LAND DEGRADATION & DEVELOPMENT

Land Degrad. Develop. **18**: 1–15 (2007)

Published online 7 August 2006 in Wiley InterScience (www.interscience.wiley.com). **DOI**: 10.1002/ldr.754

THE CONTRIBUTION OF LANDMINES TO LAND DEGRADATION

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Received 10 November 2004; Revised 15 June 2005; Accepted 26 January 2006

ABSTRACT

Landmines are one of the most environmentally destructive aftermaths of war facing the world today. The barely chronicled global landmine problem has transcended both humanitarian and sociological concerns to bring about environmental damage. Disruption of land's stability, pollution and loss of biodiversity constitute major ecological repercussions of landmine crisis. This review qualitatively integrates ecological, social, economic and political variables that play a role in creating and perpetuating a serious land degradation problem in landmine-affected regions. Through a mail survey and interview with professionals working in areas related to landmines, peace research, environmental management and law and extensive archival research this review tries to unravel the many facets and causal links in the ecological and socio-politico-economic problems. This paper highlights the complexity of the landmine problem and interrelationships between the issues surrounding the degradation and management of landmine-affected environments. Copyright © 2006 John Wiley & Sons, Ltd.

KEY WORDS: landmines; war; land degradation; sustainable development; de-mining; biodiversity loss; socio-economic impacts

INTRODUCTION

Statement of the Problem

The former Secretary General of the United Nations, Boutros Boutros-Ghali, acknowledged the scourge of landmines as one of the most atrocious global problems of our times (Boutros-Ghali, 1994). Landmines stand out from other forms of warfare, because of their very persistent, undiscriminating and uncontrolled nature. The global landmine calamity has transcended both humanitarian and sociological concerns to bring about environmental damage. But unfortunately, it is also one of the least studied and documented environmental problems.

Recently, environmental impacts of landmines have been explored by a growing number of researchers (Westing, 1985; Roberts and Williams, 1995; Gray, 1997; Winslow, 1997; Misak *et al.*, 1999; Berhe, 2000; Nachón, 2000) and organizations including the International Campaign to Ban Landmines (ICBL), International Peace Research Institute—Oslo (PRIO), Swedish Peace Research Institute (SPRI) and the United Nations (UN) (some of these studies include United Nations General Assembly UNGA/A/38/383, 1983; United Nations General Assembly UNGA/A/49/357, 1994; United Nations Department of Humanitarian Affairs, 1995; United States State Department, 1998; Harpviken, 1999; Harpviken and Millard, 1999; Harpviken, 2000; Millard, 2000; Millard *et al.*, 2002). These studies have made significant efforts to address the landmine problem. But there is still no comprehensive study that can put the landmine problem in a broader environmental context.

In this paper, a review of the environmental impacts of the landmine crisis is presented in accordance with principles and definitions of land degradation (in this work, the phrase *environmental impacts* is used to describe

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ecological problems the effects of which can transcend biophysical and biochemical considerations to influence the social, political and economic systems of a region). Central to the theme of the study are the conclusions reached by the Peace Research Institute—Oslo regarding the lack of studies that put landmine problems in a broader context that considers the health of the environment and the livelihood of the people in a region (Hanevik, 1998). A comprehensive discussion on the current understanding of the nature and complexity of the landmine-instigated ecological problem is given along with its principal after-effects, and processes and relationships that bring about land degradation and regional under-development.

The Landmine Crisis

Historical description

A landmine is 'munition placed under, or near the ground or other surface area and designed to be exploded by the presence, or proximity of a person or vehicle' (International Committee of the Red Cross, 1996: 3). This definition is sometimes extended further to include 'mass produced, victim operated, explosive traps' (Croll, 1998: 9). Landmines are broadly classified into two categories, as (1) anti-personnel and (2) anti-tank, that are targeted at and detonated by people and vehicles, respectively.

The International Committee of the Red Cross (1996) identified 360 types of anti-personnel landmines produced by approximately 55 countries. Recently, the advancement in mine technology has enabled the development of mines with switches that make them self-neutralizing or self-destructive, giving rise to the 'smart' mines whose life cycles are known, as opposed to the conventional 'dumb' mines that can stay active for more than five decades (Lloyd, 1999). Unless otherwise specified, the terms 'landmine' and 'mine' in this paper are used in reference to anti-personnel mines—type 1 above.

The global landmine problem

Today there is a global landmine problem the extent of which no one knows for sure. No one can say how many landmines are laid out there and where exactly these mines are. As a result, the sampling and data collection methods that were used to arrive at the estimated figure presented by the United Nations is disputed (Bottigliero, 2000). Nonetheless, it is believed that there are about 80–120 million landmines spread around 90 countries, with about 230 million landmines waiting to be deployed in 94 countries (Table I) (Landmine Monitor, 2002). Over 400 million landmines are believed to have been deployed since the beginning of World War II, including more than 65 million in the 15 years since the formulation of the 1980 Convention on Conventional Weapons (CCW) which attempts to regulate their use. The current global landmine problem is largely the result of the massive number of mines laid in the 1970s, 1980s and the 1990s (Roberts and Williams, 1995).

