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The Demining of Farmland - Cost/Benefit Analysis and Quality Control

Peter Schoeck

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Cost/Benefit Analysis and Quality Control

by Dr. Peter A. Schoeck,
Consultant

The value gained by the demining of farmland is estimated and compared with the cost of demining for manual demining and mechanized demining. It is found that for farmland used for growing ordinary crops (as opposed to "luxury" crops yielding higher prices) the cost of demining and recultivation for reasons of economy is not to exceed 40 cents (U.S.)/m^2. To reach this target requires mechanized demining wherever possible, confining manual demining to areas not suitable for mechanized demining. A method is shown by which 100 percent safety of the demined area can be achieved and which facilitates quality control. The required capacities for mechanized and manual demining are estimated in relation to the time schedule for the worldwide demining of all mine affected and mine suspected farmland.

Introduction

Following general convention, we shall use the term "demining" for both the removal or destruction of mines and of unexploded ordnance (UXO). While the demining of residential areas and other areas, which must be accessible to people for satisfying their basic needs, are to be considered solely under the humanitarian aspect of safety, this is not necessarily true for mine polluted farmland. The justification for its demining and its simultaneous or subsequent recultivation depends on the answers to the following questions:

1) Is the use of the land to be demined essential for the subsistence of the population or can it be replaced by available land that is not mine suspected?

2) What is the relation between investment in demining and the cost that would arise from the support of the people deprived of their land?

3) What is the benefit to cost ratio? In other words: Does the income from the use of the recultivated land justify the investment in its demining?

The Evaluation of Mine Affected Farmland

A suitable indicator for the economic value of mine affected farmland is the annual earnings derived from its use after having been demined. As shown in Table 1, taken from (1), values for production, revenue, cost and specific earnings, the latter expressed in U.S. dollars per square meter (see also fig.1) are depending strongly on the type of crop. The values refer to European conditions and are, therefore, not directly transferable to most mine affected countries (in particular developing countries) where production volume, market prices and cost of operation are lower. Accounting for these differences, the earnings per unit area listed in Table 1 are to be considered as upper limits.

Leaving vines and apples aside because of the time lag between the planting of seedlings and the first harvest, we notice the enormous difference in specific earnings between luxury crops, such as asparagus, brussel sprouts and strawberries, and those of peas, maize oats, sugar beets, and soybeans. It must, however, be kept in mind that in order to achieve high earnings from said luxury crops, in general, refrigerated storage facilities and access to a market for these crops are prerequisites. The earnings for a mix of ordinary crops that constitute base nutrients for the people of mine affected countries, amount, on the basis of Table 1, to approximately 10 cents/m^2 year.

The validity of this approximate value is confirmed by using a different approach based on (2) according to which one square kilometer (1,000,000 m^2) of farmland on the average produces nutrients for approximately 1,000 people. If we are taking into account that a typical figure for food consumption per capita in developing countries is \$100 per year, we again arrive at 10 cents per m^2 year.

Let us emphasize, however, that this figure is not more than an approximated global average. As capitalization of this value is difficult, we shall attempt to calculate the value of the land on the basis of the financial capabilities of the farmers taking a loan under the condition of annual redemption rates amounting to 20 percent of the annual earnings—2 cents/m^2 over 20 years. Based on this assumption, the annual repayments would accumulate 40 cents/m^2 without considering interest.

In this connection, we would like to stress the need for agricultural experts to be consulted before commencement of the demining for evaluation of the land and recommendations as to its optimal use. For our further investigation, we shall assume a value of the land of 40 cents/m^2 as a critical limit that, if exceeded, confines the demining to a strictly humanitarian undertaking.

The Cost of Demining

In the case of manual demining, removal or destruction of a mine is always preceded by its detection and localization in the soil. It comprises the main part of the demining work and accounts for the major part of its cost. By contrast, with mechanized demining, mine detection as a separate time and cost consuming process is omitted because of the tools moving through the soil striking and fracturing the mine without previous identification of the mine.

Further advantages of mechanized demining vs. manual demining result from its crushing of scrubs and other vegetation and from simultaneously preparing the soil for agricultural use. In other words, mechanized demining combines the process of demining with land recultivation. Mechanized demining also enables an accurate control with respect to the area being completely clear of mines, contrary to manual demining in which achieving 100 percent safety of the demined area is impossible.

