., Kimberley McKosker, and Linsey Cottrel. 'Environmental Soil Sampling and Analysis: Application in supporting sustainable land use practices in areas impacted by explosive ordnance'. *The Journal of Conventional Weapons Destruction* 25.3 (2022). https://commons.lib.jmu.edu/cgi/viewcontent.cgi?article=2978&context=cisr-journal (accessed February 19, 2023).

Barker, Amanda J., Jay L. Clausen, Thomas A. Douglas, Anthony J. Bednar, Christopher S. Griggs, and William A. Martin. 'Environmental impact of metals resulting from military training activities: A review'. *Chemosphere* 265 (2021): 129110. https://www.sciencedirect.com/science/article/pii/s0045653520333075.

Baumann, Matthias, and Tobias Kuemmerle. 'The impacts of warfare and armed conflict on land systems'. *Journal of Land Use Science* 11, no. 6 (2016): 672–688.

Beck, Aaron J., Martha Gledhill, Christian Schlosser, Beate Stamer, Claus Böttcher, Jens Sternheim, Jens Greinert, and Eric P. Achterberg. 'Spread, Behavior, and Ecosystem Consequences of Conventional Munitions Compounds in Coastal Marine Waters'. *Frontiers in Marine Science* 5 (2018): 141. https://www.frontiersin.org/articles/10.3389/fmars.2018.00141/full.

Bernard, Barasa, Mwiru Aron, Turyabanawe Loy, Nabalegwa W. Muhamud, and Ssentongo Benard. 'The impact of refugee settlements on land use changes and vegetation degradation in West Nile Sub-region, Uganda'. *Geocarto International* 37, no. 1 (2022): 16–34.

Bishop, Joshua, Sachin Kapila, Frank Hicks, Paul Mitchell, and Francis Vorhies. 'New Business Models for Biodiversity Conservation'. *Journal of Sustainable Forestry* 28, 3-5 (2009): 285–303.

Bogale, Ayalneh, and Benedikt Korf. 'To share or not to share? (non-)violence, scarcity and resource access in Somali Region, Ethiopia'. *The Journal of Development Studies* 43, no. 4 (2007): 743–765.

CEOBS. 'Integrating conflict pollution data collection into mine action'. *The Conflict and Environment Observatory*, July 26, 2022. https://ceobs.org/integrating-conflict-pollution-data-collection-into-mine-action/ (accessed May 22, 2023).

CEOBS. 'About - CEOBS'. https://ceobs.org/about/ (accessed February 26, 2023).

Chase, Michael J., and Curtice R. Griffin. 'Elephants of south-east Angola in war and peace: their decline, re-colonization and recent status'. *African Journal of Ecology* 49, no. 3 (2011): 353–361.

Chrystie, Emily. 'Environmental Mainstreaming in Mine Action: a case study of moving beyond 'do no harm': Submitted for publication (under review)' (2023).

Colloff, Matthew J., Sandra Lavorel, Lorrae E. van Kerkhoff, Carina A. Wyborn, Ioan Fazey, Russell Gorddard, and Georgina M. Mace et al. 'Transforming conservation science and practice for a postnormal world'. *Conservation Biology* 31, no. 5 (2017): 1008–1017.

Conteh, Abu, Michael C. Gavin, and Joe McCarter. 'Assessing the impacts of war on perceived conservation capacity and threats to biodiversity'. *Biodiversity and Conservation* 26, no. 4 (2017): 983–996.

Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on their Destruction: APMBC. 1997. https://ihl-databases.icrc.org/en/ihl-treaties/apmbc?activeTab=undefined (accessed February 20, 2023).

Dathan, Jennifer. 'The effects of ERW contamination in Sri Lanka'. *Journal of Conventional Weapons Destruction* 22, no. 3 (2018). https://core.ac.uk/download/pdf/214170663.pdf (accessed May 18, 2023).