Landmines, although typically not categorized with weapons of mass destruction, are believed to have killed more people than nuclear and chemical weapons combined (Cameron *et al.*, 1998). Landmines are responsible for killing ca. 800 people and disabling another ca. 1200 people per week. International Physicians for the Prevention of Nuclear War (IPPNW) (2000) estimate there is approximately one mine laid for every 48 people in the world, equivalent to one for every 16 children. There is roughly one mine in the ground for each citizen of Cambodia and Bosnia; while approximately one of every two people in Afghanistan, Iraq, Croatia, Eritrea and the Sudan potentially faces a threat from these undiscriminating and unforgiving weapons (see Figure 1). In strictly military terms, landmines are cheap weapons. But a mine that originally costs US$3, can require between US$300 and US$1000 to clear, and adds to enormous cost in humanitarian and environmental damage (United Nations General Assembly UNGA/A/38/383, 1983; United Nations General Assembly UNGA/A/49/357, 1994; Roberts and Williams, 1995; Lutheran World Relief, 1999). Their long-term impacts and indiscriminate nature have earned landmines the label of 'eternal sentry' (William and Goose, 1998). The United Nations Mine Action Service estimates, even if landmine use stopped immediately, that clearing the world of mines could cost US$33 billion and with current manpower and de-mining technology, would take 1100 years. Unfortunately, it is believed that in the 1990s, 20 new mines were laid for every mine cleared (Winslow, 1997).

Table I. Countries with reported severe landmine impacts

Africa	America	Asia	Europe
Most severe			
Angola	El Salvador	Afghanistan	Bosnia-Herzegovina
Djibouti	Nicaragua	Cambodia	Croatia
Egypt		China	Yugoslavia
Eritrea		Iraq	
Ethiopia		Kuwait	
Malawi		Vietnam	
Mozambique		Yemen	
Somalia (and Somaliland)			
The Sudan			
Severe			
Chad	Guatemala	Burma	Armenia
Mauritania	Honduras	Iran	Azerbaijan
Morocco		Israel	Georgia
Namibia		Laos	Tajikistan
Rwanda		Lebanon	
Zimbabwe		Sri Lanka	
Zambia		Syria	
Less severe			
Botswana	Chile	India	Belgium
Liberia	Colombia	Malaysia	Bulgaria
Libya	Costa Rica	New Caledonia	Cyprus
South Africa	Cuba	Oman	Estonia
Burundi		Pakistan	Germany
Uganda		Thailand	Latvia
DR Congo			Lithuania
Congo-Brazzaville			The Netherlands
Niger			Poland
Swaziland			Russia
			Turkey

Source: Data collected from Arms Project for Human Rights Watch and Physicians for Human Rights, 1993; NPA, 1999; Landmine Monitor, 1999.

The landmine crisis in the developing world

In scale, the landmine crisis is global, affecting many countries in Africa, the Americas, Asia and Europe. However, the problem is ultra-hazardous to the environment and development of a number of developing nations. Most of the highly mine-affected countries are those listed in the 2004 *Human Development Report*[1] as the least developed and poorest (see Figure 1)(Fukuda-Parr *et al.*, 2004). To many of the rural poor in these regions, co-existing with mines is becoming the norm rather than the dreaded, horrible way of life of few (Roberts and Williams, 1995). A third of all developing countries are experiencing some form of landmine crisis. Africa currently has the worst problem with 27 nation-states experiencing serious landmine problems (Table I)(Westing, 1996). Large tracts of land are mined in many struggling nations, with 8·9 per cent of the arable land of Libya (Nachón, 2000) and 5 per cent of the available land area of Eritrea (Gebremedhin, 1997) mined at one time or another making it off-limits for agriculture.

[1]According to their Human Development Index (HDI), countries are assigned a rank where those with a rank higher than 140 have low human development, while those of 47–140 are medium and those below 47 are highly developed. The HDI is developed from indicators including per capita Gross Domestic Product (GDP), life expectancy and education levels.

