Chapter 4.

# The application of machines to ground preparation


### *Summary*

*Ground preparation machines are typically underused in mine clearance operations. They can contribute significantly to the performance of a manual or MDD clearance programme, especially if machine use is tailored to the area. In order to quantify the productivity improvements that result, more demining organisations need to separate the recording of land cleared manually behind a machine from the land cleared manually without machine assistance.*

*Machines conducting* ***surface ground preparation*** *are limited by the degree of preparation they provide for follow-up clearance teams. The maximum productivity increase is restricted to areas with low levels of metal contamination. Machines conducting* ***sub-surface ground preparation*** *are also limited by the degree of preparation they perform for follow-up clearance teams, but do hasten the excavation process perfomed by manual deminers and have the potential to extend dog working-day periods into the cooler months of the year. Machines conducting* ***sub-surface with metal removal ground preparation*** *offer the most advantages as they remove all common obstacles for follow-up clearance. Such machines remove the threat of tripwires, so that the deminer is no longer required to perform a tripwire-detection drill. They remove vegetation so that the deminer no longer spends time cutting away vegetation down to ground level, and they remove the majority of metal contamination.*


## Introduction

### *Background*

In Chapter 3, we looked at the potential for mechanical systems to be employed for area reduction to enable land to be returned to the civilian population more quickly and efficiently. In this chapter, we look at the topic of ground preparation.

Many different types of machines were deployed in demining operations with the intent of completely clearing minefields. In the early days, the machines used then generally demonstrated that complete clearance could not be achieved with a high degree of confidence. However, demining organisations quickly saw the potential for machines to be used to prepare ground for subsequent clearance methods. Currently, clearance after the use of machines is conducted by both manual and MDD techniques.

In general, machines such as flails and tillers are used in a ground-preparation role and focus on removing tripwires (used to initiate some mine types) and vegetation. Tripwires are difficult, hazardous and time consuming to deal with. If the machine removes the tripwire and vegetation, both manual deminers and MDD teams can then concentrate on searching for mines.

A large variety of machines are used in other forms of ground preparation. Examples include excavators used to scoop up and lay out debris in built-up areas. Without a machine to do this, a deminer would have to laboriously excavate through piles of debris by hand, making the task very slow. Rollers or steel wheels have also been used to prepare minefields to reduce the workload of follow-up clearance. This detonates a large percentage of the mines so less time is spent excavating for mines and destroying every one uncovered.

There are three general deployment methods for ground preparation machines: machines that are driven by an operator into a minefield, machines that are controlled remotely and used inside the minefield (both types known as intrusive machines), and machines that are only operated from established safe or previously cleared land (known as non-intrusive machines).

When machines are used in a ground-preparation role, it is now assumed that some mines might be missed. The emphasis today is on improving the productivity of follow-up clearance.

## Study aims

The aims of this sub-study were to:

- identify the advantages of mechanically preparing the ground;
- document the results of ground-preparation experiences;
- recommend an optimised ground-preparation methodology; and
- discuss issues related to optimising machine use

## Categories of ground preparation

The following are the three different categories of ground preparation:

**Surface ground preparation:** the removal of vegetation and the tripwire threat. This category generally involves two types of machines. One operates and travels along cleared areas with commercial cutters attached to hydraulic arms that reach out and cut in the un-cleared areas. The other involves small remotely-controlled specialised vegetation cutters.

**Sub-surface ground preparation:** the removal of vegetation and the tripwire threat with the tool penetrating the ground to a certain depth. This method usually involves flails or tiller-type tools attached to armoured machines that operate in un-cleared areas.

**Sub-surface with metal removal ground preparation:** the removal of vegetation, the tripwire threat, penetration of the ground and the removal of metal contamination. This currently involves the same type of machine as for sub-surface ground preparation with the addition of a magnet towed behind or on board the machine, collecting metal.

## Surface ground preparation: case study HALO Cambodia

### *Introduction*

Vegetation cutting was one of the first mechanical ground-preparation methods applied in humanitarian demining. The HALO Trust in Cambodia, for instance, has been using specialised machines to cut vegetation since 1995.

The main type of vegetation cutter used by The HALO Trust is a non-intrusive commercial agricultural tractor, which has been armoured and fitted with a commercial vegetation cutter. The initial concept was to attach a commercial vegetation cutter to a standard piece of agricultural machinery that could be purchased and maintained locally.

The machine first chosen was a Belarus MTZ 82R tractor, which was purchased in Phnom Penh. While this machine could do the job, it proved too light to carry both the cutter and armour and to be reasonably manoeuvrable. The best choice of tractor is now considered to be the Ford New Holland 8340. At around eight tonnes in weight and with more than 160hp it is big enough to take the extra weight and be reasonably manoeuvrable (crucial with this type of machine). It is, however, still restricted to working on reasonably flat ground.

