MAG
saves lives builds futures

IMPACT
Shaping practices
Influencing policies
Impacting lives

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Advancing the understanding of the relationship between Mine Action, Land Use Change, Environment and Climate

Cambodia Pilot Study

May 2025

Foreign, Commonwealth & Development Office

IMPACT Shaping practices Influencing policies Impacting lives

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About IMPACT Initiatives

Created in 2010, IMPACT Initiatives is a Geneva-based NGO and the largest independent data provider in contexts of crisis. It aims to promote evidence-based decisions, shape practices and influence policies in humanitarian and development settings, to positively impact the lives of communities.

IMPACT Initiatives has an established field presence in over 30 countries and is composed of more than 400 staff. Through our team of assessment, data, geospatial, and thematic specialists, we implement people-centred research and set standards for collecting and analysing rigorous, high-quality data in complex environments.

IMPACT Initiatives takes an initiative-based approach to structuring its programming, with REACH, AGORA and PANDA, in direct partnership with aid actors

MAG

saves lives builds futures

About MAG

MAG is a humanitarian, development and peacebuilding organisation that limits the causes and addresses the consequences — both immediate and long-term — of conflict and armed violence.

Our work saves lives, eases suffering, protects human rights and contributes to sustainable peace for the hundreds of millions of people affected. It fosters stable and secure societies and is a key enabler of progress towards the 2030 Sustainable Development Agenda.

We find, remove and destroy landmines, cluster munitions and unexploded bombs from places affected by conflict. We also provide risk education programmes, so people can live, work and play as safely as possible until the land is cleared.

We also help to reduce armed violence by educating communities about the risks of small arms and light weapons, and by assisting in the destroying, marking and safe storage of weapons and ammunition.

MAG uses its expertise, experience and influence to bring about policy changes that benefit communities affected by conflict and armed violence.

Since 1989, we have helped over 20 million people in 70 countries rebuild their lives after war. In 1997, MAG shared the Nobel Peace Prize for its role in banning landmines.

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Funded by FCDO

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Abbreviations and Acronyms

CHA	*Confirmed Hazardous Area*
CMAS	*Cambodia Mine Action Service*
DAP	*Data Analysis Plan*
EO	*Explosive Ordnance*
FCDO	*Foreign Commonwealth & Development Office (United Kingdom)*
HMA	*Humanitarian Mine Action*
KI	*Key informant*
MFGD	*Mapping Focus Group Discussion*
NMAA	*National Mine Action Authority*
NTS	*Non-technical survey*
UXO	*Unexploded Ordnance*

Definitions

C1 task site – Cancelled land - defined as previously suspected land that has been put back into productive use without accident or evidence of mine in the past 3 years as per Cambodia Area Reduction Policy . The Humanitarian Mine Action (HMA) involves the non-technical surveys (NTS) on these sites.

C3 task site – Cleared land – defined as formally cleared by accredited mine clearance operators adhering to the national standards (CMAS) .

Clearance in the context of mine action, refers to tasks or actions to ensure the removal and/or the destruction of all exploded ordnance (EO) hazards from a specified area to a specified depth or other agreed parameters as stipulated by the NMAA/Tasking Authority .

Control Area: A non-contaminated randomly selected crop land and forested areas (polygons) in a 1-km buffer area outside of MAG plots to serve as a baseline for understanding general land use patterns in the area, not specifically related to mine action.

Explosive Ordnance (EO) is interpreted as encompassing mine action’s response to the following munitions: mines, cluster munitions, unexploded ordnance, abandoned ordnance, booby traps, other devices (as defined by CCW APII), improvised explosive devices .

Land cover: refers to the physical material at the surface of the earth. This includes natural elements such as vegetation, water bodies, and bare soil, as well as artificial structures like buildings and roads

Land release: the process of applying all reasonable effort to identify, define, and remove all presence and suspicion of EO through non-technical survey, technical survey and/or clearance.

Non-technical Survey (NTS) refers to the collection and analysis of data, without the use of technical interventions, about the presence, type, distribution and surrounding environment of EO contamination, in order to define better where EO contamination is present, and where it is not, and to support land release prioritisation and decision-making processes through the provision of evidence .

Task Site (in Mine Action): A task site in mine action refers to a specific area where mine clearance activities are conducted. This includes the identification, removal, and disposal of landmines and unexploded ordnance (UXO) to ensure the area is safe for use.

Technical Survey refers to the collection and analysis of data, using appropriate technical interventions, about the presence, type, distribution and surrounding environment of EO contamination, in order to define better where EO contamination is present, and where it is not, and to support land release prioritisation and decision making processes through the provision of evidence.

Executive Summary

Humanitarian Mine Action (HMA) plays a critical role in restoring land access and enabling conflict-affected communities to rebuild livelihoods. However, the environmental impacts of mine clearance activities are rarely assessed or systematically integrated into operational planning. In Cambodia and globally, post-clearance land use changes — including agricultural expansion, deforestation, and soil degradation — risk undermining the long-term sustainability of cleared land.

Without better understanding and management of these impacts, mine action interventions will continue to unintentionally contribute to biodiversity loss, carbon sequestration decline, and increased community vulnerability to climate change. A lack of evidence-based guidance for environmentally responsible mine action leaves a major gap in ensuring that clearance activities align with broader sustainability and resilience goals.

To address this knowledge gap, MAG (Mines Advisory Group), in partnership with IMPACT Initiatives and supported by the United Kingdom's Foreign, Commonwealth and Development Office (FCDO), conducted a pioneering environmental impact study in Cambodia. The research aimed to systematically assess how MAG's mine clearance activities between 2014 and 2023 have influenced land use, biodiversity, soil health, and carbon dynamics.

The study combined geospatial analysis of remote sensing data with participatory community engagement in three provinces — Battambang, Pailin, and Ratanakiri — representing different contamination types (landmines and cluster munitions/ UXO). By integrating scientific data with community perspectives, the research provides an evidence base to strengthen environmentally sensitive mine action practices both in Cambodia and globally.

The study revealed that land cover change is a significant consequence of mine clearance activities. Cleared areas experienced a rapid transition from forest and shrubland to agricultural land, with cropland expansion often beginning even before formal clearance occurred. This trend highlights the strong livelihood pressures on local communities and suggests that clearance activities act as a catalyst for accelerated land transformation. Vegetation loss was also substantial, with remote sensing data showing that 44% of cleared sites experienced their highest canopy height reduction during the year of clearance. Community members reported a noticeable disappearance of forest resources, such as medicinal plants and wild foods, and an increase in invasive plant species, all contributing to a decline in local biodiversity.

The findings also point to widespread soil degradation linked to clearance and subsequent agricultural practices. Soil compaction, loss of moisture retention, and increased erosion were common across cleared sites, undermining the long-term productivity of the land. This was further corroborated by community perceptions, which noted a decline in soil fertility, greater reliance on chemical fertilizers, and an increased risk of agricultural runoff affecting water quality. Additionally, clearance activities contributed to the loss of carbon sequestration potential, with significant declines in biomass and Net Primary Productivity (NPP) observed across the study areas. Communities also reported localized increases in temperatures and reduced availability of natural shade following vegetation removal.

While communities overwhelmingly viewed mine clearance as positive in terms of improving safety and enabling agricultural expansion, they also expressed concern about the environmental degradation that followed. The evidence indicates that without complementary environmental management practices, clearance activities can unintentionally reduce land resilience, diminish long-term agricultural viability, and increase vulnerability to climate-related stresses. These findings underscore the urgent need for mine action programs to integrate environmental safeguards and sustainable land management strategies into all phases of clearance operations.

The Cambodia pilot study reveals that mine clearance, while essential for human safety and economic recovery, can also drive unintended environmental degradation if not accompanied by proactive environmental safeguards. Clearance accelerates land use change, facilitates agricultural expansion, and disrupts local ecosystems, particularly when sustainable land management interventions are not implemented. In response to these findings, there is an urgent need for the mine action sector to integrate environmental profiling and climate risk assessments into task planning, ensuring that environmental factors are considered from the outset. Furthermore, clearance techniques must be carefully selected to minimize soil disturbance and vegetation loss, thereby reducing the risk of long-term land degradation. In addition, supporting post-clearance land recovery through sustainable agricultural practices and reforestation initiatives is critical to restoring ecological balance and enhancing land resilience. Systematic monitoring of environmental outcomes, leveraging tools such as remote sensing and participatory community approaches, is also essential to track progress and inform adaptive management strategies. By embedding environmental considerations throughout the mine action project cycle, humanitarian actors can deliver more holistic outcomes that not only safeguard human security but also protect ecosystems and strengthen community resilience to climate change. MAG remains committed to leading by example, advancing environmentally responsible mine action practices, and contributing to global efforts to align humanitarian demining with sustainable development goals.


MAG
Danger !! Mines !!

Introduction

Humanitarian Mine Action (HMA) plays a vital role in addressing the immediate and long-term impacts of landmines and unexploded ordnance (UXO), restoring access to land and enabling communities to rebuild their livelihoods. Safe access to land enables increased agricultural production to meet the demand of local and national markets, contributing to food security and food systems. However, the environmental and social impacts of these clearance activities are often understudied, leaving gaps in understanding how land use changes post-clearance and influences broader ecological and community systems.

Previous research has demonstrated that landmines and UXOs significantly hinder land productivity and biodiversity. For instance, demined areas often experience shifts in land cover as communities reclaim cleared land for agriculture, residential and community infrastructure, or conservation purposes. Further to this the type of contamination also plays an important role: landmines and cluster munitions have different spatial distributions and environmental impacts, as well as differing community perceptions around them. These changes can drive both positive and negative environmental outcomes, including land restoration, vegetation recovery, or, conversely, land degradation and habitat loss due to intensive human activity.