Downs, Charles. 'Linking Mine Action and Economic Development'. *Journal of Conventional Weapons Destruction*, no. 14 (2010). https://commons.lib.jmu.edu/cisr-journal/vol14/iss1/19/.

Dudley, Joseph P., Joshua R. Ginsberg, Andrew J. Plumptre, John A. Hart, and Liliana C. Campos. 'Effects of War and Civil Strife on Wildlife and Wildlife Habitats'. *Conservation Biology* 16, no. 2 (2002): 319–329. https://www.esf.edu/efb/lomolino/courses/MammalDiversity/Disc3/GroupC.pdf.

Dutta Gupta, Tanaya, Frans Schapendonk, Ma Suza, Dung Phuong Le, Peter Läderach, and Grazia Pacillo. *The Climate Security Inequality Nexus: A critical analysis of pathways and synergies*. 2021. https://cgspace.cgiar.org/handle/10568/117592.

Environmental Emergencies Centre. 'The Nexus Environmental Assessment Tool (NEAT+) - Resources'. https://resources.eecentre.org/resources/neat/ (accessed May 18, 2023).

Fisher, Joshua, and Kristen Rucki. 'Re-conceptualizing the Science of Sustainability: A Dynamical Systems Approach to Understanding the Nexus of Conflict, Development and the Environment'. *Sustainable Development* 25, no. 4 (2017): 267–275.

Flint, Raphaëlle, Dorothée Herr, Francis Vorhies, and James R. Smith. *Increasing success and effectiveness of mangrove conservation investments : a guide for project developers, donors and investors*. IUCN: International Union for Conservation of Nature, 2018. https://policycommons.net/artifacts/1375591/increasing-success-and-effectiveness-of-mangrove-conservation-investments/1989853/.

Francis, Robert A., and K. Krishnamurthy. 'Human conflict and ecosystem services: finding the environmental price of warfare'. *International Affairs* 90, no. 4 (2014): 853–869.

Galgano, Francis A. *The environment-conflict nexus: Climate change and the emergent national security landscape / Francis Galgano, editor.* Advances in military geosciences, 2522-8323. Cham, Switzerland: Springer, 2019.

Gander, Terry and Cutshaw, Charles, ed. *Jane's Ammunition Handbook*. 8th ed. Jane's Information Group, 1999.

Geneva International Centre for Humanitarian Demining and United Nations Development Programme. *Leaving No-One Behind: Mine Action and the Sustainable Development Goals*. Geneva, New York, NY: GICHD; UNDP, 2017. http://www.undp.org/content/dam/undp/library/Sustainable%20Development/Mine%20Action/UNDP%20GICHD%20Mine%20Action-SDG%20Study%20-%20web.pdf.

Geomodels as a key component of environmental impact assessments of military training ranges in Canada. 2007. https://conservancy.umn.edu/bitstream/handle/11299/109020/final_3-d_workshop_nov-06[1].pdf?sequence=1#page=69.

GICHD. ‘Guide to Explosive Ordnance Pollution of the Environment’. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.gichd.org/fileadmin/GICHD-resources/rec-documents/EO_Pollution_of_the_Environment_v17_web_01.pdf (accessed May 14, 2023).

GICHD. ‘Our news’. https://www.gichd.org/en/what-we-do/our-news/news-detail/ukraine-faces-massive-explosive-contamination-one-year-into-conflict/ (accessed May 18, 2023).

Goodhand, Jonathan. ‘Aiding violence or building peace? The role of international aid in Afghanistan’. *Third World Quarterly* 23, no. 5 (2002): 837–859.

Gopalakrishnan, Tharani, and Lali Kumar. ‘Linking Long-Term Changes in Soil Salinity to Paddy Land Abandonment in Jaffna Peninsula, Sri Lanka’. *Agriculture* 11, no. 3 (2021): 211.