*Fig. 1. The armouring consists of a simple three-sided eight-millimetre-thick armoured cab. The far side or the left-hand side is left open for ventilation as cutting can only be performed on the right-hand side.*
*Additionally, an armoured plate covers both the right-hand side of the engine and the fuel tank.*

The vegetation cutter chosen was a B80XM from Bomford Turner. The extendable cutting arm has an 8 metre reach from the centre of the tractor. The cutting head is 1.25 metres wide and rotates at about 2,300rpm. The only modification to this cutting arm is that two wooden skids are fitted to each side of the cutting head. These act as the main contact between the cutting head and the ground. If they initiate a pressure anti-personnel mine, they are "sacrificed", leaving the cutting head damage-free.

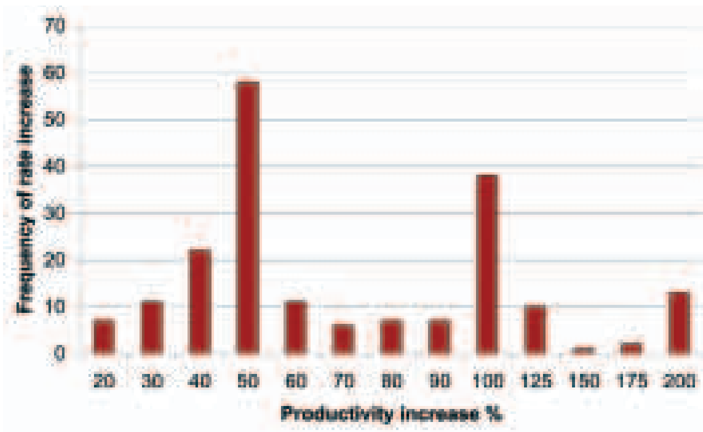
## Methods

Productivity in 190 individual manual demining lanes was estimated over a 12-month period by the HALO Mechanical Supervisor. The data was taken in 43 minefields with vegetation cutting by 11 different machines. Productivity was compared to that achieved by a manual deminer in the absence of a cutting machine (the deminer was required to cut the vegetation).

## Results

Productivity improved in all 191 instances in which the deminer followed a cutting machine (*Fig. 2*). The average increase was 73.8 per cent (±s.e. 3.3, range 7-200 per cent) with more than 100 per cent achieved in 26 instances; the median increase was 50 per cent. In general terms, productivity increased by about 50 per cent when manual deminers followed a machine, but considerably greater increases were possible under some circumstances.

**Fig. 2. Increase rate (IR) as a result of surface ground preparation with HALO Tractor.[a]**




*a. The report is a yearly summary of all monthly mechanical results for 2001.*

Figure 2 shows that the productivity increase is difficult to predict as the range is quite large. The lowest productivity increase of 20 per cent was recorded six times and the highest productivity increase was recorded 13 times.

### *What influences the IR and the range of results?*

The productivity of a manual deminer working on areas cut by the HALO tractor is influenced by two main factors: the amount of metal contamination in the ground and the type of vegetation being cut.

a) After vegetation is removed, the subsequent progress made by the deminer depends primarily on the amount of metal contamination. Areas where the machines recorded a 100 per cent IR or less were considered to contain a high level of metal contamination and areas where the machine recorded an IR higher than 100 per cent were areas considered to have relatively low metal contamination .[1]

b) Improvements in efficiency of manual demining were smaller in areas containing high elephant-type grass than in areas containing thick underbrush. Although the latter is often categorised as thicker vegetation, bushes are often easier for the deminer to remove because a much larger area of vegetation is removed when one main base trunk or stem is cut. The time costs of removing high grass are more substantial because of the small net clearance gained on each cut.

## How the machine affects overall productivity

The HALO tractor is a non-intrusive machine. It therefore works concurrently with the follow-up clearance teams. Coordinating this cooperation to optimise the machine's effect includes the following considerations:

### *Reliance on demining follow-up*

The machine is capable of cutting up to 3,400 square metres of land per day, depending on the vegetation and terrain type.[2] The average area cut daily by 11 machines over a 12-month period was 560 square metres with an average working time of three hours per day.[3] Deployment of the machine is limited by the progress made by the deminers and the availability of breaching lanes. Therefore the cutting rate of 500-600 square metres per day reflects the rate of manual demining in the minefield, a limitation likely to apply to all types of non-intrusive vegetation cutters.

### *Over use of breaching lanes*

The manual teams have to prepare four-metre wide breaching lanes before the machine is used in the minefield. When the aim is to provide enough breaching lanes to enable the machine to cut all day, a dilemma is created: breaching lanes can represent a significant portion of the minefield area, thereby reducing the increase in productivity which is the main benefit of using the machine. For example, if the breaching lanes represented 25 per cent of the total area being demined and the effect of mechanically cutting vegetation was a 50 per cent productivity increase, then the net effect would be a 37.5 per cent increase in productivity. Requirements for breaching lanes need to be calculated for each individual site, as the size of the minefield and the ease of access for the machine will differ for each task.

Using breaching lanes has an obvious advantage: they can be used to target obstacles (tree stumps, ditches, etc.) which could limit deployment of the machine. These obstacles can be removed or otherwise negated during the demining of the breaching lane.