Whenever an area is "mine suspected," manual demining requires the attempt of mine detection over the entire area. Should no mine be detected, the whole process is useful only with respect to assigning a certain probability of safety to the land before its recultivation. In contrast, with mechanized demining, the land recultivation achieved represents an upgrade in the value of the land which is independent of whether or not the land was mine affected or merely mine suspected. But for applying mechanized demining, two prerequisites must be fulfilled:

One: The area to be demined must be accessible to the carrier vehicle of the equipment.

Two: The land to be demined must be approximately level, at least if heavy carrier vehicles are applied.

For this reason, manual demining can never be totally replaced by mechanized demining. A rough estimate indicates that one third to one half of the land on earth to be demined must remain the domain of manual demining, possibly partly assisted by small scale mechanized demining applying special equipment.

Based on data taken from (3), we estimate the lower limit of all mine suspected land area at 100,000 km^2.

TABLE 1- PROFITABILITY CALCULATION FOR VARIOUS CROPS
QUANTITIES REFER TO 1 HECTAR (10,000 M2) AND 1 YEAR UNLESS STATED OTHERWISE

		STRAW BERRIES	APPLES	VINE	CARROTS	ASPARA-GUS	POTATOES	SOJA	BRUSSELS SPROUTS
Production	kg	17,000.00	22,400.00	-	45,000.00	2,400.00	28,500 00	2,700.00	10,500.00
Revenue per kg	US$/kg	2.35	0.59	-	0 26	6.76	0 29	0 97	1.59
Operating Revenue	US$	40,000.00	13,176.47	29,000.00	11,911.76	16,235.29	8,382.35	2,620.59	16,676.47
Seeds	US$	9,194.12	2,539 41	1,480.59	928 82	1,352 94	1,764.71	141 18	1,645.29
Fertilizer	US$	47.06	152 94	245.29	285.88	282.35	264.71	58.82	307.65
Protective Agents	US$	1,629.41	950.00	847.06	1,018.24	464 71	405 88	88 24	891.76
Diverse	US$	10,000.00	2,352.94	1,352.94	345.29	1,235.29	176.47	270.59	260.59
Total Direct Cost	US$	20,870.59	5,995.29	3,925.88	2,578 24	3,335.29	2,611.76	558 82	3,105.29
Machinery and Equipment	US$	4,900.00	997.65	2,823.53	126.47	294.12	1,176.47	470 59	764.71
Contribution I	US$	14,229.41	6,183.53	2,823.53	9,207.06	12,605.88	4,594.12	1,591 18	12,806 47
Working Hours	h	270	560	750	870	970	270	43	850
Cost of labor per hour	3.5 US$								
Cost of labor	US$	952.94	1,976.47	2,647.06	3,070.59	3,423.53	952.94	151.76	3,000.00
Earnings	US$	13,276.47	4,207.06	19,603.53	6,136.47	9,182.35	3.641 18	1,439 41	9,806.47
Earnings per unit area	US$/m2	1.33	0.42	1.96	0.61	0.92	0.36	0.14	0.98

TABLE 2- PROFITABILITY CALCULATION FOR VARIOUS CROPS
QUANTITIES REFER TO 1 HECTAR (10,000 M2) AND 1 YEAR UNLESS STATED OTHERWISE

		SUGAR BEETS	PEAS	CORN (MAIZE)	RAPE	WINTER WHEAT	RYE	OATS
Production	kg	65,000.00	4,500.00	7,500.00	3,000.00	6,400.00	5,900.00	5.500.00
Revenue per kg	US$/kg	0.07	0.35	0.32	0.97	0.47	0.41	0.29
Operating Revenue	US$	4,588.24	1,561.76	2,382.35	2,911.76	3,011.76	2,429.41	1,617.65
Seeds	US$	235.29	188.24	176.47	64.71	147.06	105.88	100.00
Fertilizer	US$	192.94	82.35	164.71	223.53	188.24	135.29	147.06
Protective Agents	US$	364.71	100.00	158.82	200.00	217.65	152.94	94.12
Diverse	US$	117.65	264.71	752.94	400.00	294.12	270.59	229.41
Total Direct Cost	US$	910.59	635.29	1,252.94	888.24	847.06	664.71	570.59
Machinery and Equipment	US$	1,058.82	441.18	494.12	352.94	411.76	411.76	411.76
Contribution I	US$	2,618.82	485.29	635.29	1,670.59	1,752.94	1,352.94	635.29
Working Hours	h	170	46	40	45	40	40	40
Cost of labor per hour	3.5 US$							
Cost of labor	US$	600.00	162.35	141.18	158.82	141.18	141.18	141.18
Earnings	US$	2,018.82	322.94	494.12	1,511.76	1,611.76	1,211.76	494.12
Earnings per unit area	US$/m2	0.20	0.03	0.05	0.15	0.16	0.12	0.05

The Cost of Manual Demining.