Gopalakrishnan, Tharani, and Lalit Kumar. ‘Modeling and Mapping of Soil Salinity and its Impact on Paddy Lands in Jaffna Peninsula, Sri Lanka’. *Sustainability* 12, no. 20 (2020): 8317.

Gopalakrishnan, Tharani, Lalit Kumar, and Thushyanthy Mikunthan. ‘Assessment of Spatial and Temporal Trend of Groundwater Salinity in Jaffna Peninsula and Its Link to Paddy Land Abandonment’. *Sustainability* 12, no. 9 (2020): 3681.

Hamad, Rahel, Kamal Kolo, and Heiko Balzter. ‘Land Cover Changes Induced by Demining Operations in Halgurd-Sakran National Park in the Kurdistan Region of Iraq’. *Sustainability* 10, no. 7 (2018): 2422. https://www.mdpi.com/314890.

Hampton-Smith, Melissa, Deborah S. Bower, and Sarah Mika. ‘A review of the current global status of blast fishing: Causes, implications and solutions’. *Biological Conservation* 262 (2021): 109307. https://www.sciencedirect.com/science/article/pii/s0006320721003591.

Hanson, Thor. ‘Biodiversity conservation and armed conflict: a warfare ecology perspective’. *Annals of the New York Academy of Sciences* 1429, no. 1 (2018): 50–65.

Hanson, Thor, Thomas M. Brooks, Gustavo A. B. Da Fonseca, Michael Hoffmann, John F. Lamoreux, Gary Machlis, Cristina G. Mittermeier, Russell A. Mittermeier, and John D.

Pilgrim. 'Warfare in biodiversity hotspots'. *Conservation Biology* 23, no. 3 (2009): 578–587.

Healy, Hall. 'Korean Demilitarized Zone Peace and Nature Park'. In *Parks, Peace, and Partnership*, 383–410. University of Calgary Press, null.

Hoffman, Bernd. 'An Integrated Global Demining and Development Strategy'. *Journal of Conventional Weapons Destruction* 3, no. 1 (1999). https://commons.lib.jmu.edu/cisr-journal/vol3/iss1/4/.

Hofman, U. and Juergensen, O. 'Leaving no one Behind: Mine Action and the Sustainable Development Goals'. https://www.gichd.org/en/resources/publications/detail/publication/leaving-no-one-behind-mine-action-and-the-sustainable-development-goals/ (accessed May 20, 2023).

Hofmann, Ursign and Rapillard, Pascal. 'Do no harm in mine action: Why the environment matters'. *Journal of Conventional Weapons Destruction* 19, no. 1 (2015). https://commons.lib.jmu.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=1031&context=cisr-journal (accessed February 20, 2022).

Homer-Dixon, Thomas F., Jeffrey H. Boutwell, and George W. Rathjens. 'Environmental Change and Violent Conflict'. *Scientific American* 268, no. 2 (1993): 38–45.

ICBL. 'International Campaign to Ban Landmines - Arguments for the Ban | Problem | ICBL'. http://www.icbl.org/en-gb/problem/arguments-for-the-ban.aspx (accessed May 22, 2023).

ICBL-CMC. 'Landmine Monitor 2022'. *International Campagn to Ban Landmines* (2022). http://the-monitor.org/media/3352351/2022_Landmine_Monitor_web.pdf (accessed February 19, 2023).

Ikpe, Eka, and Sarah Njeri. 'Landmine Clearance and Peacebuilding: Evidence from Somaliland'. *Journal of Peacebuilding & Development* 17, no. 1 (2022): 91–107.

International Federation of the Red Cross. 'Applying BPI: Do No Harm: In a Changing Context' (2016). https://www.ifrc.org/sites/default/files/2021-08/2016_ApplyingBPI-DoNoHarm.pdf (accessed February 26, 2023).

International Mine Action Standards. ‘Environmental Management in Mine Action: 07.13’. https://www.mineactionstandards.org/en/standards/document-detail/?tx_imas_document%5Bdocument%5D=253&tx_imas_document%5Baction%5D=show&tx_imas_document%5Bcontroller%5D=Document&cHash=d179be56d38f797a7bde74d3518e95b7 (accessed May 18, 2023).