### *Informative reporting*

The machine needs to be used to target as many demining lanes as possible. However, simply recording the area cut per day by the machine and the area cleared manually by the deminers gives a false representation of what is happening. One could be fooled into thinking there is a balance between what is being cut and what is being subsequently cleared. For example if 500 square metres per day were cut by the machine and 500 square metres per day were cleared by follow-up clearance, this could mean that half of the deminers are working on cut land and clearing at twice the rate. Different sites can more easily support different percentages of demining lanes (not all lanes can be supported). It is very difficult to template or pre-plan the work of the machine. It is again a case of making day-to-day decisions as the demining operation progresses.

### *Summary/conclusions*

The large range for the individual-lane productivity increase is explained by the varying degrees of metal contamination in the ground and the types of vegetation being cut. Best use of the machine to maximise overall productivity increase is achieved by minimising breaching lanes which should be ideally as far apart as practical so as to support as many demining lanes as possible. Additionally, deploying the machine a few days before follow-up clearance is more productive, provided initial breaching lanes have first been established.

It seems apparent that because this type of machine cannot support all demining lanes (breaching lanes are a necessity) an intrusive machine could prove more beneficial if deployed to cut all the vegetation before clearance began.

## *Small intrusive vegetation cutters*

The HALO Trust in Cambodia also operates a small vegetation cutter known as the Tempest.[4] The Tempest is a low cost unit that is simple to operate and is constructed using materials and manufacturing techniques that are available in mine-affected countries. The Tempest is remotely controlled, therefore forward vision of the unit is compromised. As a result its vegetation-clearance capacity is slowed by time spent manoeuvring the machine away from and around obstacles (tree stumps, dead-fall, etc.).

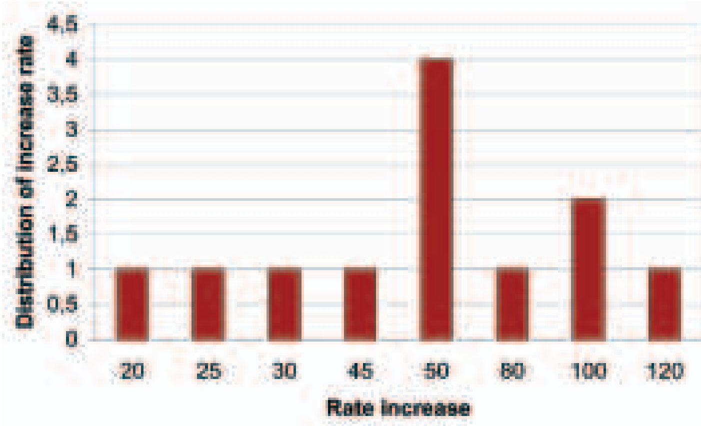
*Fig. 3. Tempest operating in Thailand.*

Intrusive vegetation-cutting machines were designed because of their potential to clear vegetation in areas which larger non-intrusive machines could not access (e.g. between closely-located large trees and over undulating ground). An original objective for this machine was for it to work with non-intrusive machines, so that a greater percentage of vegetation could be cut. This, however, seldom happened.

### Methods

Clearance data was taken over a 12-month period. Twelve different minefield results were recorded in total as the monthly average productivity increase taken from an analysis of the daily reports. Figure 4 shows that the average recorded increased rate (IR) was 60 per cent. The range was from a 20 per cent IR to a 120 per cent IR.

Fig. 4. IR as a result of surface ground preparation with Tempest




*Source: HALO Trust (2001b).*

## Results

All monthly measures of adjusted productivity were positive, indicating that using vegetation cutters always improved productivity. Productivity increased by 60%$\pm$s.e.9.4 (range 20-120%, N=12). The median was 50 per cent.

## What influences the IR and the range of results?

Similar productivity increases would be expected from any type of vegetation cutter as the productivity increase of the deminer is a result of the areas to which they are deployed and not the type of vegetation cutter. However, different machine types have a different effect on the overall minefield productivity. The main factor influencing the Tempest's ability to maximise overall minefield productivity is its daily productivity.

The Tempest weighs 2.7 tonnes and is driven by a single 70hp diesel engine. The fact that it is remotely controlled means forward vision is non-existent. This combination of a small, lightweight machine with limited horsepower and no forward vision results in a very low rate of productivity. The average clearance rate to be expected from the Tempest in both Bosnia and Cambodia was 800$m^2$ per six hour working day.[5]

Low productivity can occur when the machine is working concurrently with manual deminers because of safety distance requirements. The minefield size decreases over time, further increasing the machine-deminer space restriction. This often limits the amount of vegetation that is cut each day as the work of the deminer takes priority. Sometimes the amount of area cut by the unit in a day is less than that cleared by the deminers, who then catch up to the machine.[6]

Catch-up is most likely to occur when the minefield is small and the metal contamination level is low. These two circumstances represent an ideal deployment situation for a vegetation-cutting machine as the conditions can potentially optimise the overall productivity increase.