Additionally, HMA technical survey and clearance operations often require vegetation clearance, soil tilling, and the use of heavy machinery, which can further impact environmental conditions and post-clearance land use. Vegetation clearance can lead to soil erosion and loss of habitat while the use of machines can lead to compaction and degradation of soil.

Recent advances in geospatial analysis have provided tools to measure these impacts systematically. Studies utilizing remote sensing techniques, such as Sentinel-1-2 and Landsat imagery, have been particularly effective in assessing land cover change and vegetation dynamics. These methods have been successfully applied to measure carbon sequestration potential and soil health changes in agricultural landscapes, offering insights into the long-term environmental benefits and challenges associated with the clearance of mines and UXOs.

In Cambodia, where decades of conflict have left vast areas contaminated by landmines, cluster munitions and other UXOs, the intersection of land use, environmental conditions, and community livelihoods is of critical importance (see Figure 1). Previous studies in the region have highlighted the rapid conversion of cleared land into agricultural use, often with significant implications for soil quality, carbon sequestration, and water resources. However, these studies have primarily focused on isolated aspects, lacking a comprehensive framework that integrates environmental and social dimensions.

It is crucial to analyse the impact of different technical survey and clearance techniques, such as non-technical surveys (C1 task sites), technical survey (C2 task sites) and the use of manual and machines clearance (C3 task sites), against the types of contamination (landmines vs UXOs), to develop targeted strategies for the environmental impact assessment of Humanitarian Mine Action (HMA). This analysis is essential for mitigating negative environmental impacts and promoting sustainable land use post-clearance. Understanding these processes better will provide evidence for post-clearance landscape recovery.

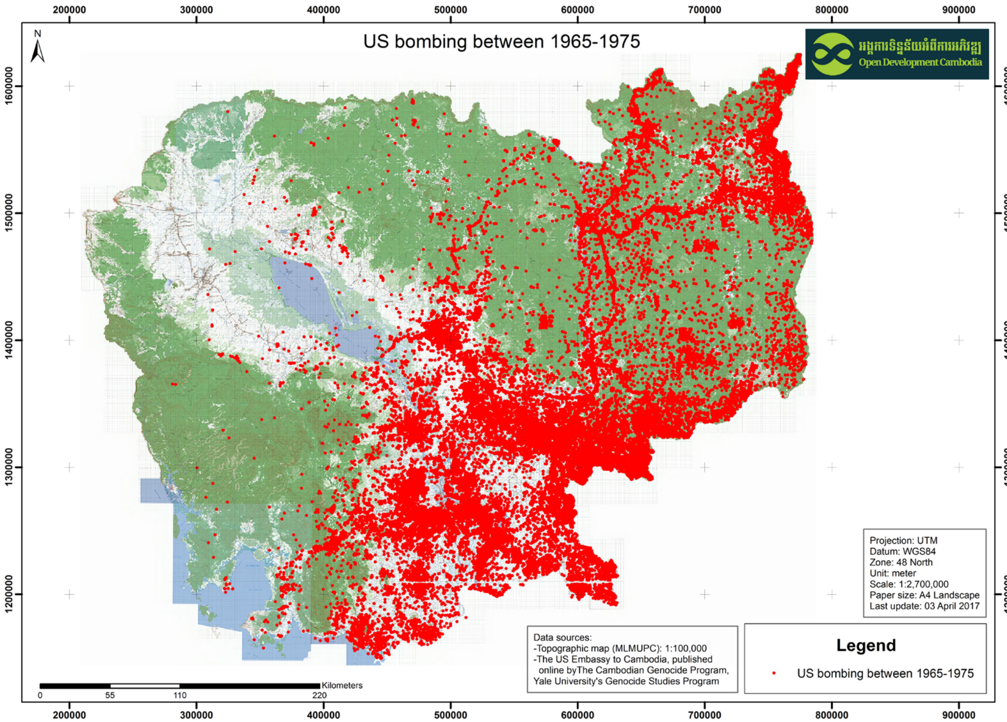

Figure 1: Map of past bombing locations in Cambodia, highlighting the scale of potential UXO contamination

The type of contamination is a critical factor to consider when analysing land use patterns in Cambodia. In the western provinces, landmines remain the predominant threat (see Figure 2). These are particularly hazardous due to their ability to cause severe harm and their tendency to be buried in the soil, making detection and clearance more challenging. In contrast, the eastern provinces face a higher prevalence of unexploded ordnance (UXOs), especially cluster munitions, which are often more visible but can also be found sub-surface. It is noted that land in UXO-affected areas is often cultivated despite the presence of contamination. These differences in contamination type influence pre-clearance land use patterns, with notable variations between the eastern and western provinces.

This research will contribute to the growing body of knowledge on the environmental dimensions of mine action, offering actionable insights for organizations like MAG to optimize their programming for both human security and environmental outcomes. Reflecting on lessons learned and methodological challenges will also provide a foundation for replicability and standardization across global mine action contexts. Advocating for environmental considerations in mine action policies globally will foster a holistic approach balancing human security, sustainable, environmentally responsible socio-economic development.

With the findings from this work, the aim is to advocate and support the ongoing development of a standardized approach and framework for environmental analysis & reporting across the mine action sector.

Figure 2: Map of provinces selected for pilot study

Methodology

IMPACT Initiatives conducted a geospatial analysis using remote sensing of land use and land condition changes to understand the environmental implications of humanitarian demining activities in a sample of MAG task sites in Cambodia released between 2014 and 2023. To contextualize the findings, IMPACT supported MAG in analysing community intentions and perceptions of land use before and after clearance activities through a participatory approach that engaged local communities to provide qualitative and spatial insights into land use and cover changes. These discussions explored how land is utilized and perceived across cancelled and cleared task sites and control plots, examining differences in pre- and post-clearance land use, the types of crops cultivated, and any emerging concerns about hazards or environmental impacts post-clearance.

Geographic Coverage

Battambang and Pailin provinces in the west, and Ratanak Kiri province in the east, were selected for analysis—under the guidance of MAG colleagues—to enable a comparative study of different contamination types. Battambang and Pailin represent areas heavily affected by landmines, while Ratanak Kiri reflects contamination primarily from cluster muntions and UXOs This geographic and contamination-based contrast was essential to understanding how different forms of legacy ordnance contamination and clearance operations impact the environment and communities over time.

Research, data collection and analysis methods

The study employed both secondary and primary data collection methods to provide a comprehensive understanding of the environmental impacts of humanitarian mine action (HMA).

Secondary data collection involved remote sensing analysis (see Annex 1) alongside an extensive literature review of existing environmental screening tools and impact assessments relevant to demining. This included international, national, and MAG-specific standards such as IMAS 07.13, MAG's Global Technical Standards, and frameworks developed by the Environmental Impact of Mine Action (EIMA) working group. The goal was to generate a detailed, lessons-learned overview of current practices, identify key challenges and barriers, and provide actionable recommendations to strengthen the integration of environmental considerations into HMA programming and assessments.

Primary data focused on capturing community perceptions and intentions related to post-clearance land use and environmental changes. This was done through Mapping Focus Group Discussions (MFGDs) and Key Informant Interviews (KIIs) with local community representatives. Semi-structured questionnaires were used in conjunction with reference maps that displayed selected MAG task sites via satellite imagery, allowing participants to reflect on specific areas of concern. The design of these tools was informed by remote sensing analysis of land use change and insights from MAG's community liaison teams in Battambang and Ratanak Kiri, gathered during a training session held in Battambang. Site selection took into account various factors including contamination context (types of contamination, clearance timelines, and task types), environmental variability (changes in land cover and livelihood diversity), and logistical considerations (proximity to settlements and clustering of sites for operational efficiency). The qualitative data collected was analysed using IMPACT's Data Saturation and Analysis Grid (DSAG), providing structured insights into community experiences and environmental perceptions across the study areas.

Task Site Comparison

To assess the environmental and community impacts of land clearance, the analysis focused on two site typologies representing different pathways for land release. The first category included C3 'cleared' task sites, which are areas where clearance activites were conducted by MAG in accordance with national mine action standards. These sites were formally cleared and released based on confirmed contamination. The second category comprised C1 'cancelled' task sites, which were previously suspected of contamination but were released following non-technical surveys. These areas showed no evidence of contamination or accidents over the past three years and have since been returned to productive use without requiring clearance .

To contextualize the findings and distinguish the impacts of mine action from broader environmental and land use trends, the study also included a set of control sites. These consisted of nearby land parcels—specifically cropland and forested areas—that were neither confirmed nor suspected of contamination. Randomly selected within a 1-kilometer buffer around MAG task sites, these control areas provided a baseline for understanding general land use patterns unrelated to mine action activities (see Figure 3). This comparative approach allowed for a more nuanced evaluation of how different types of land release may influence environmental conditions and land use trajectories.

Land cover and land use changes were assessed across four time intervals—baseline (2003), to provide a long-term perspective and contextualize changes), one year before clearance, one year after clearance, and the most recent data from 2023—with sites grouped and analyzed based on the year HMA tasks were complete.

Time intervals used in the analysis:

- 2003 (Baseline year)

- One year before clearance

- One year after clearance

- 2023 (Most recent year)

These intervals were applied across C1 (cancelled), C3 (cleared), and control plots to assess trends in land cover transitions.