———. ‘04.10: Glossary of mine action terms, definitions and abbreviations.docx’ (2019). https://www.mineactionstandards.org/fileadmin/MAS/documents/standards/Glossary_of_mine_action_terms_and_abbreviations_Ed.2_Am.10.pdf (accessed February 23, 2023).

International Mine Action Standards. ‘07.11: Land Release’. https://www.mineactionstandards.org/en/standards/document-detail/?tx_imas_document%5Bdocument%5D=262&tx_imas_document%5Baction%5D=show&tx_imas_document%5Bcontroller%5D=Document&cHash=a6bc6b5efdc872050f10f20085c953bf (accessed May 22, 2023).

International Mine Action Standards. ‘IMAS’. https://www.mineactionstandards.org/ (accessed February 27, 2023).

Jebens, Martin. ‘Protecting the Environment: Mine Clearance in Skallingen, Denmark’. *The Journal of Conventional Weapons Destruction* 19, no. 1 (2015): 37–42. https://commons.lib.jmu.edu/cisr-journal/vol19/iss1/11/.

Johnson, Mark S., Mark Williams, Gunda Reddy, and Michael Quinn. *Wildlife toxicity assessments for chemicals of military concern*. Amsterdam: Elsevier, 2015.

Katie Harris, David Keen, and Tom Mitchell. ‘When disasters and conflicts collide: Improving links between disaster resilience and conflict prevention’. http://resp.llas.ac.cn/c666/handle/2xk7jswq/11028.

Kgathi, D. L., D. Kniveton, S. Ringrose, A. R. Turton, C.H.M. Vanderpost, J. Lundqvist, and M. Seely. ‘The Okavango; a river supporting its people, environment and economic development’. *Journal of Hydrology* 331, 1-2 (2006): 3–17. https://www.sciencedirect.com/science/article/pii/s0022169406002496.

Kim, John H. ‘Korean DMZ Peace Park And The Landmine Problem’. *ILSA Journal of International and Comparative Law*, no. 21 (2015): 556–570.

Kocse, Ryan. ‘Final detonation: How customary international law can trigger the end of landmines’. *Geo. LJ* 103 (2014): 749. https://heinonline.org/hol-cgi-bin/get_pdf.cgi?handle=hein.journals/glj103§ion=24.

Lawrence, Michael J., Holly L. Stemberger, Aaron J. Zolderdo, Daniel P. Struthers, and Steven J. Cooke. ‘The effects of modern war and military activities on biodiversity and the environment’. *Environmental Reviews* 23, no. 4 (2015): 443–460.

Le Billon, Philippe. ‘The political ecology of war: natural resources and armed conflicts’. *Political Geography* 20, no. 5 (2001): 561–584. https://www.sciencedirect.com/science/article/pii/s0962629801000154.

Logan, Rory. ‘IMAS_01.10_Ed.2_Am.10_02’. https://www.mineactionstandards.org/fileadmin/user_upload/IMAS_01.10_Ed.2_Am.10_02.pdf (accessed February 27, 2023).

Machlis, Gary E., ed. *Warfare ecology: A new synthesis for peace and security*. With the assistance of Gary E. Machlis … (et al.). NATO science for peace and security series. Series C, environmental security, 1874-6519. Dordrecht, London: Springer, 2011.

Machlis, Gary E., and Thor Hanson. ‘Warfare Ecology’. *BioScience* 58, no. 8 (2008): 729–736.

Maki K. Habib. *Mechanical Mine Clearance Technologies and Humanitarian Demining Applicability and Effectiveness*. 2002. https://www.researchgate.net/profile/maki-habib/publication/253012180_mechanical_mine_clearance_technologies_and_humanitarian_demining_applicability_and_effectiveness.