Deminers tend not to catch up to machines deployed on large minefields where the metal contamination is high. This circumstance is not an ideal deployment situation for a vegetation-cutting machine, as the productivity increase of the deminer is restricted by the level of metal contamination. With high levels of metal contamination, the presence of vegetation does not slow the progress of manual demining.

If the unit is used to cut the entire minefield in front of follow-up teams, there is a limit as to what size the minefield can be. Deploying more than four weeks in advance in places like Cambodia (high vegetation growth rate) could mean having to contend with vegetation re-growth and therefore time spent re-cutting some areas. Deploying four weeks in advance (20 working days as a maximum) would mean deploying the Tempest in minefields no larger than 20,000 square metres to ensure the entire area is prepared.

In a situation where the unit is not deployed to clear the entire minefield, the pattern the unit cuts can determine the minefield IR (*see Figs. 5 and 6*).

Fig. 5. Cutting at right angles to baseline

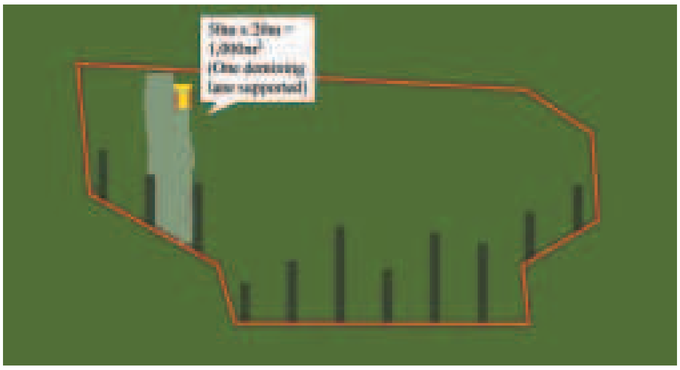
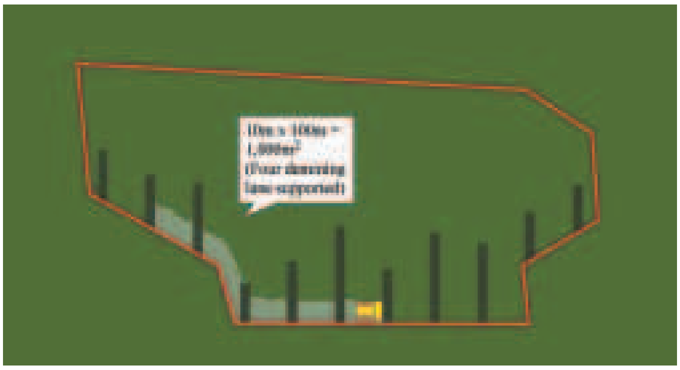


Fig. 6. Cutting along baseline



The distance between each manual lane influences the minefield IR. The farther away the deminers are from each other, the more vegetation the unit has to cut per day to support a given number of lanes (cutting in front of each lane is not viewed as practical). For example, when lanes are 25 metres apart and each demining team clears 50 metres per day, the required length of the baseline is 500 metres and contains 20 lanes. However, when demining lanes are 15 metres apart, the 500-metre baseline will contain 33 lanes. The distance between working lanes is a risk management issue, which depends on the severity of the mine threat. Organisations tend to increase the distance between deminers when the severity of the mine threat increases, but the reverse is rare.

### Summary

The advantage of small remote machines is their ability to get into smaller and more difficult places than larger machines. Small vegetation cutters are inexpensive but productivity is low. The remote-control nature of this type of machine is necessary because of its size but contributes to its low productivity rate.

Small, remote machines are optimised when they are cutting along the front of demining lanes, ensuring as many lanes as possible are supported. When not operating concurrently with manual teams, best use could be expected in small minefields (< 20,000 square metres). To be fully independent (no area size restriction) this type of machine would probably need a daily productivity rate of about 2,000 square metres per day.

In small minefields with low metal contamination, a normal-sized demining team working about 20 lanes is likely to clear more land than can be cut by a small vegetation cutter.

# Sub-surface ground preparation

## *Introduction*

Sub-surface ground preparation machines are generally intrusive machines (able to enter a mined area to operate). Machines that can break up the surface of the ground are usually more powerful than machines that only remove vegetation. They therefore generally have higher daily productivity rates than vegetation cutters, as they are able to work independently of subsequent clearance methods.

## *Advantages of sub-surface ground preparation*

Sub-surface ground preparation combines the advantages of surface ground preparation with the additional ability to break up the ground. This gives at least two potential advantages over surface ground preparation:

1. facilitating the use of MDDs; and
2. reducing the time spent investigating signals registered by the metal detector.

In temperate climates, the layer of soil between the mine and the ground surface is normally quite moist for most of the year, influencing the ability of explosive molecules to reach the surface.[7] Dogs may find it easier to locate scent of explosive behind machines that break up the earth's surface. A greater explosive plume is produced by exposing the sub-soil to the atmosphere. The advantage is short-term only and depends on the amount of rain after sub-surface ground preparation and air temperatures at the time dogs are searching.