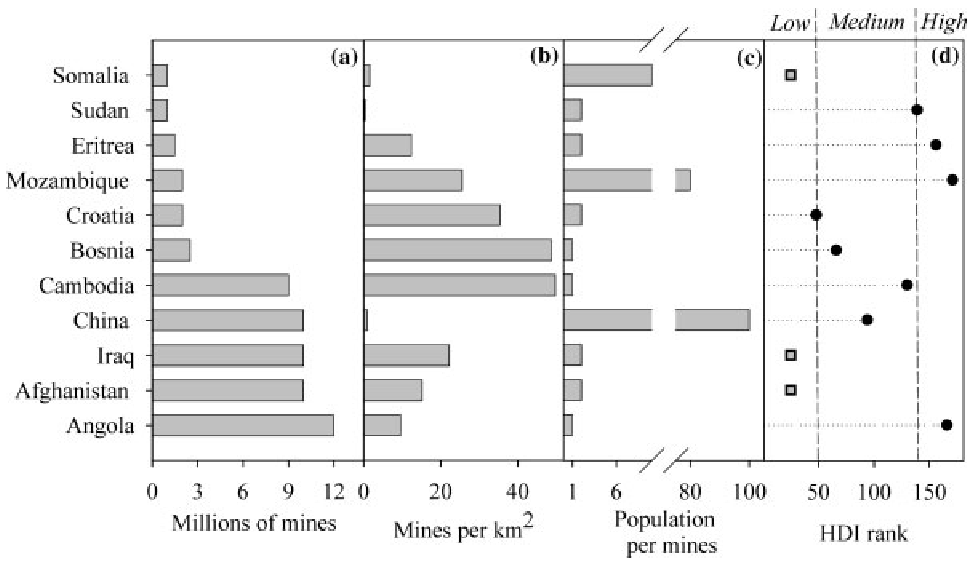

Figure 1. (a) Number of mines, (b) occurrence per km^2 and (c) number of people per mine (= population/number of mines) in some of the landmine-affected countries of the world (United States State Department, 1998; Gray, 1997; Misak *et al.*, 1999). (d) Human Development Index rank for the most affected countries. The chart is divided into three according to the classification of each country as having low, medium or high human development (HD). Afghanistan, Iraq and Somalia are ranked as having low HD, but an exact HDI rank is not available (Fukuda-Parr *et al.*, 2004).

GUIDING FRAMEWORKS

Land Degradation

Land degradation has been defined as a substantial reduction or loss of the intrinsic qualities or biophysical productivity and complexity of land due to land uses or processes arising from human activities. Land degradation can vary in both temporal and spatial scales, and quality. Land degradation indicates a drop in rank or status; and signifies the loss of utility (including particular current use or possible intended future uses) or the reduction, loss or change of features or organisms that are hard, if not entirely impossible, to replace. Movement of topsoil, introduction of harmful heavy metals, increase in salinity, reduction in organic matter content and soil crusting do not necessarily constitute land degradation. Consideration of these processes as ‘degradation’ implies a socially decisive factor that relates land to its actual or possible uses (Blaikie and Brookfield, 1987; Johnston and Lewis, 1995; Pagiola, 1999).

Lately, land degradation has emerged as a more formal, generalized and interdisciplinary concept that covers the dynamics of soil, vegetation and entire ecological systems. Land degradation has come to embrace social issues that arise as responses to various complex interacting factors, human values and biophysical limits in the biosphere. The contemporary, somewhat customized and holistic, definition of land degradation incorporates different natural and man-made phenomena that result decay of human living conditions; including: deforestation, drought, chemical contamination, soil erosion, development related activities and war. This view recognizes the ability of the ‘quite crisis’ that is land degradation to erode the basis of civilization and development (Brown, 1981; Blaikie and Brookfield, 1987; Dahlberg, 1994; Eden, 1996).

Sustainable Development

Sustainable development is ‘development that meets the current needs without compromising the ability of future generations to meet their own needs’ (Dubey, 1998: 316). Development as a concept is multidimensional; encompassing ecologic, economic, social, and political attribute of a system. Sustainable development principles then advocate a process of change in which resource use, investment directions, orientation of technological advances and associated institutional changes endeavour to accommodate the needs of present and future generations by looking beyond narrow, conventional solutions to social and environmental problems in order to address them from a broad, comprehensive perspective (Daly, 1990; Barrow, 1991; Bentley, 1994; Gupta and Asher, 1998; Sharma, 1998).

METHODOLOGY

The Research Approach

Information for this review was collected from multiple sources including the author's Masters research involving survey of professionals working with landmine-related problems and landmine victims around the world (Berhe, 2000), review of published and unpublished documents from various international organizations involved in mine action, along with country-level information presented in the annual *Landmine Monitor* reports and periodicals. Despite the excessive impacts of landmines, very little information is available on their ecological repercussions.[2] Therefore, instead of a quantitative approach that depends on extensive empirical research with predefined theories, hypotheses and assumptions, this review approaches the problem by posing open-ended questions that reflect the experiences of people who have been/are involved in the issue.

Data Collection

A questionnaire was sent to 46 individuals that were identified by their involvement in the *Landmine Monitor* report production process, a group of individuals that come together almost yearly to review the status of the landmine problem in their native countries or countries they are based in with landmine related missions. Out of the 46, 21 individuals participated in the study. Among those that participated in the survey were researchers in the areas of: environmental toxicology, environmental impact assessment, environmental law and its application to damages of war, social researchers and medical doctors. The participants were asked to give their expert opinions and/or results of previous studies conducted by themselves or their institutions. They were asked questions on the ecological damage that results from landmines and its socio-politico-economic implications. When necessary—for clarification or when more information was needed—follow-up questions were asked via telephone or e-mail.