Manley, Paul V., Vasit Sagan, Felix B. Fritschi, and Joel G. Burken. ‘Remote Sensing of Explosives-Induced Stress in Plants: Hyperspectral Imaging Analysis for Remote Detection of Unexploded Threats’. *Remote Sensing* 11, no. 15 (2019): 1827.

Martin, Paul S., and Christine R. Szuter. ‘War Zones and Game Sinks in Lewis and Clark's West’. *Conservation Biology* 13, no. 1 (1999): 36–45.

Mbaiwa, Joseph E. ‘Causes and possible solutions to water resource conflicts in the Okavango River Basin: The case of Angola, Namibia and Botswana’. *Physics and*

Chemistry of the Earth, Parts A/B/C 29, 15-18 (2004): 1319–1326. https://www.sciencedirect.com/science/article/pii/s1474706504001780.

McLean, Ian. 'Environmental Applications in Demining'. *The Journal of Mine Action* 9:2 (2006). https://core.ac.uk/download/pdf/153199427.pdf.

Miklín, Jan, and Lukáš Čížek. 'Erasing a European biodiversity hot-spot: Open woodlands, veteran trees and mature forests succumb to forestry intensification, succession, and logging in a UNESCO Biosphere Reserve'. *Journal for Nature Conservation* 22, no. 1 (2014): 35–41. https://www.sciencedirect.com/science/article/pii/s1617138113000794.

Mildner, Stormy-Annika, Gitta Lauster, and Wiebke Wodni. 'Scarcity and Abundance Revisited: A Literature Review on Natural Resources and Conflict'. *International Journal of Conflict and Violence (IJCV)* 5, no. 1 (2011): 155–172; 155-172 Pages / International Journal of Conflict and Violence (IJCV), Vol 5 No 1 (2011). https://www.ijcv.org/index.php/ijcv/article/view/2852.

Mine Action Review. 'Mitigating the Environmental Impacts of Explosive Ordnance and Land Release: Policy Brief No. 1'. https://www.mineactionreview.org/assets/downloads/MITIGATING_THE_ENVIRONMENTAL_IMPACT_OF_EXPLOSIVE_ORDNANCE_AND_LAND_RELEASE.pdf (accessed February 19, 2023).

Mitchell, Stephen A. 'The status of wetlands, threats and the predicted effect of global climate change: the situation in Sub-Saharan Africa'. *Aquatic Sciences* 75, no. 1 (2013): 95–112. https://link.springer.com/article/10.1007/s00027-012-0259-2.

Morin, Anthony. 'Demining and the environment: A primer'. *Journal of Mine Action* 11: 2: 13 (2008). https://core.ac.uk/download/pdf/153198305.pdf.

Moyes, Richard, Richard Lloyd, and Rae McGrath. 'Explosive remnants of war: Unexploded ordnance and post-conflict communities'. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://article36.org/wp-content/uploads/2008/10/erw_report.pdf (accessed May 15, 2023).

Murillo-Sandoval, Paulo J., Kristina van Dexter, Jamon van den Hoek, David Wrathall, and Robert Kennedy. 'The end of gunpoint conservation: forest disturbance after the

Colombian peace agreement'. *Environmental Research Letters* 15, no. 3 (2020): 34033. https://iopscience.iop.org/article/10.1088/1748-9326/ab6ae3/meta.

National Academies of Sciences, Engineering, and Medicine, Sciences, Division on Engineering and Physical, Technology, Board on Army Science and, and Munitions, Committee on Alternatives for the Demilitarization of Conventional. *Alternatives for the demilitarization of conventional munitions.* A consensus study report of the National Academies of Sciences, Engineering, Medicine. Washington, DC: National Academies Press, 2019.

Nunn, Nathan, and Nancy Qian. 'US Food Aid and Civil Conflict'. *American Economic Review* 104, no. 6 (2014): 1630–1666. https://www.aeaweb.org/articles?id= 10.1257/aer.104.6.1630.