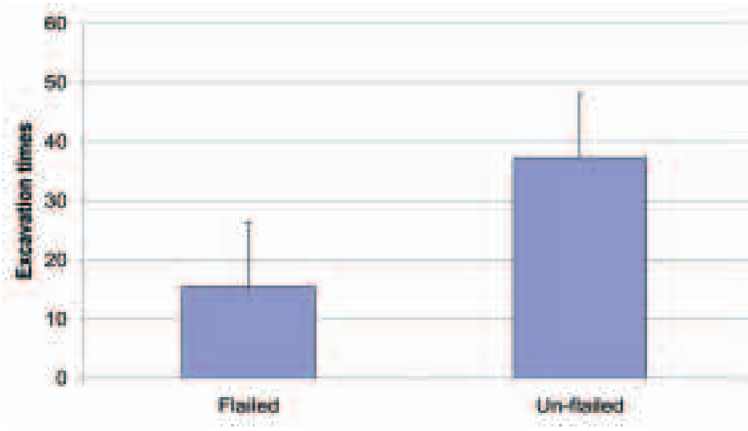
However, there is potential to extend the working-day period of dogs into the cooler months if the machines were used to churn up the moist soil thereby exposing it to the sun to dry which, in turn, releases explosive molecules.

In September 2002, the GICHD study team conducted an experiment in Croatia. The area chosen was flat grass land (no vegetation) and the soil was soft as it had been raining for about eight days prior to the experiment. Two deminers were each given 10 metal pieces to investigate (nails at 10 centimetres) along separate 20-metre paths.

One path had been flailed by a machine to a depth of 10cm; the other had not. The time taken to excavate each signal was recorded. The times recorded for each of the excavations do not represent excavation times in a real minefield as the deminers were excavating for nails not mines. Instead, the experiment was concerned with the relative efficiency of each type of excavation (flailed ground vs. un-flailed ground).

It took significantly longer to locate each target in unflailed ground than in flailed ground ($t_{(18)} = 4.24$, $p = .0005$, Fig. 7).

**Fig. 7. Time costs of excavating for metal pieces in flailed and unflailed ground (blue represents average, "T" represents standard deviation)**




### Experiment observations

Excavating in ground that had been broken up was more efficient because a sharp tool (bayonet) was not necessary to penetrate the ground and remove or cut through the root systems present. The tool was necessary in un-flailed ground. A small hand spade was used in flailed ground and therefore digging was more efficient for removing loose soil surrounding the item being investigated.

### Assistance to manual excavation techniques

Some organisations use manual excavation techniques as a full clearance method when the metal contamination in an area is too high for the use of a metal detectors. NPA has conducted two tests to gauge the effect of breaking up the ground prior to manual excavation.[8]

In the first test, one 10 x 10 metre box was flailed and one 10 x 10 metre box was left un-flailed. Ten deminers took 130 minutes to excavate the flailed box, and 190 minutes to excavate the un-flailed box, representing a productivity increase of 46 per cent in the flailed box.

In the second test, two groups of five deminers excavated for four hours each, one group in flailed ground and one group in un-flailed ground. In flailed ground, 47.2 metres were completed. In un-flailed ground, 36 metres were completed. This represents a productivity increase of 31 per cent in the flailed ground.

## *Effects of metal contamination in sub-surface ground preparation*

In the surface ground preparation section it was argued that higher productivity increases occur after vegetation cutting in areas where there is less metal contamination, because the vegetation represents the major obstacle to manual demining. However, breaking up the soil provides added value after sub-surface ground preparation in high metal-contaminated areas because the excavation process is hastened. This advantage is not obtained after surface ground preparation.

## Sub-surface with metal removal ground preparation

### *Introduction*

Sub-surface with metal removal ground preparation incorporates all aspects of surface and sub-surface ground preparation with the additional benefit of removing metal contamination. This technique is seldom used and is a relatively new approach to mechanical ground preparation.

Mine clearance organisations often disapprove of the use of machines which cause mines to detonate and spread numerous metal fragments into the area to be cleared, because it exacerbates clearance productivity. The use of magnets could remove the added contamination thereby expanding the potential use of machines to detonate mines in more situations.

There are two general types of magnets: the permanent (or earth magnet) and the electro-magnet. Magnets are used in industry to clear away ferrous debris at airport runways, driveways, parking lots, etc.; to reduce vehicle and aircraft maintenance and reduce occurrence of flat tyres. In these roles, permanent magnets seem to be preferred over electromagnets as there is no need to provide an electrical power source. Fragments are removed from the magnet by either collecting them on a non-ferrous separator plate or by inverting the magnets. Suitable commercial tow-behind magnet systems sell for about US$6,000 and weigh approximately 400kg. Magnet strength is categorised in grades, with Grade 8 being the strongest available.