Some of the things that were covered by archival research include: identification of baseline conditions of affected regions; implications of the ecological damage on land quality, future land use and planning; people's adaptations for survival when faced with these kinds of situations; the risks they take; possible migration; and the role of humanitarian assistance in sustainable development.

Analysis Procedures

Interpretation of the data collected from the survey or literature review sought to identify patterns, recognize relationships from the collected information and aggregate the findings into relevant categories based on those patterns, relationships and pertinent theoretical concepts. A cognizant effort was made not to consider every section independently.

The fact that there was hardly any consistency among the respondents (in terms of their expertise and area of research) makes it impractical to talk about percentages of respondents that answered a question in one way or another. The same impracticality also applies to trying to examine relationships, measure associations in the collected data, or tests of mean. This is mainly because one of the objectives of this study was to understand the different impacts and not the percentage of people who think one impact is graver than the other. After the replies

[2]Ideally, investigation of the ecological repercussions of landmines requires collection and evaluation of diverse kinds of information, including: pre-war conditions of the ecosystem; extent of war damage to soil structure; chemical analysis of water, plant and soil in the region; long-term data on biodiversity; vegetation patterns along with extent of human use of (interference in) the ecosystem; decline in productivity of the land; population health and movement; income and market conditions; and value and productivity of resources. However, this type of information is seldom collected for landmine-affected regions and if it is gathered it is usually done by the military and remains inaccessible for the general public. Environmental impact assessments are not necessarily part of landmine action and victim assistance projects.

to the questionnaire were grouped together and tabulated around the research questions, they were triangulated with literature from archival research in order to reduce potential biases in the study sources, researchers or methods; to increase understanding and corroboration of the findings (to reduce possible misunderstandings between those in diverse fields or between the researcher and the participants); to achieve better convergence of the results; and to introduce a comprehensive perspectives on the issue (Creswell, 1995; Romsdahl, 1999).

LANDMINE EFFECTS

General Statement of Results

The participants of the study stressed that landmines cause particularly complex phenomena of environmental degradation across different temporal and spatial scales. All but three of the respondents[3] stated that the mine problem is not localized to mined pastures and arable lands, and that the problem is of regional and international significance. The respondents recognized that the environmental aftermath can vary depending on: (i) the objectives and methodological approaches of the investigation; (ii) concentration of mines in a unit area; (iii) chemical composition and toxicity of the mines; (iv) previous uses of the land and (v) alternatives that are available for the affected populations. The respondents also highlighted the need for 'science' to provide more in-depth insights into the problem and evaluation of consequences.

A spectrum of variables and interrelationships were identified as significant in studying land degradation in mine-affected regions. The results and discussions of this multi-dimensional problem are organized into two categories as environmental and socio-politico-economic.

Categorization of Landmine Effects

Ecological dimensions

The impacts of landmines on soil, flora and fauna, and people are felt at different levels of the ecological system, whether the mines have detonated or not. The ways in which landmines cause land degradation are broadly classified into five groups: access denial, loss of biodiversity, micro-relief disruption, chemical contamination, and loss of productivity.

Access denial. All the participants of the study pointed out that the most prominent ecological issue associated with landmines presence (or fear of) is access denial to vital resources. Here 'access' is defined as the *ability* to derive benefits from resources, as opposed to 'property' that signifies the *right* to benefit from resources (Ribot and Peluso, 2003). It is estimated that landmines have denied access to or degraded 900 000 km^2 of land, globally (Buenker, 2000). For their military purpose, landmines guarantee that people and their movements are channelled away from strategically significant sites, and prevent military incursion. But the use of landmines is not by any means confined to military establishments or sites of military significance. The fear of presence of even a single landmines can deny people access to land that they desperately need for agriculture, water supply or to undertake conservation measures, and for technical teams engaged in pest control. Personal observations of the participants indicate that landmines are used in large quantities around arable lands in Lebanon, Angola, Mozambique, Cambodia; pasturelands in the Sinai, Kuwait and Iraq; forests in Nicaragua and the demilitarized zone between North and South Korea; coastal areas in Kuwait and Egypt; borders, infrastructures (bridges, roads, electrical installations, canals and water sources) and nearby commercial and public centres in Vietnam, Zimbabwe, Eritrea and Ethiopia; and residential areas in Serbia.

Access denial was indicated as being able to retard or stop development activities altogether. When landmines restrict access to arable or pastoral lands, the people who depended on those lands are pushed to use or abuse marginal resources, or move into refugee camps or urban centres, depending on the availability of alternatives (similar observations were reported by Gray, 1997; Harpviken, 2000; Troll, 2000). Moreover, declining

[3]The three participants that stated the problem is local indicated that the immediate concerns of toxic contamination are local, but in principle agreed that the other impacts extend far beyond the immediate localities.

availability of land was found to increase the need for practicing more intensive agricultural production systems that rely on heavy application of mechanical, chemical or biological supplements for production on the safe land. At the most basic levels, some of the ways these practices could endanger the health of the soil include: (i) rapid exhaustion of the soil's mineral nutrient stock due to continuous cultivation with no fallow or rotations; (ii) mechanically intensive agriculture and (iii) excessive use of chemical supplements and their consequent accumulation in the ecosystem.