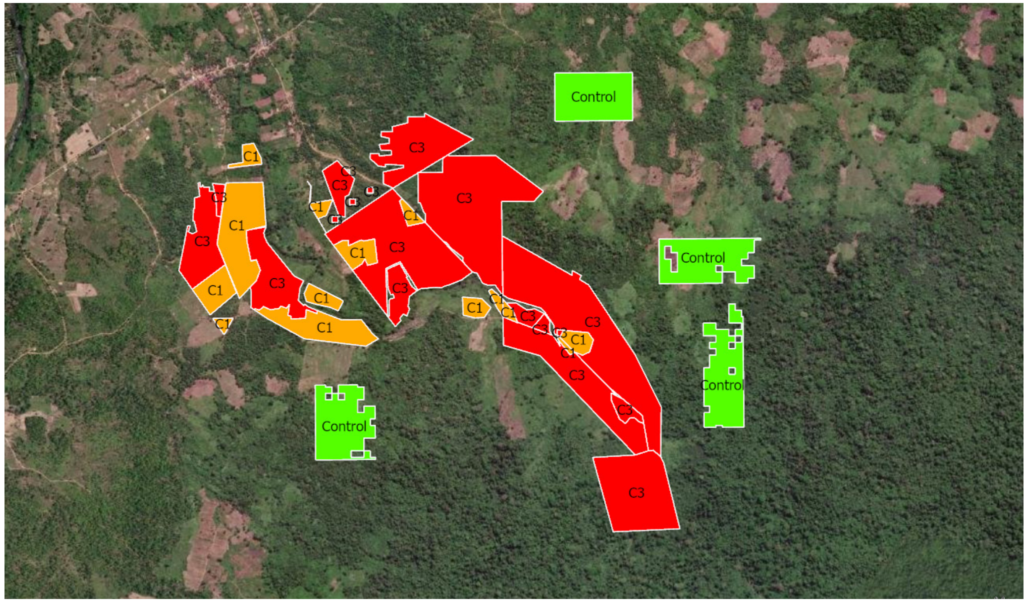

Figure 3: Map showing selected task sites and sample 'control' sites

Environmental Impact of Mine Action

This section unpacks the findings of the Cambodia pilot study on the environmental and social impacts of humanitarian mine action (HMA), based on remote sensing analysis and Mapping Focus Group Discussions (MFGDs) conducted across Battambang, Pailin, and Ratanak Kiri provinces. Each thematic finding includes a detailed narrative integrating geospatial analysis with insights from local communities, along with a concluding reflection that draws both strands together.

Land Cover Change Observations

Remote sensing data using Landsat 8 SERVIR datasets reveal a clear shift in land cover across the study areas over a twenty-year period. In western Cambodia, cleared (C3) sites saw forest cover drop from 60% to 39%, while cropland expanded from 31% to 43%. Even cancelled (C1) sites showed similar trends, suggesting land use change often began before formal clearance. Rice cultivation in C1 plots rose from 6% in 2003 to 30% post-clearance. Evergreen forests, shrubland, and grasslands declined sharply, with some plots showing near-total disappearance by 2023. In the east, plantations and rubber crops emerged after clearance, reflecting broader land use shifts linked to both clearance and pre-existing pressures.

Control sites, which were not contaminated or cleared, exhibited slower and more stable land use trends, reinforcing the association between HMA activities and land transformation. Figure 4 satellite time series shows the intensification of agricultural land use around released sites.

Figures 5 and 6 on next page show examples of land use change analysis conducted on the C1 (cancelled) and C3 (cleared) task sites. These sites were grouped by their release year and analysed collectively. They highlight the consistent pattern of cropland expansion, forest decline, and shifts in other land cover types both before clearance, after clearance, and in the most recent year.

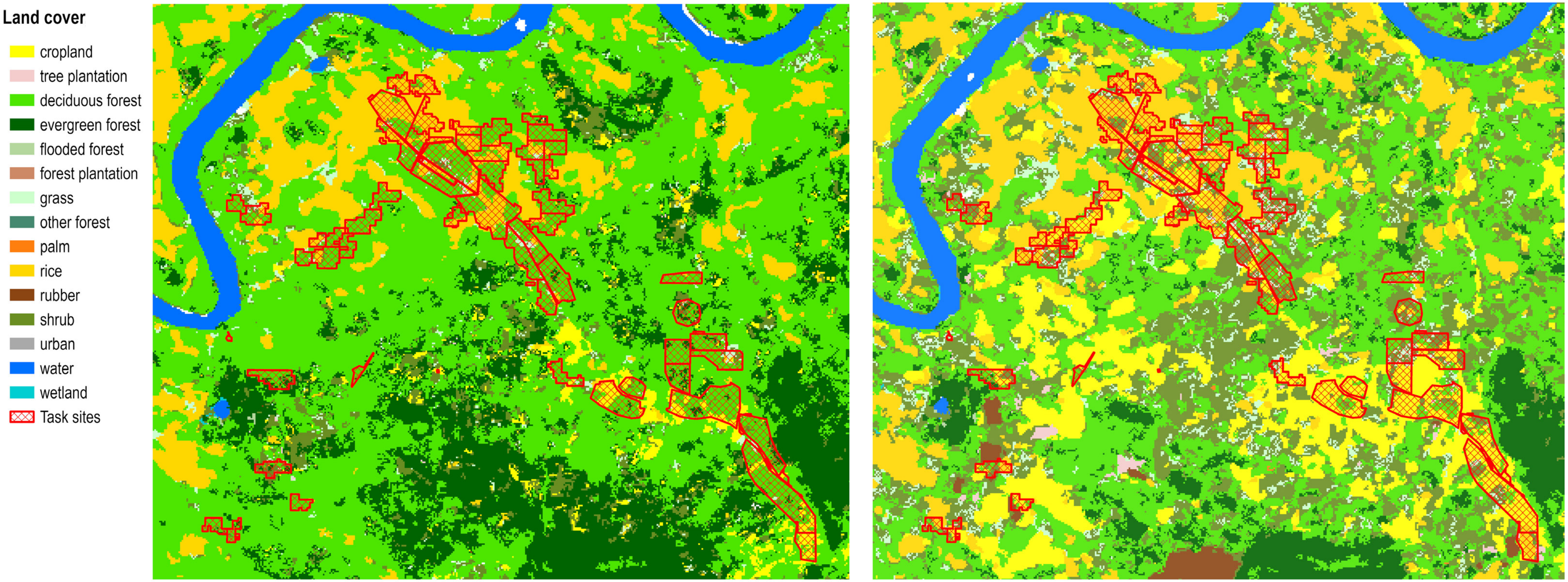

Figure 4: Landcover change around selected task sites from 2013 (L) to 2023 (R)

The land cover analysis across C1 and C3 task sites, as well as control plots, reveals notable trends in deforestation, agricultural expansion, and shifts in land use over time. These changes are observed across the four key time periods.

Deforestation

High levels of deforestation were recorded between 2003 and 2013–2014, primarily involving the conversion of deciduous forest into cropland. Although the rate of deforestation has slowed, it continues to be observed in recent years. In C3 task sites in the West, deciduous forest cover decreased from 60% the year before clearance to 51% the year after, and further to 39% by 2023. C1 sites in the West, which were less forested prior to clearance, followed a similar pattern, with forest cover declining from 29% to 25% post-clearance, and to 21% by 2023.

As demonstrated in Figure 7-8 on next page, in several cases, both C1 and C3 sites appear to have been converted from forest to cropland before formal clearance. Deciduous forests showed more substantial changes than evergreen forests. Remaining forested areas are largely within locally protected mountainous zones.

It is notable that tree plantations, including rubber, were not present in 2003 or in the year before clearance but began appearing after clearance, particularly in Eastern C3 plots.

Cropland Expansion

Cropland area increased significantly across all task site types, especially in the year before and after clearance. As shown in Figure 7, in C3 sites in the West, cropland rose from 31% to 43%, while in C1 sites, it increased from 41% to 49%.

A similar trend was observed in control plots, though with slightly smaller increases. Rice cultivation expanded particularly in C1 and C3 sites in the West, with rice fields in C1 areas increasing from 6% in 2003 to 28% before clearance and to 30% post-clearance. This suggests that land was already in use prior to the completion of demining.

Reports from 27 out of 40 Mapping Focus Group Discussions (MFGDs) confirmed pre-clearance land use, with references to crops such as cassava, cashew nut, coconut, bean, durian, longan, quinoa, soybean, pumpkin, and sesame. Rice was mentioned more frequently in the East (6 MFGDs) than in the West (3 MFGDs). Remote sensing data also show a higher proportion of cropland in C1 sites compared to C3 sites before clearance.

It is interesting to note that Control plots remained more stable a year before and after the clearance, with more diverse vegetation, compared to C1 and C3 (see Figure 8). This may confirm the clearance effect of the land use change.