Sub-surface with metal removal ground preparation was observed only in Thailand. TMAC uses a Pearson magnet as part of the ground preparation process to remove the majority of metal pieces found at sites along the Thai/Cambodian border (*see case study Area reduction of non-patterned minefields in Thailand*). The magnet is fitted to a prime mover with a hydraulic lift and external service. In use, the magnet is either pushed or pulled over the minefield with the depth wheels set to position the magnet 50 to 100millimetres clear of the ground.

*Fig. 8. Pearson magnet as used by TMAC.*

### *Advantages of sub-surface with metal removal ground preparation*

The obstacle which most hampers the progress of the manual deminer is metal contamination. Some areas can be so highly contaminated that the metal detector will continually signal the presence of metal and consequently require full manual excavation. This can result in daily clearance figures lower than five square metres per six-hour working day. Sub-surface with metal removal ground preparation incorporates the advantages of both surface and sub-surface methods with the added advantage of removing a significant portion of the metal contamination.

This section focuses on the metal-removal effects of sub-surface with metal removal ground preparation and is based on the results of a trial conducted by the HALO Trust in Cambodia, and The Japanese Alliance for Humanitarian Demining Support (JAHDS) in Thailand, using the Pearson magnet.[9]

## Methods

The trial was conducted between 25 March and 10 April 2001 in Thmar Pouk district, Banteay Meanchey Province, Cambodia (internal trial report dated March 2001).

Six closely-located 200 square metre boxes were marked out. Box 1 was cleared using normal manual techniques to gauge the amount of metal contamination in the area. A Pearson magnet was passed over the surface of Box 2 and the number of metal pieces counted.

In Boxes 3 and 4, a cultivator working to a depth of five-six centimetres was used to expose the metal contamination below the surface. The magnet was then passed over the area and the number of metal items collected was counted.

In Boxes 5 and 6, the magnet was passed over the box and the items counted before cultivation to assess the surface metal contamination. After cultivation, the magnet was passed over the boxes again and the items counted.

After processing, all boxes were cleared by a manual deminer, and the number of metal items found recorded. The daily clearance rate by the manual deminer was recorded.

## Results

Similar amounts of metal were found in all of the boxes (*see Table 1 overleaf*). The magnet reduced the amount of metal to be found by the deminer under both removal conditions. Passing the magnet over the ground both before and after cultivation removed more metal than passing it only after cultivation, as the amount of metal found by the manual deminer in Boxes 3 and 4 (52 of 149 pieces) was significantly higher than in Boxes 5 and 6 (27 of 160 pieces) ($X^2 = 13.2$, $P=0.003$).

Removing surface metal contamination resulted in an IR of 21 per cent (Box 2). Removing sub-surface metal contamination resulted in an IR of between 93 per cent (Box 3) and 101 per cent (Box 4). Removing surface then sub-surface metal contamination resulted in an IR of between 127 per cent (Box 5) and 200 per cent (Box 6).

Box 1 was cleared completely by one deminer who found 76 metal pieces in total with a clearance rate of 66 square metres per six-hour working day.

In Box 6, the magnet was passed over the area to collect surface metal. The area was then cultivated to expose sub-surface metal and the magnet passed over the box. The number of metal pieces in Box 6, coincidently, was the same as the number in Box 1 but the clearance rate increased to 200 square metres per six-hour workday. This represents a 200 per cent increase in the manual demining rate.

An indication of metal contamination levels was obtained at the Nong Yakeao minefield (ref No. 005) in Thailand, which was cleared by JAHDS. At this site the

**Table 1. Number of metal items collected by magnet and deminer after different cultivation treatments (cultiv.=cultivation)**

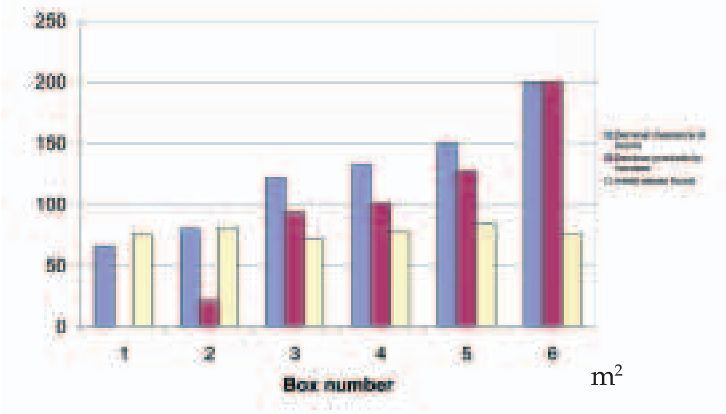
| | Metal items collected before cultivation | Metal items collected after cultivation | Metal items found by deminer | Total items found | Percentage of items removed by magnet |
|---|---|---|---|---|---|
| **Box 1** | No collection | No cultivation | 76 | 76 | |
| **Box 2** | 28 | No cultivation | 56 | 84 | **33** |
| **Box 3** | No collection | 41 | Surface: 2<br>Sub-surface: 28 | 71 | **58** |
| **Box 4** | No collection | 56 | Surface: 2<br>Sub-surface: 20 | 78 | **72** |
| **Box 5** | 29 | 37 | Surface: 2<br>Sub-surface: 16 | 84 | 35 before cultiv.<br>45 after cultiv.<br>**Total: 80** |
| **Box 6** | 27 | 40 | Surface: 1<br>Sub-surface: 8 | 76 | 36 before cultiv.<br>53 after cultiv.<br>**Total: 89** |

The different treatment conditions influenced the subsequent rate of manual demining, with Boxes 5 and 6 (magnet, followed by cultivation, followed by magnet) giving the most productive return (Table 2).