According to (4), the global average of cost per deminer amounts presently to approximately \$10,000 per year, with approximately one half delegated for wages and housing and the other half indirect cost for training, support and administration and capital cost and depreciation of equipment.

The clearing rate per deminer depends on the mine density since removal or destruction of mines consumes time. It further depends on terrain conditions, topography, soil properties and vegetation. According to (5) and (6), typical clearing rates of mine suspected and mine affected areas vary between 4 m^2 per man-hour and 7 m^2 per man-hour.

Because of the extreme physical and mental stress to which deminers are exposed, their daily working time may, for reasons of safety, be limited by local regulations. In Croatia, for instance, the daily working time for a deminer is limited to five hours. In other countries, such restrictions do not exist. Thus, the range of working hours per man and year varies between 1,500 (Croatia) and 2,600 (Afghanistan, Cambodia).

From the above figures we receive the following lower and upper limits for the area cleared per man and year.

Lower limit: 4 m^2/h x 1,500 h/man-year = 6,000 m^2/man-year

Upper limit: 7 m^2/h x 2,600 h/man-year = 18,000 m^2/man-year

If we now assume that the above quoted annual cost per deminer applies in both cases, we receive for the specific cost of manual demining.

Lower limit: (\$10,000/man year) / (18,000 m^2/man year) = 57 cents/m

Upper limit: (\$10,000/man year) / (6,000 m^2/man year) = \$1.70/m^2

It must, however, be kept in mind that these values are valid for only one manual demining process. Should for reasons of safety a second independent process be required, the above values will double. As a consequence, at a global average, the above assumed critical limit for the economic demining of farmland of 40 cents/m^2 cannot be reached by manual demining, making the latter a humanitarian undertaking.

The Cost of Mechanized Demining

In view of the omission detection process with the mines being fractured upon impact of the destruction tool before detonation, the demining rate is practically independent of the number of mines struck. In other words, whether an area is merely "mine suspected" or actually "mine affected" does not have a considerable effect on time and cost if we neglect the time and cost for the repair of damaged tools.

Depending on topography and soil condition, realistic clearance rates for machines of 1000 kW power are between 3,000 m^2/hour and 5,000 m^2/hour. With an average of 12 working hours per day and with 250 working days per year, we arrive at a total of approximately 3,000 working hours per year. We then receive the following limits for the area demined per year by one machine:

Lower limit: 3,000 m^2/h x 3 000 h/year = 9,000,000 m^2/year = 9 km^2/year

Upper limit: 5,000 m^2/h x 3,000 h/ year = 15,000,000 m^2/year= 15 km^2/year

*The term "year" stands for machine year.

Unlike in manual demining, these figures stand for the complete recultivation of land, which, after completion of the whole process, is ready for agricultural use.

The price at which mechanized demining is available is regulated by the market. For the awarding of demining contracts, the offered price is an important factor. A cost estimate for the operation of mechanized demining equipment indicates that a price of 40 cents per m^2 equal to the above-assumed critical limit should cover cost and profit at least for demining equipment. This takes into account the use of commercial tractors as carrier vehicles as opposed to modified battle tanks or newly developed special carrier vehicles, which can hardly be conceived to be competitive with respect to cost.

Safety and Quality Control

As one can easily recognize, the safety of a demined area is solely a function of the number of mines left undetected per unit area. In order to determine the efficacy of a certain demining process, one must experimentally determine the number of mines left undetected per unit area after application of the respective process. It goes without saying that the boundary conditions for such an experimentally determined value vary from case to case, depending on the type of mines and their placement in the soil. As far as farmland is concerned, it is to be expected that within one season there is not a single spot left that has not been walked upon. As a consequence, any safety factor less than 100 percent is not tolerable.