Nzengung, V. and Redmond, B. 'On-Site Neutralization of Civil War Munitions Recovered From an Underwater Environment'. *Marine Technology Society Journal* 50, no. 6 (2016). https://www.researchgate.net/profile/valentine-nzengung/publication/312402935_on-site_neutralization_of_civil_war_munitions_recovered_from_an_underwater_environment/links/5cb782c0a6fdcc1d499c49a4/on-site-neutralization-of-civil-war-munitions-recovered-from-an-underwater-environment.pdf (accessed May 16, 2023).

Olson, David M., Eric Dinerstein, Eric D. Wikramanayake, Neil D. Burgess, George V. N. Powell, Emma C. Underwood, and Jennifer A. D'amico et al. 'Terrestrial Ecoregions of the World: A New Map of Life on Earth'. *BioScience* 51, no. 11 (2001): 933.

Oppong, Joseph R., and Ezekiel Kalipeni. 'The Geography of Landmines and Implications for Health and Disease in Africa: A Political Ecology Approach'. *Africa Today* 52, no. 1 (2005): 3–25.

Parks, Peace, and Partnership. University of Calgary Press, null.

Pearce, Fred. 'Collateral Damage: The Environmental Cost of the Ukraine War'. Yale Environment 360. https://e360.yale.edu/features/ukraine-russia-war-environmental-impact (accessed May 18, 2023).

Rai, Nitin D., M. S. Devy, T. Ganesh, R. Ganesan, Siddappa R. Setty, Ankila J. Hiremath, Sarala Khaling, and Priyadarsanan D. Rajan. 'Beyond fortress conservation: The long-term integration of natural and social science research for an inclusive conservation practice in India'. *Biological Conservation* 254 (2021): 108888. https://www.sciencedirect.com/science/article/pii/s0006320720309460.

Rasmussen, Lewis. 'Whither HMA Policy: Linking HMA and Development Assistance'. *Journal of Conventional Weapons Destruction* 24, no. 1 (2020). https://commons.lib.jmu.edu/cisr-journal/vol24/iss1/3/.

Roly, E. 'A Brief History of Mine Detection Dogs', 26: 1: 5 (2022). https://commons.lib.jmu.edu/cgi/viewcontent.cgi?article=2985&context=cisr-journal (accessed February 27, 2023).

Rotberg, Fiona. *Pakistan and India's Siachen Glacier: No Man's Land for Conservation and Peace*. World Security Network, 2006. https://www.diva-portal.org/smash/record.jsf?pid=diva2:45043.

Rupiah, Martin. 'A historical study of land-mines in Zimbabwe, 1963-1995'. *Zambezia* 22, no. 1 (1995). https://pdfproc.lib.msu.edu/?file=/DMC/African+Journals/pdfs/Journal+of+the+University+of+Zimbabwe/vol22n1/juz022001005.pdf (accessed May 14, 2023).

Rutherford, K. and Williams, M. 'Unplanned Explosions of Munition Stockpiles'. *Journal of ERW and Mine Action* (2015). https://commons.lib.jmu.edu/cisr-journal/vol19/iss2/13/ (accessed February 27, 2023).

Salehyan, Idean. 'From Climate Change to Conflict? No Consensus Yet'. *Journal of Peace Research* 45, no. 3 (2008): 315–326.

Sall, Mohamed L., Abdou K. D. Diaw, Diariatou Gningue-Sall, Snezana Efremova Aaron, and Jean-Jacques Aaron. 'Toxic heavy metals: impact on the environment and human health, and treatment with conducting organic polymers, a review'. *Environmental Science and Pollution Research* 27, no. 24 (2020): 29927–29942. https://link.springer.com/article/10.1007/s11356-020-09354-3.

Sandbrook, Chris. 'What is conservation?'. *Oryx* 49, no. 4 (2015): 565–566.