**Table 2. Manual demining rates for clearance of boxes under different treatment conditions after magnet and cultivator (cultiv.=cultivation)**

| | Manual demining rate per 6-hour day | Area cleared | Total metal items found |
|---|---|---|---|
| **Box 1** | No metal removal | 66 $m^2$ | 76 |
| **Box 2** | Metal removal without cultivation | 80 $m^2$ | 84 |
| **Box 3** | Metal removal after cultivation | 122 $m^2$ | 71 |
| **Box 4** | Metal removal after cultivation | 133 $m^2$ | 78 |
| **Box 5** | Metal removal before and after cultiv. | 150 $m^2$ | 84 |
| **Box 6** | Metal removal before and after cultiv. | 200 $m^2$ | 76 |

**Fig. 9. Effects of magnet of use on deminer productivity**



number of metal pieces of different size and configuration within a 11,241 square metre block was 36,119 (averaging 3.2 pieces per square metre).[10]

If deminers were spending, on average, 15 minutes to excavate each and every metal signal and the magnet removed 70 per cent of the metal contamination, and this was being done in a six-hour working day, 1,053.5 working days would be saved by using a magnet in this block. If 30 demining lanes were deployed on site then the saving would be 35 operational days (1,053.5/30).

### Use of magnets in operations

It is necessary to remove any vegetation prior to deployment of the magnet. Additionally, in this example, rollers were used on land before the magnet was towed behind to limit the chance of mine damage. Future magnet use may involve a flail with a commercially-available tow-behind magnet. In this way, vegetation is removed, the chance of mine damage to the magnet is limited, and the ground is broken up to make metal fragments more accessible to the magnet.

### Summary

Removing the vegetation and breaking up the ground significantly improves the productivity of manual demining. However, the result of these techniques depends on the amount of metal contamination in the ground. Therefore, removing metal contamination prior to the deployment of manual deminers potentially offers the most effective time saving method of ground preparation.

There are two categories of metal contamination — surface and sub-surface. Removing sub-surface metal contamination would have a greater effect than removing surface contamination as the deminer will spend more time investigating the former than the latter.

Removing surface then sub-surface metal contamination is the most effective use of a magnet in the metal-removing process. Neglecting the surface metal contamination and immediately breaking up the ground to expose the sub-surface metal contamination will result in some of the surface-metal items being buried and therefore becoming less accessible to the magnet.

Removing metal contamination has major potential benefits in terms of clearance efficiency. The HALO Trust test results showed that as much as 89 per cent of metal contamination can be removed under some conditions leading to a 200 per cent increase in the manual-demining rate.

Evidence of the operational effectiveness of a magnet was seen in operations conducted by TMAC which initially conducted mine clearance along the Cambodian border manually. Each deminer was averaging four to five false metal investigations for each square metre cleared.

*Fig. 10. Metal collected by the Pearson Magnet on TMAC operations.*

After the deployment of the Pearson Magnet, manual deminers were averaging one false metal investigation every four to five metres.[11]

## Conclusions, findings and recommendations

**Conclusion 1.**

**Ground preparation machines are generally underused.**

*Findings*

Within some mine action programmes, machines still play only a small role in the mine clearance process. For example, the Cambodian Mine Action Centre's manual demining platoons cleared a total of 6,921,372 square metres in the first six months of 2002 but only 640,252 square metres (10.3 per cent) were prepared by machine.[12] In Angola, NPA mechanically prepared 23 per cent of the total area they cleared in 2001.[13] Manual teams in the Mine Action Programme for Afghanistan cleared a total of 15,645,634 square metres in 2001 but only 288,998 square metres (1.8 per cent) was prepared mechanically.[14]

However, in Thailand, the Humanitarian Mine Action Unit One mechanically prepares 100 per cent of all the land it clears.[15] In Croatia, of the 13,640,000 square metres demined in 2001, approximately 75 per cent (10,230,000 square metres) were prepared mechanically and followed up with either manual demining or MDD techniques.[16]

The GICHD *Study of Global Operational Needs* found that "*In the great majority of demining scenarios, mined areas contain very few mines, and time spent dealing with these individual mines is insignificant in relation to the time spent carrying out other activities such as vegetation clearance and the detection or removal of scrap metal.*"

Also, the risk assessment sub-study report (*see Chapter 2, Table 1*) explained that, on average, mines occupy a very small part of a suspect area. This indicates the need for ground preparation machines to contribute more, particularly if such large percentages of suspect areas do not contain mines. Moreover, ground preparation machines can contribute significantly to a manual or MDD clearance programme's performance if machine use is tailored to the area.