On-the-other-hand, access denial has been observed to have 'positive' effects when the mined areas become 'no-man's land'. A couple of participants observed that, during limited anthropogenic interference flora and fauna get a chance to flourish and recover. Formerly arable- and pasture-lands in Nicaragua were turned into forest and forests remained undisturbed after the introduction of landmines. However, it should be pointed-out that, these benefits would only last as long as animals or tree roots do not detonate the mines. In addition, in land of lesser quality, long fallow periods could potentially end up creating or exacerbating loss of productivity.

Loss of biodiversity. The impact of landmines on different plant and animal populations was discussed by all the participants and was considered to be a foremost environmental concern, next to access denial. As long as they receive enough mass to activate them landmines do not differentiate between human beings or other life forms (Westing, 1996; Dudley *et al.*, 2002). Landmines can threaten biodiversity in a given region by destroying vegetation cover during explosions or de-mining, and when animals fall victim. Landmines pose an extra burden for threatened and endangered species. Landmines have been blamed for pushing various species to the brink of extinction (Troll, 2000). Although it is widely believed that landmines destroy vegetation and kill untold numbers of animals every year, this is unfortunately one of the areas where there is hardly any numerical data to determine how many individuals of a species or where and how they fall victims. The very little data that exists on animal population is also highly biased towards domesticated animal and little is known about the impacts suffered by wild populations.

Some of the animals that regularly fall victim to landmines include brown bears in Croatia; barking bear, clouded leopard, snow leopard and royal Bengal tigers in India; and gazelles in Libya. Landmines are accused of threatening extinction of elephants in parts of Africa and in Sri Lanka, and leopards in Afghanistan. Additionally, almost four per cent of the very rare European brown bears were reported killed by landmines in Croatia between 1991 and 1994 alone. Mines have killed one of the very few remaining mature, male silver-backed mountain gorillas in Rwanda and virtually eradicated gazelles from Libya (Roberts and Williams, 1995; Gray, 1997). With regards to domesticated animals, Andersson *et al.* (1995) studied the social costs of landmines in 206 communities in Afghanistan, Bosnia, Cambodia and Mozambique and reported that more than 57 000 animals were killed due to landmines, over 35 000 of which belonged to the Kuchi Nomads in Afghanistan. Another study also reported that more than 125 000 camels, sheep, goats and cattle have been killed in Libya between 1940–1980 (Gray, 1997).

Many of the biodiversity loss hotspots of the world are severely affected by landmines. Nachón (2000) referred to biodiversity data from the World Conservation Monitoring Centre and identified a large number of species that are threatened or endangered due to many factors, including the presence of landmines (Table II) in their habitat or

Table II. Species of living things at risk in mine affected countries (species abundance data for Cambodia was not available)

Country	Species diversity	
	No. species found	No. species at risk
Vietnam	9494+	434
Angola	766+	125
Afghanistan	5076+	53
Somalia	4568+	80
Cambodia	n/a	62
Mozambique	6835+	28

Source: Nachón, 2000.

migratory paths. Moreover, landmines are used for poaching endangered species of wildlife (Nachón, 2000), and refugees and internally displaced people further contribute to loss of biodiversity when they hunt animals for food or when they destroy their habitat in order to make shelters for themselves (Troll, 2000).

Landmine impacts on plants are even less documented. Landmines affect plant populations by causing slow-death of trees when they sustain shrapnel injuries or abrasions of their bark or roots when fragmentation mines detonate, providing an entry site for wood-rotting fungi (Troll, 2000). In regions where arable and pastoral activities turn out to be impossible due to landmines, forests become the last resort for food, fuel wood and shelter. Valuable forest products, including fruits and timber, from previously avoided sensitive, endangered ecosystems are exploited by affected populations looking to start new livelihood somewhere else. Moreover, wood destined for lumber becomes unsafe and troublesome when metal fragments are embedded in it (Westing, 1996).

De-mining activities also influence biodiversity in many ways. Domesticated animals are frequently used for mine clearance purposes, especially dogs, sheep and cattle. These animals are let loose in minefields as easy and fast means of clearance. Furthermore, de-mining operations demand clearing all the vegetative cover, including forests from mine-suspected areas, usually by using fire. The result is removal of litter that plays crucial roles in infiltration, protecting soil from erosion and the impact of rain drops, and providing organic matter that is important to biota and stability of soil's structure.

Micro-relief disruption. Landmine detonation causes damage to the soils' stability by shattering the soil structure, and causing local compaction, and increasing the susceptibility of soil to erosion. Deterioration of soil structure due to explosion, compaction or burning can be a slow and insidious progression, but their combination results in long-term changes that have significant, sustained impacts on moisture availability, erodibility and productivity of the land.