Schuerholz, Goetz. 'KAZA TFCA Project External Review'. http://www.goetzschuerholz.com/wp-content/uploads/2013/10/report13kaza.pdf.

Sims, Kearrin. 'Consolidating Post Conflict Development: Unexploded Ordnance and the Legacy of the Conflict in laos'. *Global CWD Repository* 1124 (2009). https://commons.lib.jmu.edu/cgi/viewcontent.cgi?article=2195&context=cisr-globalcwd (accessed 15/05/23).

Singh, M. 'Attempting palaeoenvironmental reconstructions in war-torn zones: the case of the Okavango source wetlands in Angola'. https://wiredspace.wits.ac.za/server/api/core/bitstreams/2ac000df-172c-4554-a372-4742e3824707/content.

Sosai, Augustin S. 'Illegal Fishing Activity – A New Threat in Mannar Island Coastal Area (Sri Lanka)'. *Transylvanian Review of Systematical and Ecological Research* 17, no. 1 (2015): 95–108. https://sciendo.com/article/10.1515/trser-2015-0051.

Stoldt, Mirja, Thomas Göttert, Carsten Mann, and Ulrich Zeller. 'Transfrontier Conservation Areas and Human-Wildlife Conflict: The Case of the Namibian Component of the Kavango-Zambezi (KAZA) TFCA'. *Scientific Reports* 10, no. 1 (2020): 7964. https://www.nature.com/articles/s41598-020-64537-9.

'THE 17 GOALS | Sustainable Development'. https://sdgs.un.org/goals (accessed February 27, 2023).

Turcotte, Earl. 'Mine Action and Development'. *Journal of Conventional Weapons Destruction* 9, no. 2 (2006). https://commons.lib.jmu.edu/cisr-journal/vol9/iss2/18/.

UNEP. 'Decade on Restoration: Decade on Restoration'. https://www.decadeonrestoration.org/strategy (accessed May 25, 2023).

———. 'CBD/COP/DEC/15/4: Decision adopted by the conference of the parties to the convention on biological diverstiy'. https://www.cbd.int/doc/decisions/cop-15/cop-15-dec-04-en.pdf (accessed May 29, 2023).

United Nations Sustainable Development. '193 Member States Archives - United Nations Sustainable Development'. https://www.un.org/sustainabledevelopment/blog/tag/193-member-states/ (accessed May 19, 2023).

Unruh, Jon D. 'The interaction between landmine clearance and land rights in Angola: A volatile outcome of non-integrated peacebuilding'. *Habitat International* 36, no. 1

(2012): 117–125. https://www.sciencedirect.com/science/article/pii/s0197397511000543.

van Butsic, Matthias Baumann, Anja Shortland, Sarah Walker, and Tobias Kuemmerle. ‘Conservation and conflict in the Democratic Republic of Congo: The impacts of warfare, mining, and protected areas on deforestation’. *Biological Conservation* 191 (2015): 266–273. https://www.sciencedirect.com/science/article/pii/s0006320715300045.

Weir, Doug, Dan McQuillan, and Robert A. Francis. ‘Civilian science: the potential of participatory environmental monitoring in areas affected by armed conflicts’. *Environmental monitoring and assessment* 191, no. 10 (2019): 618.

Wertz, Megan. ‘Somaliland country profile’, no. 10.1 (2006). https://commons.lib.jmu.edu/cisr-journal/vol10/iss1/12/ (accessed May 11, 2023).

WWF. ‘Assessing the environmental impacts of the war in Ukraine’. WWF. https://wwfcee.org/news/assessing-the-environmental-impacts-of-the-war-in-ukraine (accessed May 18, 2023).

Zentelis, Rick, David Lindenmayer, J. D. Roberts, and Stephen Dovers. ‘Principles for integrated environmental management of military training areas’. *Land Use Policy* 63 (2017): 186–195. https://www.sciencedirect.com/science/article/pii/s0264837716311218.