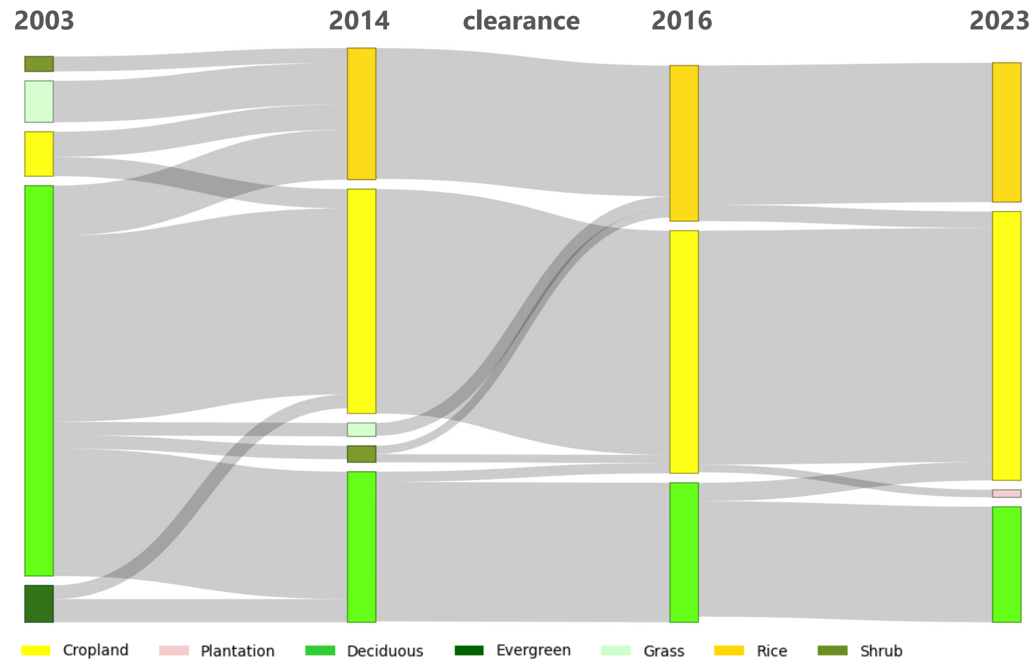

Figure 5: Land cover change across C1 plots cancelled in 2015 in the Western provinces

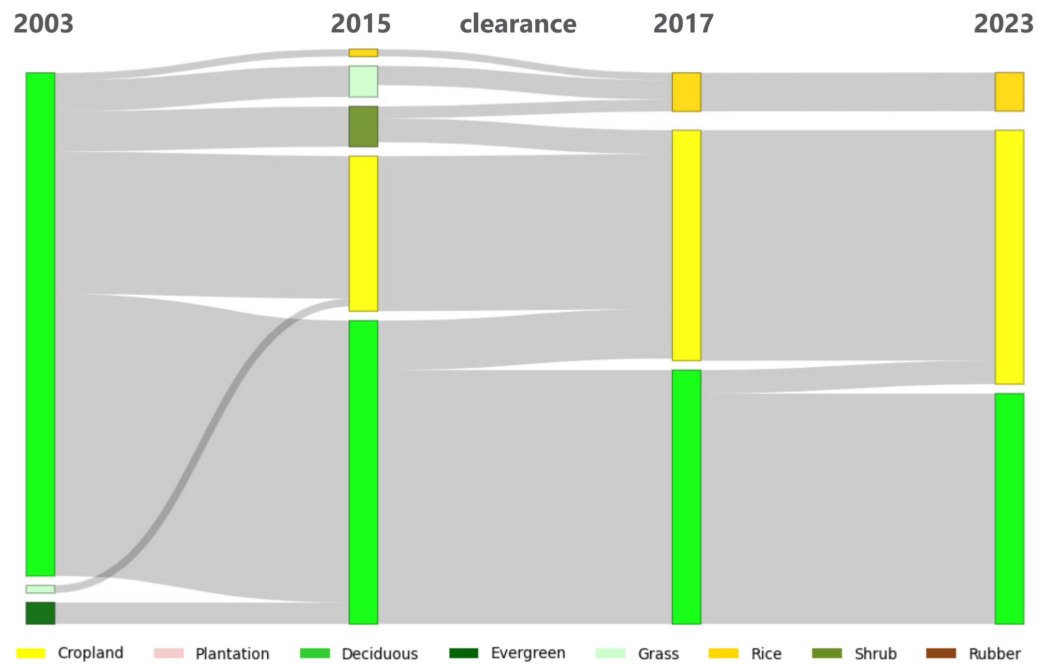

Figure 6: Land cover change across C3 plots cleared in 2016 in the Western provinces

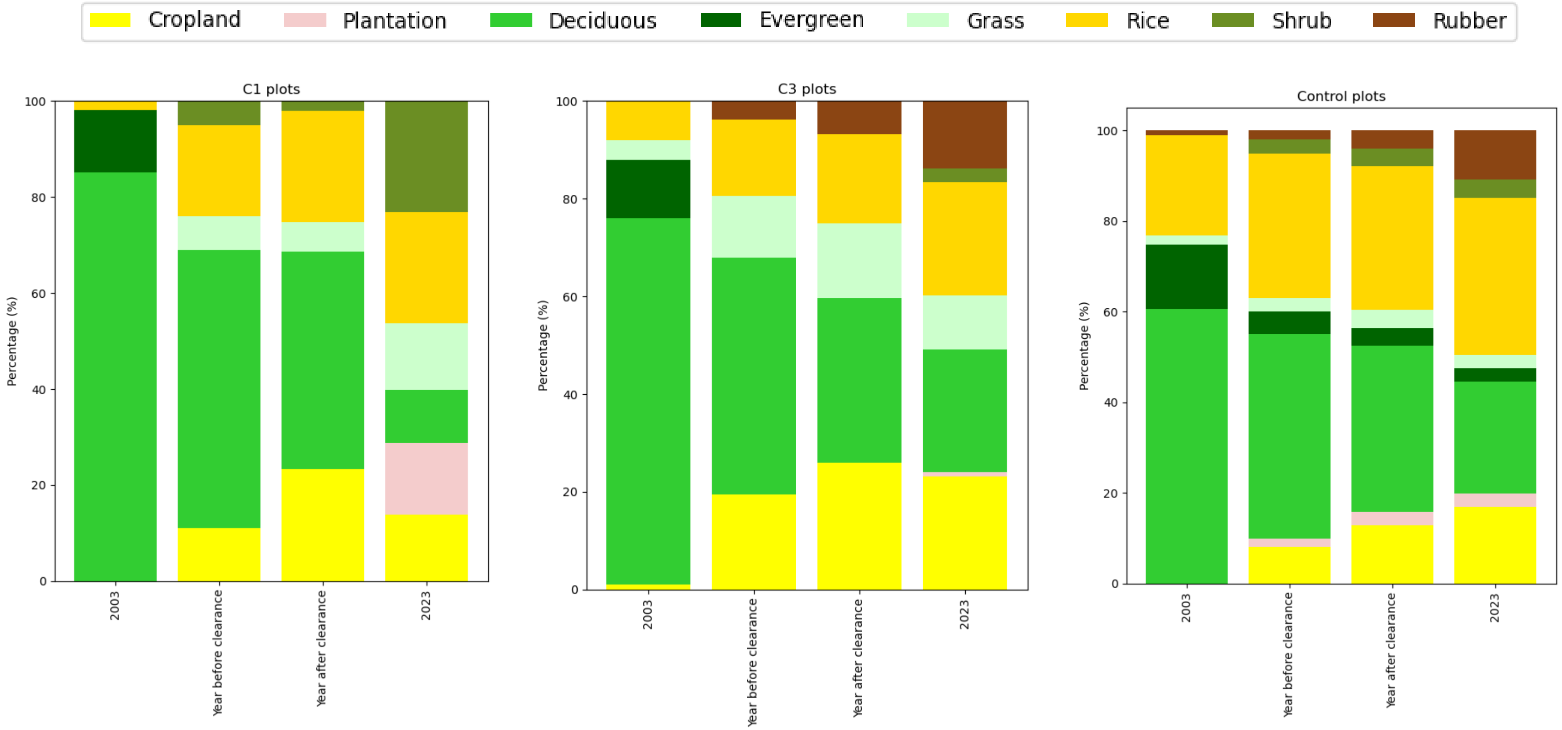

Figure 7: East province land cover change trends (%)

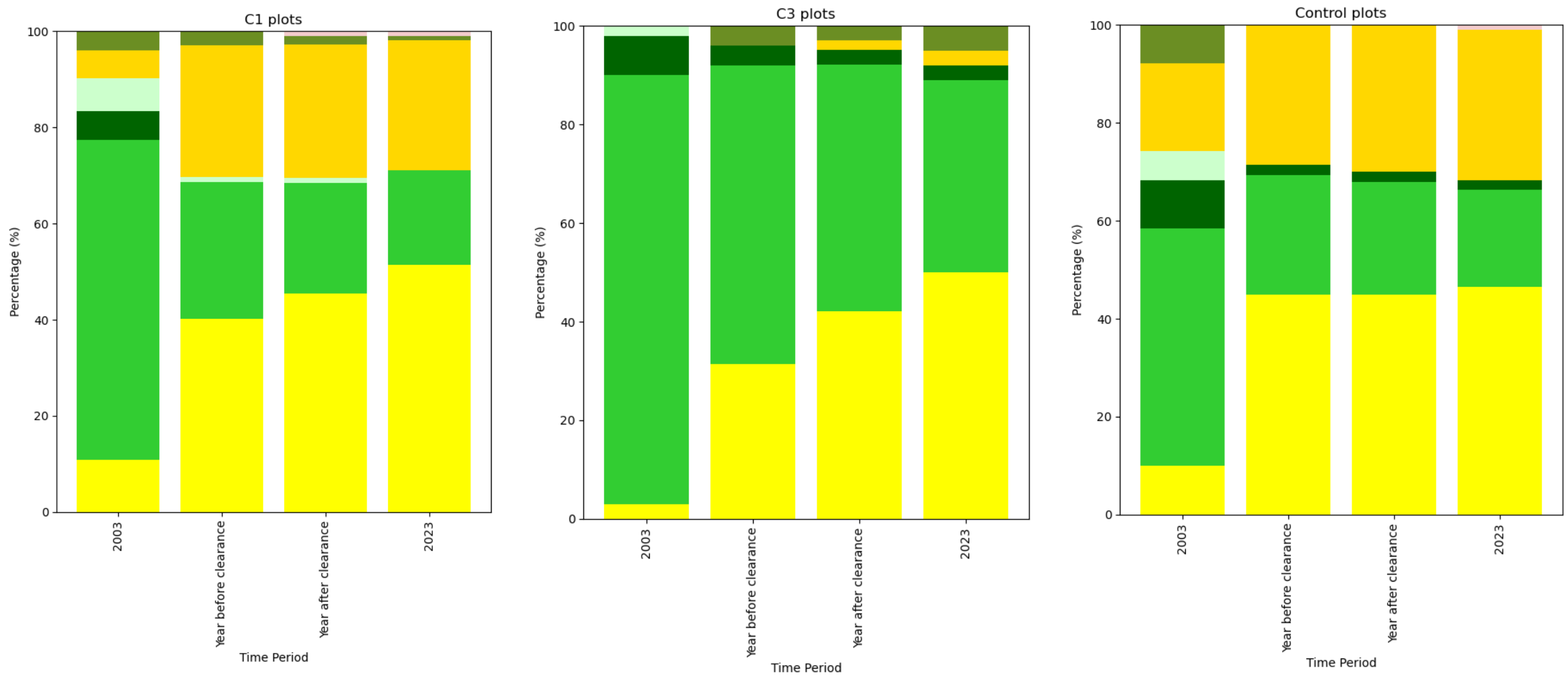

Figure 8: West provinces land cover change trends (%)


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Community perceptions of land clearance, as expressed during the MFGDs, were generally positive. Participants widely viewed clearance as enabling agricultural expansion and supporting livelihoods. In nearly all focus group discussions (34 out of 40), participants reported involvement in preparing land for agriculture during pre-clearance.