When a 250 g antipersonnel landmine detonates, it can create a crater with a diameter of approximately 30 cm (United Nations General Assembly UNGA/A/38/383, 1983; Troll, 2000). The explosion was described by nine of the participants as having the ability to facilitate removal and displacement of topsoil while forming a raised circumference around the crater and compaction of soil into the side of the crater. The level of the impact can vary depending on the physical conditions of the soil; the type and composition of the explosive and how many landmines detonate in the vicinity. The impact is greater in dry, loosely compacted and exposed desert soils but is less severe in humid soils that have vegetation or physical protection. Susceptibility to reduced infiltration, flooding and erosion is also higher in areas with steep slopes. In such cases, transported soil increases sediment load of drainage systems. When soil is compacted due to external forces, its resistance to penetration by plant roots and emerging seedlings increases, the exchange of oxygen and carbon dioxide between the root zone of plants and the atmosphere is also retarded. Generally, as long as repeated explosions do not occur in the same location, the crater can develop into a stable element of the landscape when runoff or wind erosion washes soil to its bottom. In warm and humid regions, however, it has been reported (United Nations General Assembly UNGA/A/38/383, 1983; Troll, 2000) that the crater may hold water, turn into a marsh and serve as breeding ground for mosquitoes.

Around 20 per cent of the respondents highlighted that de-mining activities result in micro-relief disruption by affecting the soil's biochemical and physical quality. A particularly harmful practice reported after the Gulf War is the use of fuel-explosive bombs. These bombs are dropped from the sky, creating heavy shock-waves that are propagated into the ground seeking to cause buried landmines to detonate (see also Troll, 2000). In addition, a lot of organic pollutants (from the fuel and the explosive material) get into the soil during this aerial de-mining process. A couple of the participants reported that fires are used to facilitate de-mining, thus modifying the amount, form and distribution of biomass, organic matter and essential nutrients with in the soil profile. The high temperature of burning causes more rapid than 'normal' humus loss. Similarly, the temperature increase can cause pH of soil to become more alkaline and nutrient elements may be converted into more bioavailable forms, or are lost from the soil by volatilization into the atmosphere, and transfer of ash with water or wind erosion.

Chemical contamination. Most of the respondents noted that landmines interfere with the ability of the soil system to serve as a geochemical sink for contaminants (i.e. act as a natural buffer to control the exchange of elements between the atmosphere, hydrosphere and biota). Depending on density of mines per unit area; the type and composition of the mine; and the length, amount and degree of exposure of resources to the mines, landmines can pose a serious pollutions threat, accumulation of non-biodegradable toxic waste of casings or unexploded remnants (see Gray, 1997). Moreover, after conflicts, many regions are left with a massive volume of exploded and unexploded ordinances that ruin the aesthetic quality of the area.

Landmines are made of metal, timber or plastic casing and are filled with 2,4,6-trinitrotoluene (TNT), hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX or Cyclonite®) or tetryl. Landmines can also introduce other non-biodegradable and toxic waste, such as depleted uranium. These compounds have been known to leach into soil and underground water as cosing of the mines disintegrate (Gray, 1997). Specific contaminants have unique consequences—the effects depends on many complex factors. In laboratory experiments with rats, TNT and RDX were found to be carcinogenic, causing tumours in the bladder and male reproductive systems, and congenital defects, skin irritation, and disruption of the immunological system (Organization of American States, 1999).

Landmines, to a lesser extent, also contain additional compounds including iron, manganese, zinc, chromium, cadmium, nickel, copper, lead and mercury, of which iron, manganese, zinc, copper and nickel are essential micronutrients in the plant-soil system. Soil contamination with heavy metals is observed in areas surrounding mines when the mines decay or explode. In extreme cases, contaminations can be detected in as much as 6 kms from the site of an explosion. Even higher concentrations of the heavy metals are found at the centre of the explosion site (Table III) (Orehovec *et al.*, 1998).

Many of the organic and inorganic substances and compounds that are derived from the explosives are long lasting, water-soluble and toxic even in small amounts. The contamination can be delivered directly or indirectly into soil, water bodies, microorganisms and plants with drinking water, food products or during respiration.[4] These pollutant compounds can leach into subterranean waters and bioaccumulate in the organs of land animals, fish and plants. Their effects can be mortal to some mammals and aquatic macro- and micro-organisms by acting as a nerve poison to hamper growth (Organization of American States, 1999; Troll, 2000). A significant landmine related chemical contamination threat is lead toxicity. Lead can have continuum of toxicity, meaning it can be harmful even at very small amounts, and its effects rise with increasing concentration. In human beings lead toxicity can result in kidney damage, sterility, miscarriage, and birth defects. Moreover, high levels of mercury can result in neurological disorder; while cadmium can cause kidney failure and osteomalacia—softening of bones and multiple bone fractures (Agency for Toxic Substances and Disease Registry (ATSDR), 1999a, 1999b, 1999c).

Loss of productivity. Landmines affect resource productivity whether they have detonated or not. Low availability of land (access denial), degradation of the soil (micro-relief disruption, chemical contamination), combined with loss of flora and fauna diversity add up to land degradation—reduction in productivity of previously productive land.