The lack of detailed comparative data collected by demining organisations may be the reason that ground preparation machines are not being used to a greater degree. Most organisations do not have effective recording procedures and therefore do not know what quantitative benefits their machines are producing. We should assume that if organisations knew the quantitative benefits, they would then capitalise on them by maximising their mechanical ground preparation capacity.

The normal demining organisation's operational reporting format is seldom detailed beyond the amount of land processed by machine. However, measures of productivity alone do not lead to improvements in productivity, or a greater understanding of the usefulness of a machine.

***Recommendation 1.***

***Mine clearance operations should make significantly greater use of machines for ground preparation. In order to quantify the productivity improvements that result, more demining organisations need to separate the recording of land cleared manually behind a machine from the land cleared manually without machine assistance as a basic requirement.***

**Conclusion 2.**

**Machines conducting sub-surface with metal removal ground preparation offer the best quality of ground preparation as they remove all practical obstacles for follow-up clearance.**

*Findings*

Machines capable only of surface ground preparation are limited in the assistance they can provide to manual deminers and MDD teams. They merely remove vegetation and, on occasion, tripwires. Productivity is increased when they are deployed to areas with minimal metal contamination, where vegetation is the main obstacle facing subsequent deminers. Optimising the productivity of intrusive and non-intrusive vegetation cutters involves considering:

- how the greatest number of demining lanes can be supported;
- the most effective use of breaching lanes for non-intrusive machines; and
- the metal contamination levels in each minefield.

Machines conducting sub-surface ground preparation are limited by the degree of preparation they perform for follow-up clearance teams, but offer a higher degree than surface ground preparation as benefits are cumulative. Additional advantages include:

- speeding up the excavation process the manual deminers perform;
- enabling dog working-day periods to extend into the cooler months of the year; and
- speeding up the excavation process undertaken by a deminer investigating each metal signal from a metal detector.

Ground preparation machines are probably more productive if they are driven into the minefield containing invisible obstacles (dead-fall, tree stumps, wire fencing and ditches, etc.) as opposed to being remotely controlled.

Productivity would be maximised by the increased ability of the driver to see and avoid obstacles. By including a driver, the cost of a machine will increase because of the operator protection needed. However, this extra expense would probably be more than compensated for by the extra productivity.

Machines conducting sub-surface with metal removal ground preparation offer the best quality of ground preparation as they remove all common obstacles for follow-up clearance. These obstacles can be grouped in a hierarchal order as described in Figure 11.

As the machine or mechanical process removes each level of obstacle, follow-up clearance productivity is increased depending on the degree that each obstacle poses to the subsequent clearance technique.

Sub-surface with metal removal ground preparation machines remove the threat of tripwires, so that the deminer is no longer required to perform a tripwire-detection drill. They remove vegetation so that the deminer no longer spends time cutting away all vegetation down to ground level and they remove a high degree of metal contamination. A magnet is best used to remove metal contamination on the surface then reused after exposing the sub-surface. This technique requires multiple passes and the use of several tools, and as such, may negate the advantage of using a magnet twice. The better ground preparation machine is, therefore, one which performs these tasks in as few passes as possible.

***Recommendation 2.***

***Demining organisations and mine action centres should give particular consideration to the use of machines that perform sub-surface with metal removal ground preparation, especially where a machine can achieve all three categories of preparation in as few passes as possible.***

Fig. 11. Hierarchical order of obstacles (bottom to top)

# Endnotes

1. The HALO Trust (2001b).
2. *Ibid.* 3,400 square metres was the highest recorded area cut by the machine in 2001.
3. The machines actually cut intermittently throughout the day, this is the average aggregate time.
4. See the GICHD *Mechanical Demining Equipment Catalogue 2004*.
5. This average is consistent with MAG Cambodia, NPA Bosnia as well as HALO in Cambodia.
6. Records in 2001 show that more land was being cleared manually than was being cut by the machine in all the sites it operated.
7. Phelan and Webb, in press.
8. Information provided by Aksel Steen-Nilsen, Programme Manager, NPA Angola.
9. Saratha (2001). This report is just one section of a larger trial report on the range of Pearson tools which were attached to a Volvo 4400 front-end loader.
10. Information provided by J Van Zyl, JAHDS, Thailand.
11. Information provided by D. McCracken, Technical Advisor to TMAC.
12. CMAC (2002). CMAC annual reports can be downloaded from their website *www.camnet.com.kh/cmac*.
13. Internal report provided to GICHD, summarising operational results of 2001.
14. Results of all operational activities for 2001, provided to the GICHD by the MAPA operations office.
15. This is limited to Humanitarian Mine Action Unit 1 working on the Thai/Cambodian border.
16. Results for 2001 provided by Nicola Pavkovic, Assistant Director, Centre for Testing Development and Training, CROMAC.