The most commonly reported method for land preparation was manual clearing—using axes and knives—which was mentioned in 24 of the 40 groups. Many participants expressed fear of using mechanical methods due to the suspected presence of unexploded ordnance (UXO) and landmines. The second most frequently mentioned method was burning vegetation, noted in 22 groups, with this practice reported slightly more often in landmine-affected western provinces (15 out of 24).

Communities acknowledged that land cover and land use changes occurred both before and after humanitarian mine action (HMA) land release, suggesting that these changes are influenced not only by clearance but also by other drivers.

After clearance, participants consistently reported that cleared land was generally used for agriculture. Agricultural productivity appeared to be the primary factor in land use decisions, with less productive land often abandoned in favor of newly cleared, more fertile areas. In many locations, farmers expanded cropland using modern equipment, such as tractors, and transitioned from small-scale to larger-scale farming.

Most FGD participants expressed awareness of the negative environmental impacts associated with clearance methods. They highlighted several immediate environmental impacts following clearance, particularly those linked to vegetation removal. The clearing of plant cover—especially on sloped land—was reported to trigger soil erosion, reduce soil moisture retention, and lead to the disappearance of traditional and medicinal herbs. Communities also observed in some areas a rapid spread of invasive species, such as thorny bushes and fast-growing weeds, which compete with crops and hinder agricultural productivity.

Over time, cleared land is increasingly brought under cultivation through more intensive agricultural practices, often involving the use of heavy machinery. This intensification accelerates soil degradation and increases reliance on chemical fertilizers and irrigation. As a result, the risk of water pollution from agricultural runoff rises, while also contributing to the broader decline of wildlife habitats and biodiversity.

KEY TAKE AWAYS

The remote sensing analysis reveals significant trends of cropland expansion and forest and rangeland decline before and after clearance. Significant amount of land cover / land use change both before and after clearance pointing towards other drivers of land use change as well as a potential ‘clearance effect’ on land use change.

Control plots experience a similar overall trend of cropland expansion and yet are more stable a year before and after clearance further supporting this duality. MFGD participants in both the East and West, reported using land before clearance, with nearly all mentioning preparing land for agriculture, and some communities reported self-clearing land by burning or manually removing landmines and UXOs, despite known risks. These findings underscore the importance of integrating environmental considerations into mine action workflows, enhancing planning by developing environmental profiles and factoring in climate risks, engaging with local communities to understand land use intentions and environmental concerns and continuously monitoring environmental outcomes using tools like remote sensing to guide adaptive learning and improve future interventions.

Vegetation Loss and Biodiversity Decline

Vegetation loss was significant at mine action sites, with remote sensing data indicating that in 33% of cancelled (C1) and 44% of cleared (C3) sites, the most severe canopy height reduction occurred during the clearance year. This directly impacted carbon sequestration capacity. Community feedback confirmed this trend, especially in eastern provinces, where 40% of focus groups reported the disappearance of forest products like mushrooms and medicinal plants. Clearance activities, while not involving tree cutting, often remove other vegetation, indirectly facilitating logging and further deforestation.

Figure 9 shows the percentage of task sites with the highest canopy height loss in relation to clearance year, highlighting that the most severe vegetation reduction occurred in the clearance year.

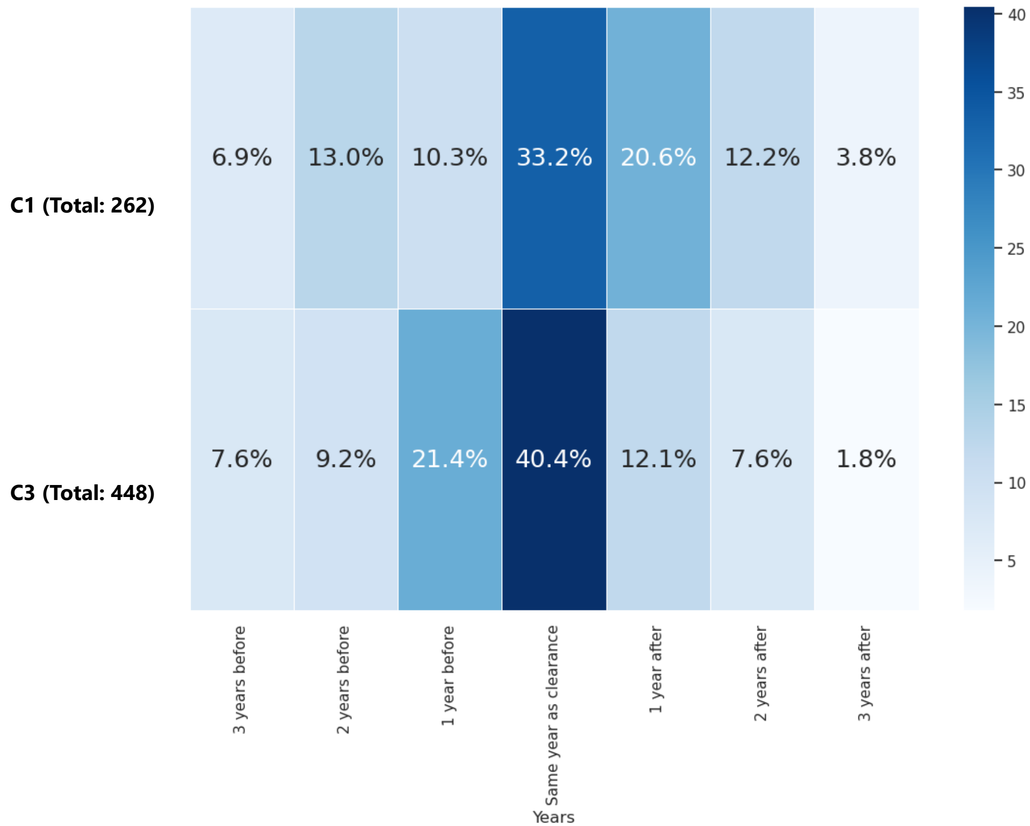


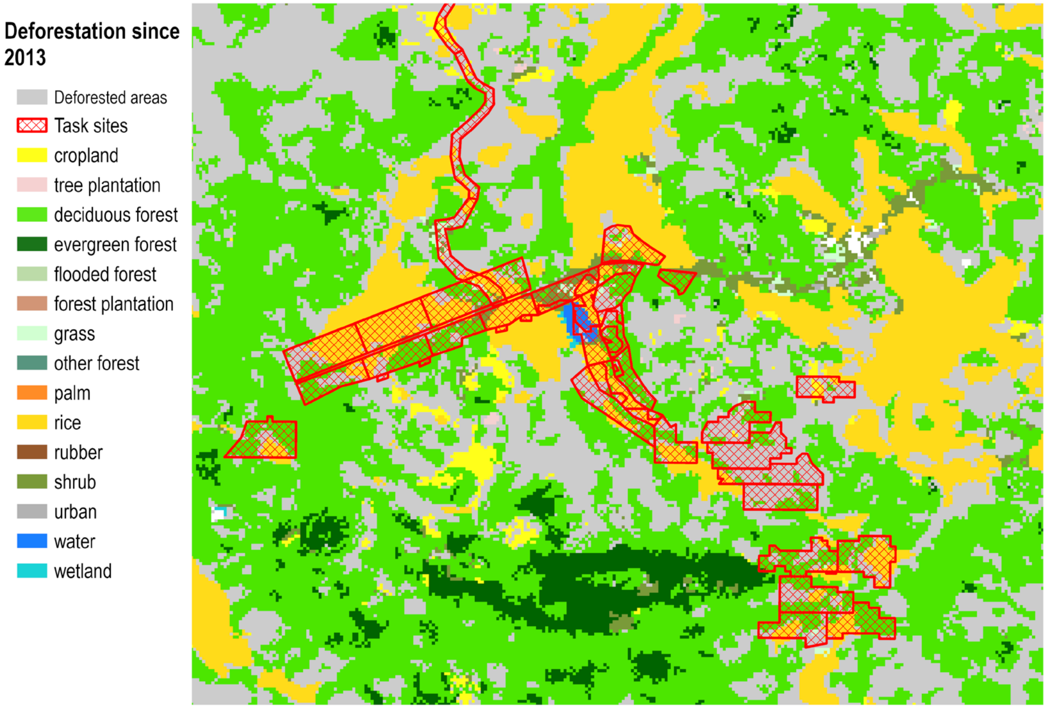
Figure 9: % of task sites of the highest canopy height loss

In the West, although biodiversity concerns were less frequently raised, 25% of MFGDs still identified a loss of natural vegetation with one participant reporting:

"After clearance, heavy machines such as tractors and excavators are used to prepare the land for agriculture. This is not from clearance operation because whenever we do agriculture, we need to prepare land and vegetation needs to be cleared." Male MFGD Participant.