Solution for Combining Economy with Safety

The only way to achieve 100 percent safety is to apply a tool that combs the whole volume of soil to be demined with a kinetic energy and momentum sufficient to fracture each mine upon impact. This principle has already been applied to equipment developed by a number of manufacturers and some has been field-tested. It consists, as is well known, of a rotating drum with chisels or tool bits attached to its perimeter. The drum, in turn, is attached to the front of a carrier vehicle. It is driven by a power supply at a rotational velocity much larger than the forward speed of the vehicle. The position of the chisels or tool bits are exactly defined with respect to the axis of rotation so that their paths through the soil can be exactly traced for a given ratio of carrier speed to rotational velocity.

In order to ascertain that no object above a certain size, i.e., that of the smallest possible mine, can escape being struck by a chisel or tool bit, the following condition must be fulfilled:

$$(6x10^4 / i) v/n \leq c$$

where

c = minimum size of the object measured in mm

i = number of tools per row over the parameter of the drum

v = transverse velocity of the carrier vehicles measured in m/sec

n = revolutions per minute of the drum

What is now needed to ascertain that every object larger than c in a certain area, or more exactly, in a certain volume of soil, is struck and destroyed, is the continuous measurement of the following data and their electronic recording:

- the ratio v/ n
- the depth of tool penetration into the soil
- the coordinates of the carrier vehicle with respect to a bench mark during the whole operation (to be measured by differential GPS)

This results in the required detection process making manual demining superfluous, and eliminates the considerable cost increase. If compliance with legal regulations is needed, a second detection process can be used. To double check the clearance of a mine in the soil, a clearing rake attached to a commercial tractor, such as those used by the U.S. Army that can penetrate to the prescribed depth into the soil can be used.

Global Demining Capacity and Demining Rate of Farm Land

Under the condition that demining any agricultural land be economical, any deferment of its demining and recultivation represents an opportunity loss. To estimate its lower limit worldwide, we shall assume a global mine infested and mine suspected area of 100,000 km^2 as mentioned in section 3.1, equally divided between land suitable for mechanized demining and land requiring manual demining.

With the numbers taken from (2), according to which 1 km^2 produces food for approximately 1,000 people, the annual opportunity loss by not demining and recultivating an area of 100,000 km^2 is equivalent to the value of food for 100 million people. With the above assumption of $100 for food per person and year, this corresponds to an annual loss of $10 billion per year.

By setting a target of 20 years for the worldwide completion of the recultivation of all mine affected and mine suspected land, the necessary capacities can be estimated. By employing 1,000 demining machines each having a capacity of 10 km^2/year, the annually demined area is 10,000 km^2. This means that within approximately five years, the area suitable for mechanized demining (estimated at 50,000 km^2) could be demined and recultivated. Five years correspond to the lifetime of a machine operating 3,000 hours per year. Assuming a price of 40 cents/m^2, the total cost of this phase of global demining would be approximately $20 billion. There remain approximately another 50,000 km^2 for manual demining.

To achieve an average manual demining rate of 2,500 km^2/year (corresponding to 1/20 of 50,000 km^2) approximately 250,000 deminers with an average capacity of 10,000 m^2/year each are required. It is beyond all imagination that such an army of deminers can ever be recruited and trained worldwide. An upper limit of 50,000 seems more realistic, with the result that the demining of the land not suited for mechanized demining will take 100 years instead of the targeted 20 years. It is to be hoped that, in the course of that time, technologies will be developed by which mines can be detected and removed more efficiently than.

There is no limit of scenarios from which this task could be tackled. As far as our scenario is concerned, it refers to average global conditions. It goes without saying that each country affected by mine pollution will have to work pursuant to its own mine action program geared to its own socioeconomic requirements.

Final Remarks

The results of this study are based on numerous assumptions regarding quantities, which were estimated and therefore inevitably contain errors. The objective of this paper was to find the orders of magnitude to determine the criteria to decide about the economy of demining farmland that, even if not needed entirely now, will be needed sooner or later as the world population increases. The author would appreciate any suggestions regarding his assumptions and any corrections that might lead to an improvement of the above results and to a better understanding of the subject. ■

Contact Information

Dr. Peter Schoeck
Runkelsstr.27 FL Triesen / Liechtenstein
E-mail: schoeck@schoeck.lol.li

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