Table III. Safe concentration of some heavy metals and their concentrations in and around the site of landmine explosions. Water, food or air in parentheses represent contaminated element (Agency for Toxic Substances and Disease Registry (ATSDR), 1999a, 1999b, 1999c, 2000a, 2000b, 2003; Davies *et al.*, 1993; Aubert and Pinta, 1997; Orehovec *et al.*, 1998)

Element	Safe concentrations	Surrounding explosion site (ppm)	At the center of the explosion (ppm)
Hg	2.0 ppb (water), 1 ppm (food)	0·101	0·280
Cd	5.0 ppb (water), 15 ppm (food)	0·45	2·22
Cr	100.0 ppb (water)[Cr III and VI]	23	54
Mn	0·05 ppm (water)	88	559
Ni	0·7 ppm (water)	35	35
Pb	15.0 ppb (water), 1·5 ppb (air)	27	145

[4]Consumption of the contaminants is most common during and around the place where explosives are manufactured (Organization of American States. 1999. *Informe—Impactos Socioambiontales de las Minas Antipersonnel en la Cordillera del Condor.*).

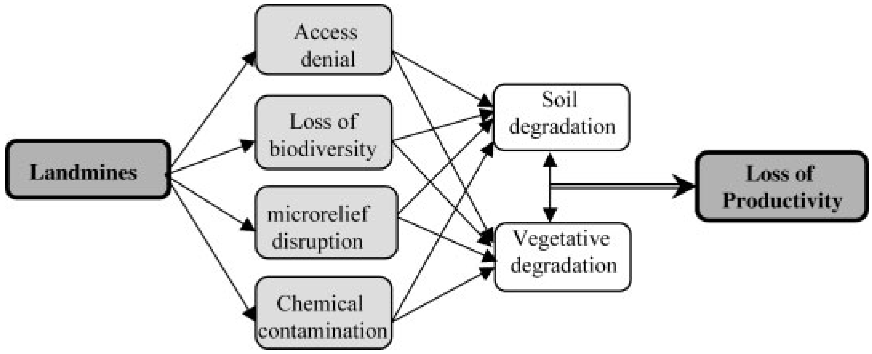

Figure 2. Compounding of landmine effects to result in loss of productivity and associated socio-politico-ecological problems.

Landmines have restricted agricultural production on a land area equivalent to 6 per cent of the 1474 million ha of land cultivated globally (Food and Agriculture Organization, 1997). Participants in this study blame landmines for being partly responsible for decreased agricultural productivity and lowered food security in mine-affected countries. In 2000, it was reported that in the absence of the landmine crisis the productivity in Afghanistan could have increase by 88–200 per cent, 135 per cent in Cambodia, 11 per cent in Bosnia and 3·6 per cent in Mozambique compared to pre-war levels (Troll, 2000). If we assume the inaccessible land can have average cereal yield of 10·6 kg ha^{-1} yr^{-1} (the lowest global productivity, for Sub-Saharan Africa for the period between 1981–1997), and per capita cereal consumption of 150 kg for Sub-Saharan Africa (Dyson, 1999). Then, based on the above assumptions, returning only a quarter of the 900 000 km^2 affected by landmines to cultivation could mean production of $2{\cdot}4 \times 10^8$ kg cereal annually, with a capacity to feed around 1·6 million people in sub-Saharan Africa annually.

As agricultural and other important lands are taken out of production, the socio-economic state of affairs of the segments of population that were once self-sufficient suffers. When people can not get access to their land resources because it is no longer safe to enter a whole host of problems are created. Land degradation leads to many complex socio-politico-economic problems, including but not limited to, exploitation of available resources beyond their ecological carrying capacity, unemployment, poverty, social marginalization, desperation, and aid dependency (Figure 2).

Socio-politico-economic dimensions of the ecological crisis

Generally, the participants of the survey categorized the socio-politico-economic dimensions of the landmine problem as those that affect or result in community health, poverty, social marginalization and aid dependency. Plus, especially in developing nations that have limited resources and capacity to deal with calamity, landmine effects are experienced in environments already experiencing effects of wars, unfavourable climatic and economic conditions, and governments' uncertain commitment to the environment (Eden, 1996; Stone, 1998). It is essential to note that, even without the additional burden of landmines, 70 000 km^2 of farmland, which is mostly in the developing world, is abandoned because of ecologically degrading factors such as: exploitative agriculture, deforestation, overgrazing and so on (Mehra, 1995).

Community health. Long after the troops have withdrawn and all the guns have been silenced 'landmines remain in the ground as brutal reminders that successful peace building and development are still beyond the horizon' (Boutros-Ghali, 1994: 8). As McGrath (1994) reported, landmines (until recently) cannot be recalled by the military when a cease-fire is declared, each and every mine must be individually disarmed or destroyed. Even decades after cease-fire children, farmers, nomads, herders, returning refugees and internally displaced persons continue to fall victims to landmines when the only choices they have are: (a) take no risk and starve or (b) risk death while trying to survive. In the absence of coordinated mine clearance operations, desperation causes communities to employ their own means of risk assessment that is mostly based on rumours or local knowledge.