Further, the remote sensing analysis suggests the expansion of agricultural lands as noted above has led to significant biodiversity loss, particularly in deciduous forests. The analysis shows that community-clearance (outside of the red shaded task sites below in Figure 10) methods, such as burning, have the most severe impact on wildlife habitats, leading to the disappearance of various species. The findings also indicate the spread of invasive plants, which further disrupts the ecosystem.

In addition, MFGD participants reported longer term spread of invasive plants, particularly thorny vegetation (locally called Bonla Yuon), long grass, and vine species that were not present before clearance. Additionally, weeds were reportedly reducing productivity and destroying crops, making farming difficult.



KEY TAKE AWAYS

Remote sensing analysis of canopy height dynamics reveals a significant correlation between clearance year and vegetation loss, with 33% of C1 and 44% of C3 task sites experiencing the most severe canopy height reduction in the clearance year. Community feedback corroborates these findings, indicating that the expansion of agricultural lands may lead to biodiversity loss and the spread of invasive plants, which disrupt ecosystems and reduce agricultural productivity.

The findings underscore the need to view mine action not only through a safety and access lens, but also as a key moment of ecological transition. To reduce unintended ecological damage, mine actors can aim to:

- Minimize vegetation clearance during operations, especially in biodiverse areas;

- Adapt clearance methods to avoid heavy machinery where possible, to reduce soil compaction and preserve ground vegetation;

- Train clearance teams on environmental impacts, including identification and protection of key natural features;

- Collaborate with communities post-clearance to support soil restoration and control the spread of invasive species, using tools like mulching or managed reforestation.

Finally, it appears important to document and monitor vegetation change over time, using geospatial tools already in use, to improve decision-making and share lessons.

Soil Degradation and Erosion

Community members raised several concerns about soil degradation linked to land use, mine action, and local environmental conditions. Heat and water scarcity were identified as some of the most pressing challenges. MFGD participants reported that the focus on short-term agricultural gains was contributing to long-term soil degradation. Newly cleared land was often initially more productive than surrounding plots, but over time, the soil became dry, compacted, and less fertile. This decline in soil quality led many farmers to increase their use of chemical fertilizers and pesticides. Some eventually abandoned degraded plots, while others noted that chemical use appeared to encourage the spread of invasive plants, such as thorny vegetation. In addition, erosion and flooding—particularly in hilly areas—were cited as growing concerns, with erosion making some cleared land unsuitable for farming.

These reported patterns were reflected in the Normalized Difference Water Index (NDWI) and Normalized Multiband Drought Index (NMDI) soil moisture analysis conducted across the task sites. Data was averaged by crop growing season (January to March) and annually averaged to reflect both the water component in open soil and in vegetation. The results show lower moisture values starting from 2017 in C3 task sites (red line of the graphs in Figure 11) with similar tendencies when comparing the annually-averaged and rainy season (crop growing season) datasets. This trend was even more evident with NMDI compared with NDWI.

A similar trend is visible when selecting a subset of the task sites released in a specific year which better visualizes the clearance timestep, particularly for task sites released in 2018 (see Figure 12 below).

The graph in Figure 12 displays the NMDI values for sites released in 2018, marked by the vertical dashed line. The results show that, after having similar NMDI values in 2014, there is a clear decline in moisture values for C3 task sites starting from 2016, while C1 and Control sites maintain similar values. To further the analysis, a visual retrospective analysis of high-resolution satellite imagery, available via Google Earth revealed clear evidence of soil erosion following land clearance processes. However, it is unclear whether the soil erosion clearly seen on the imagery in Figure 13 is attributable to the clearance itself or to subsequent intense agricultural activities, especially involving heavy machinery for land cultivation.

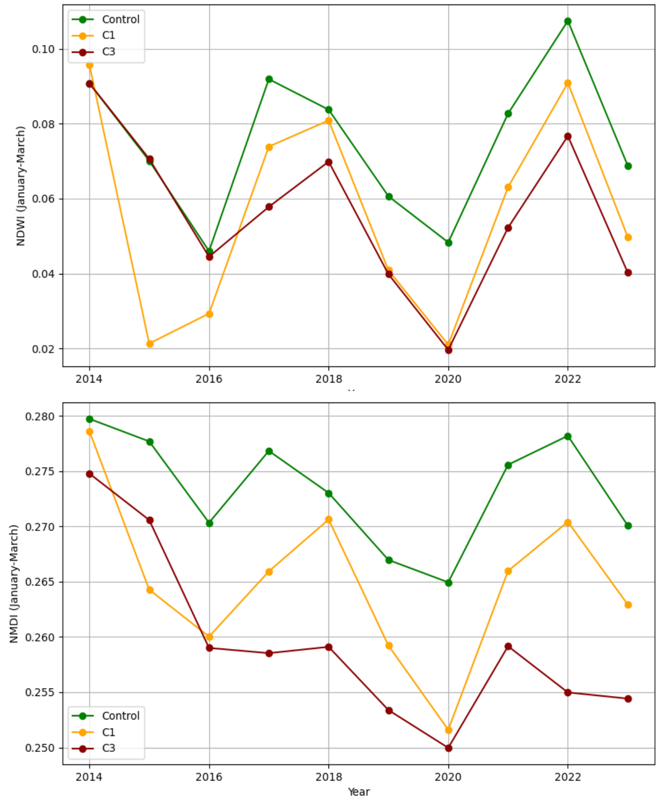


Figure 11: NDWI (top) and NMDI (bottom) crop growing season averages from January to March

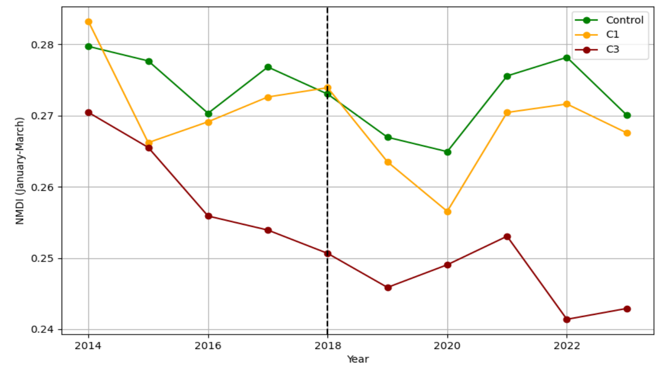
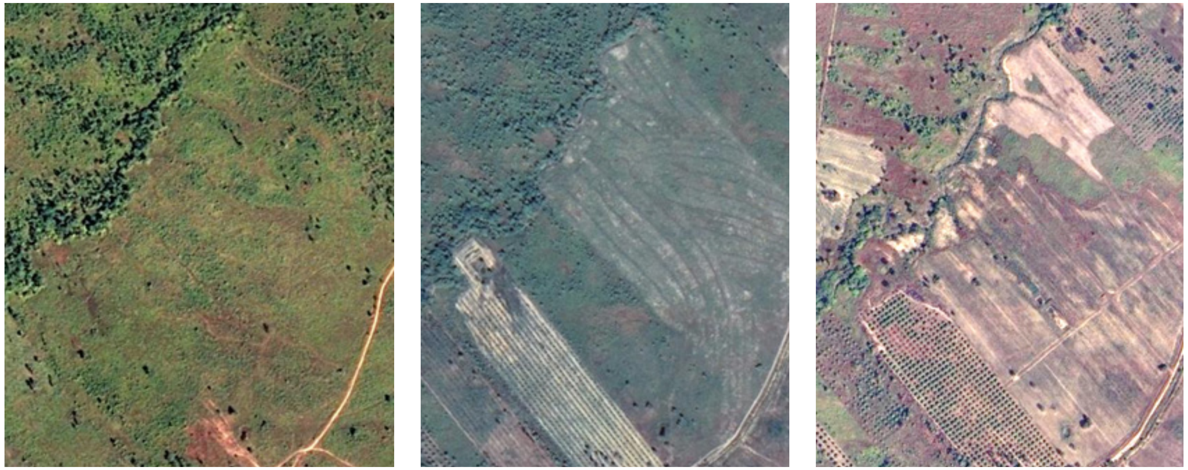


Figure 12: NMDI crop growing season averages from January to March within the task sites re-leased in 2018



December 2016 (pre-clearance) | **December 2019 (clearance year)** | **January 2025**

Figure 13: Examples of soil erosion in a C3 task site before and after clearance

KEY TAKE AWAYS

Evidence of soil erosion is clearly detectable using high-resolution imagery. MFGD participants point to potential community and clearance-related causes. Analysis of soil moisture indexes reveals differences between task and control sites. FGD participants indicate environmental change and unsustainable practices as potential contributing factors.

Implementing environmentally conscious clearance techniques, erosion control measures (e.g. minimize vegetation clearance during operations, especially on slopes prone to erosion), and training personnel on environmental impacts can minimize soil compaction and long-term degradation.

Other concrete recommendations include integrating simple soil protection measures into clearance SOPs, such as leaving organic matter on the ground, maintaining vegetative buffers, or staggering clearance in sensitive areas. Mine actors can also collaborate with development actors post-clearance to introduce sustainable land management practices that prevent degradation, such as crop rotation, mulching, or contour planting.

Addressing soil degradation risks early can contribute to help communities build resilience to climate extremes (e.g. floods and drought), and align mine action efforts with long-term environmental sustainability and food security.

Carbon Sequestration and Biomass Loss

Carbon sequestration was assessed using tree canopy height dynamics and Net Primary Productivity (NPP). The GEDI L2A data provided estimates of biomass loss, while the MODIS dataset (2011-2023) was used to calculate NPP. The results show a significant reduction in carbon sequestration potential due to vegetation loss and soil degradation. The biomass loss graph shows a similar tendency, to the tree canopy height loss, while it illustrates the amount of biomass loss in relation to the clearance year (see Figure 14).

Net Primary Productivity (NPP) is the amount of carbon that remains after accounting for plant respiration. It represents the net energy available for plant growth and biomass accumulation. It was used as another indicator of carbon sequestration change.

The results indicate that the highest NPP loss occurred one to two years before rather than during the clearance year (see Figure 15). A similar trend is visible in the regional breakdowns of this analysis, which could further point to pre-clearance land use change, which is in line with trends revealed in the land cover analysis and focus group discussions.

The difference between biomass loss and NPP loss trends may be attributable to two key factors:

- The GEDI Canopy Top Height dataset only runs from 2019-2023 whereas the MODIS dataset analysed included a longer range, from 2011-2023. This time series difference may account for the differing trend in NPP loss, factoring in several additional pre-clearance years.

- This difference may also be attributed to the resolution of the MODIS data itself, which likely captures some influence from surrounding areas, potentially reflecting agricultural activities in plots of land adjacent to task sites.

Community feedback mirrored these observations. In 12 MFGDs, participants noted an increase in local temperature and reduced availability of shade, suggesting a lived experience of diminished tree cover.

Feedback from MFGD participants indicates that task site clearance may have an indirect effect on deforestation. While clearance doesn't involve tree cutting, the removal of other vegetation facilitates logging that is later conducted by community members.

These observations did not reference carbon directly but clearly reflected changes in local microclimates and vegetative density.

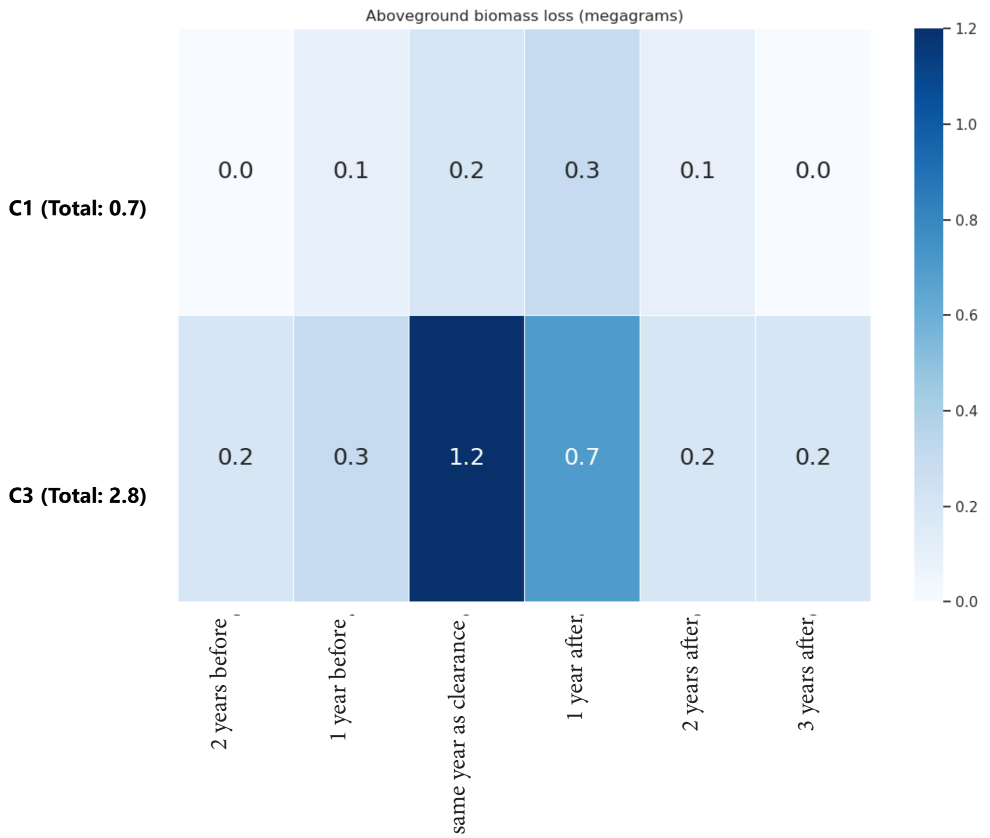


Figure 14: Biomass loss per task site

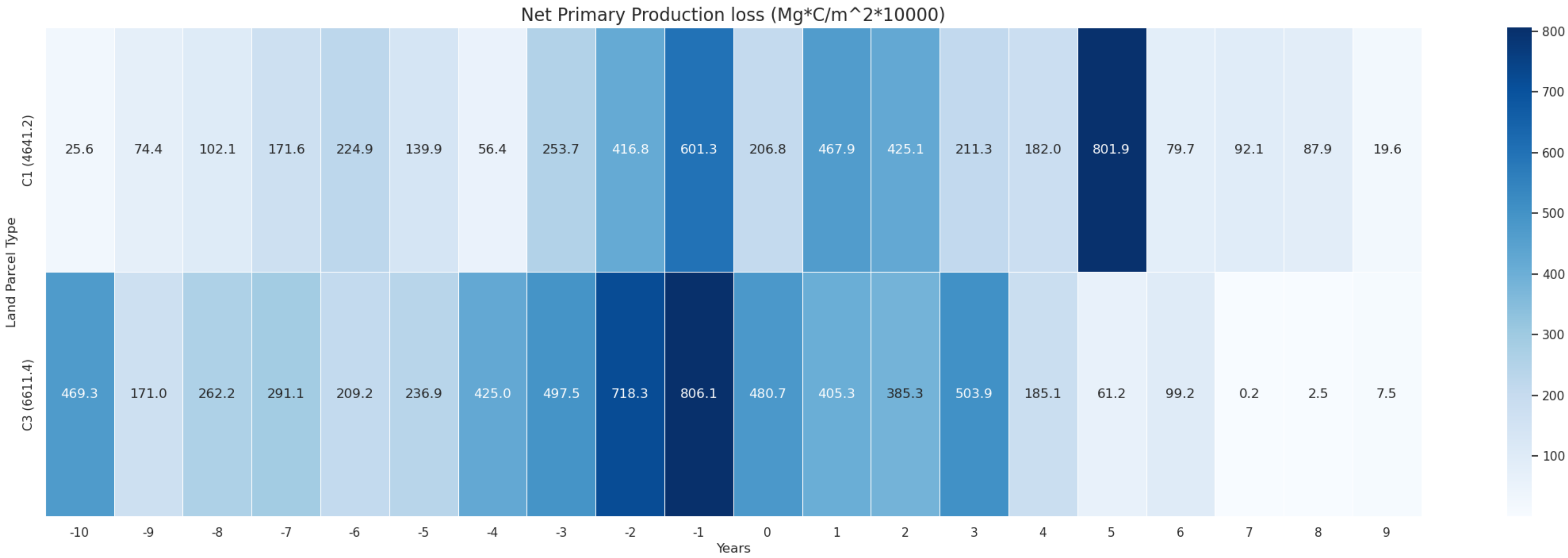


Figure 15: Net Primary Productivity loss in relation to clearance

KEY TAKE AWAYS

Carbon sequestration is clearly impacted by biomass and net primary productivity loss. Unsurprisingly, biomass loss similarly peaks in the clearance year, just as canopy height loss (same dataset). However, NPP loss appears to peak in the years prior to clearance, which is not out of step with trends revealed in the land cover analysis and focus group discussions. Supporting reforestation, ecosystem, and landscape recovery projects appears to be crucial to mitigate environmental degradation.

Consequences for the Mine Action Sector

While this study was an initial pilot with a defined scope and clear limitations (see Annex 3), the findings are illustrative and offer valuable insights with broader implications for the mine action sector. In Cambodia, several key trends were identified that highlight the complex relationship between land clearance, land use change, and environmental impacts.

Community feedback revealed that demand for agricultural land is a significant driver of land use change—even before formal mine clearance takes place. Communities, motivated by economic necessity and lack of alternative land, begin using land that is still officially suspected to be contaminated. In 27 out of 40 Mapping Focus Group Discussions (MFGDs), participants reported cultivating such land prior to formal clearance. This includes preparing land for agriculture and, in some cases, engaging in informal "self-clearance"- through burning vegetation or even manually removing unexploded ordnance. These practices expose community members to severe risks.

This underscores a critical challenge: land use changes are not solely the result of demining operations, but are influenced by broader socioeconomic pressures that shape how land is accessed and managed.

Following clearance, land becomes more accessible, often prompting further conversion for agricultural or other productive uses. While this expansion supports economic recovery and local development, it also introduces environmental pressures, including soil degradation, deforestation, reduced water retention, and disruption of local ecosystems. The study found that these pressures are not only linked to mine clearance but also to community-led practices which can further compromise soil quality and biodiversity.

The findings emphasize the need for the mine action sector to recognize and respond to both the direct and indirect environmental impacts of clearance in both the near and long term. For instance, different clearance methods have varying environmental footprints with mechanical clearance techniques indicated to lead to soil compaction, erosion, and loss of moisture. Categorizing these impacts—as direct or indirect, avoidable or unavoidable, and short-term or long-term—is essential for developing effective and context-specific mitigation strategies.

A range of broader environmental consequences were observed, including:
- Air, water, and soil pollution
- Disruption or destruction of habitats and wildlife
- Deforestation and reduced carbon sequestration
- Soil fertility loss and landscape degradation
- Alteration of local ecosystem functions

- Increased vulnerability to climate impacts such as drought, flooding, and extreme weather events

These findings point to the opportunity—and the responsibility—for mine action actors to integrate environmental safeguards into their operational planning and implementation. Doing so not only protects natural systems but also enhances the sustainability of post-clearance land use and community resilience to climate change.

Importantly, community perceptions were central to this study, complementing geospatial findings and offering grounded insights not visible through remote sensing. While communities overwhelmingly view demining as a positive intervention—due to improved safety and increased agricultural access—they are also aware of environmental consequences such as declining soil quality and loss of biodiversity. Community members provided a range of practical recommendations for mitigating these effects.

During Mapping Focus Group Discussions (MFGDs), community members shared that they generally did not expect MAG to address environmental concerns and had not previously considered mine action from an environmental perspective. Their primary focus remains on safety and gaining secure access to land for farming. However, through lived experience, many have observed the environmental consequences of demining and offered practical recommendations to mitigate these impacts:

1. Minimize the Environmental Impact of Clearance Techniques
Community members suggested reducing the use of heavy machinery where possible, as it often compacts soil and damages vegetation. Instead, they advocated for the use of low-impact, environmentally sensitive clearance methods that better preserve land quality.

2. Support Sustainable Land Recovery After Clearance
Communities emphasized the need for support in rehabilitating cleared land. This includes providing seeds, tools, and training in sustainable agricultural practices such as reforestation, the use of organic fertilizers, water conservation, and long-term land management techniques that restore soil health and productivity.

3. Encourage Retention of Vegetation Post-Clearance
Leaving cut vegetation on the ground rather than removing or burning it was identified as a beneficial practice. This helps retain soil moisture, encourages natural decomposition, and contributes to soil fertility.

4. Implement Erosion Control Measures
To prevent soil erosion and land degradation, communities recommended installing physical structures such as berms, grass buffers, and water retention systems. These interventions help stabilize the land, particularly in areas vulnerable to runoff and weather extremes.

5. Strengthen Community Involvement in Land Recovery Planning
Engaging local communities in post-clearance planning processes ensures that land recovery efforts are grounded in local knowledge, needs, and priorities. This participatory approach promotes sustainability and fosters a stronger sense of ownership and stewardship.

6. Ensure Ongoing Clearance to Secure Land Access
Communities stressed the importance of continuing clearance operations to guarantee that land remains safe for productive use. Safety is seen as the foundation for both environmental recovery and long-term wellbeing.

These recommendations underscore the value of locally informed, participatory approaches in designing environmentally responsible mine action programs. By integrating community perspectives and increasing environmental awareness in planning and operations, mine action actors can help achieve more holistic, resilient, and sustainable outcomes.

Recommendations for Environmentally Sensitive Mine Action Programming

Why environmental considerations are important for mine actors

Humanitarian Mine Action (HMA) restores access to land, enabling communities to rebuild their livelihoods and contributes to food security. However, demining activities can have significant environmental impacts, including soil erosion, loss of biodiversity, and changes in land use patterns. Integrating environmental considerations into mine action ensures sustainable land use and supports long-term community resilience.

Mine action organizations must comply with national mine action environmental policies, organizational environmental policies, relevant environmental regulations, and donor requirements and IMAS 07.13.

The International Mine Action Standard (IMAS) 07.13 on Environmental Management and Climate Change outlines the following requirements:

- Reduce greenhouse gas emissions and strengthen resilience and adaptive capacity to climate-induced impacts.

- Apply land release principles (as per IMAS 07.11, 08.10, 08.20, and 08.30) to minimize the number of square meters processed without compromising the quality of demining activities.

- Reflect principles of ISO 14001:2015 (Environmental management systems) and ISO 9001:2015 (Quality management systems).

- Collect data on the environment and climate adaptation risks to make informed decisions.

Opportunities for integration into mine action workflows

Integrating environmental considerations into humanitarian mine action (HMA) workflows presents an important opportunity to enhance both the sustainability and effectiveness of clearance operations. This section outlines practical entry points across the project cycle—from planning and survey through to implementation, land release, and outcome monitoring.

Programme Planning and Local Engagement

At the outset of mine action programming, developing environmental profiles for task site areas can lay the groundwork for more environmentally responsible interventions. This involves gathering relevant information on national environmental policies, regulatory frameworks, and donor or stakeholder environmental safeguards. Factoring in climate risks, environmental constraints, and climate change projections—such as flood risk or local heat island effects—can help prioritize areas at greater risk of long-term degradation or hazard exposure.

Local engagement is equally critical. Community consultations offer valuable insights into land use intentions, local priorities, and specific environmental concerns. However, to move beyond information gathering, MAG should also support the development of community-led land recovery planning processes. Facilitating participatory decision-making ensures that post-clearance land use strategies reflect community needs, build local ownership, and embed environmental sustainability from the start. This approach strengthens the relevance and long-term impact of interventions while raising awareness of environmental risks and opportunities for climate adaptation and mitigation.

Furthermore, identifying and fostering partnerships with local environmental or development organizations can amplify impact and enhance community-led initiatives. MAG and its partners should collaborate on activities such as reforestation, soil conservation, sustainable agriculture, and climate resilience projects that align with local priorities. These partnerships should operate through shared planning, joint implementation, and capacity building, integrating environmental best practices into post-clearance land use. By working alongside organizations with ecological expertise and strong community ties, mine action interventions can deliver lasting environmental and socio-economic benefits.

Additionally, links between mine action and disaster risk management should be explored, particularly in areas vulnerable to climate-related hazards, noting existing broader disaster risk reduction efforts across the humanitarian, development peace nexus.

Non-Technical Survey

The pre-clearance non-technical survey phase presents an ideal opportunity to begin collecting baseline environmental data. This may include soil type and quality, existing mitigation measures, and current land management practices. Conducting site-level environmental impact assessments at this stage can help anticipate potential impacts and inform the selection of appropriate clearance methods and timelines, as well as aligning with the recently updated IMAS 07.13 standards for environmental impact assessment.

Importantly, this phase should also define how environmental information will be integrated into the broader information management (IM) workflow, ensuring that environmental data is accessible and actionable across teams and decision-makers.

Field Implementation

During field operations, implementing environmentally conscious clearance techniques is essential. Training mine action personnel on the environmental consequences of their work—and equipping them with assessment tools—can reduce unintentional harm to ecosystems. Clearance techniques should be chosen not only for their technical efficiency but also based on intended future land use, with the aim of minimizing soil compaction and long-term degradation.

Erosion control measures, such as berms and grass buffers, can be implemented during and after clearance to protect soil and water systems. Partnering with local actors on reforestation or water conservation initiatives can further support land recovery. In addition, proper disposal of cleared materials and the strategic planning of access routes are vital to limiting environmental disruption and preserving habitats.

Environmental monitoring should be embedded into standard operational procedures, including the documentation of techniques used, observed impacts, and potential mitigation measures. Operational planning should also incorporate emergency response protocols for critical or major environmental incidents.

Land Release and Handover

The land release and handover phase offers a critical opportunity to conduct post-clearance environmental impact assessments. These assessments can help determine how the land is recovering and identify any ongoing risks or needed interventions. Integrating environmental considerations into community liaison activities, including Explosive Ordnance (EO) risk awareness campaigns, ensures that communities are informed not only about the benefits but also about the responsibilities associated with different types of land reuse.

Post-clearance recovery support should be tailored to the intended land use, whether for agriculture, residential development, infrastructure, or conservation. In agricultural areas, partnerships with local organizations focused on sustainable land management, biodiversity conservation, and climate-smart farming practices can enhance long-term recovery. In urban or peri-urban settings, partnerships should focus on promoting sustainable urban planning, soil remediation where needed, green infrastructure development, and climate-resilient land use. Community involvement in land recovery planning is critical across all contexts to prevent further degradation, enhance sustainability, and foster a strong sense of local ownership.

Providing farmers, developers, and land users with training and resources—whether in sustainable agricultural techniques, environmentally conscious construction practices, or ecosystem restoration—can further contribute to improved stewardship of released land. Engaging subject matter experts in fields such as agriculture, urban planning, environmental management, and disaster risk reduction can ensure that training and recovery efforts are technically sound, locally appropriate, and aligned with best practices. Additionally, links between mine action and disaster risk management should be strengthened, particularly in areas vulnerable to climate-related hazards, to ensure that post-clearance development contributes to building safer, more resilient communities.

Outcome Monitoring and Assessment

Monitoring the long-term environmental outcomes of HMA is essential for adaptive learning and continuous improvement. Repeated environmental impact assessments can track changes in land conditions, identify emerging issues, and guide future interventions. These assessments should aim to capture longer-term trends, as many impacts may only become apparent years after clearance.

Advanced tools such as remote sensing and unmanned aerial vehicles (UAVs) can be leveraged to generate detailed topographic and vegetation data, enabling more precise and efficient monitoring. This technology-supported approach can help ensure that mine action contributes not only to human security but also to environmental resilience and sustainability.

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www.impact-initiatives.org

@IMPACT Initiatives

+41 22 566 29 63

9 chemin de Balexert
1219 Geneva
Switzerland

geneva@impact-initiatives.org

MAG saves lives builds futures

www.maginternational.org

@mag-mines-advisory-group

+44 (0) 161 236 4311

Suite 3A, South Central
11 Peter Street
Manchester, M2 5QR
United Kingdom

info@maginternational.org