As a result, 100 per cent of peacetime victims are civilians, compared to 90 per cent overall. Children face a particular risk because of their limited vision of the ground ahead and because of their tendency to mistake landmines for toys.[5] These realizations cause psychological trauma and keep populations in a state of persistent fear that is manifested by refusal to cultivate their fields, and to return to their homelands. Furthermore, continued militarization of former battlegrounds and denial of access to resources have been observed to perpetuate power struggles and cause even more conflicts.

Poverty and Social Marginalization. Landmines are weapons of social cataclysm (Inter-African Network for Human Rights and Development, 1997) that have a subtle multiplier effect with the ability to drain societies' resource potential and bring misery for generations (Davies, 1994). The danger created by landmines frequently make subsistence and sustainable development difficult, if not impossible.

Landmines contribute to perpetuations of underdevelopment by killing or injuring a community's sources of income (people and livestock), inhibiting effective cultivation or control of locust (and other pests) and scaring away tourism and other means of income (similar observations were reported by Hanevik, 1998). Several of the participants indicated that a large portions of landmine victims are adult men, the bread-earners and heads of households. Similarly, Andersson *et al.* (1995) reported that the highest risk group are men between the ages of 15 and 64 years. The loss of more than 57 000 animals that Andersson et al. attribute to landmines is equivalent to a minimum annual market value of roughly US$200 per household. It is assumed that Afghanistan, Bosnia, Cambodia and Mozambique alone have suffered more than 6 million US dollars loss due to landmine's effect on animals. For the nomadic populations in North and Eastern Africa and the Middle East loss livestock reared for production of dairy, meat, leather products or subsistence farming activities has had significant socio-economic effects.

At a larger scale, landmines and their impacts become added burdens to the already over-taxed economies and over-stretched resource bases of struggling nations. Fragile financial systems of developing nations become more susceptible to failure as funds are diverted away from development, to take care of disproportionate health bills of victims. Landmines interfere with economic development. Landmines in Vietnam hindered the construction of a new major north–south highway, while de-mining activities drained the resources of the community in Mozambique to the point that there were no funds left to restore de-mined roads. Furthermore, with growing land scarcity the poor, women and minorities are disadvantaged.

Aid Dependency. When the land becomes off-limits or disrupted and its productivity is reduced the rural, subsistence populations are forced to live with aid from different humanitarian institutions (Harpviken, 2000). International aid for landmine assistance is critical, but when it is ineffectively handled it has the capacity to inadvertently cause more harm than good by undermining local strengths and endorsing aid dependency (Anderson, 1999; Harpviken and Millard, 1999). Fear of returning to previously mined areas along with an unhealthy dose of aid dependency created problems of underreporting in Mozambique, while efforts were made by communities in Cambodia in an attempt to delay the departure of de-mining teams. Harpviken (2000) and Millard (2000) also reported similar events where de-mined communities have been accused of laying new mines in order to attract other mine action programmes to their areas. It is plausible to point out that repeated problems of such kind can lead to donor fatigue, in which case the affected communities would be left to fend for themselves.

Temporal and Spatial Scales of Impact

The ecological impacts of landmines and associated socio-politico-economic implications are manifested in a variety of temporal and spatial scales. When asked to give temporal and spatial extent of how the presence of landmines poses danger to the environment, the respondents categorized them as follows:

(a) Instantaneous—injury and/or death of flora and fauna, destruction of soil stability from explosion
(b) Immediate—on the vicinity of the incidence, for instance, in terms of chemical contamination

[5]Although there is no evidence that anti-personnel mines have deliberately been made to resemble toys or other everyday objects, there is some evidence of booby-trapped children's toys and household objects. Some mines, for example the Soviet made PFM-1 are made to resemble a butterfly and can easily attract children (McGrath, 1994. *Landmines: Legacy of Conflict: a manual for development workers*. Oxfam. UK and Ireland).

(c) Protracted—at a distance from the point of explosion, such as in the case with population spill into non-mine affected areas
(d) Persistent—continuous and long term impacts such as access denial and associated psychological trauma that perpetuates a state of ongoing fear
(e) Cumulative—problems that get aggravated with time such as loss of biodiversity and productivity.

Sustainable Development in the Aftermath of Landmine Crisis

Combined effects of landmines have tremendous influence on development activities. Narrating the rhetoric of how environment and development are particularly interweaved in a cause and effect chain becomes particularly necessary here because this linkage puts landmines, ecological degradation and underdevelopment in a triangular relationship (Figure 3—loosely based on the work of Suliman, 1999). Land degradation occurs as a result of complicated feedbacks, while consequent underdevelopment causes simultaneous degradation of societies and their natural resources. The triangular representation demonstrates the complexity of the environmental effects of landmines and shows how the variables in the different corners of the triangle are related to each other, and can lead to a vicious cycle of destruction.

To describe the causal link of landmine-induced land degradation with development one can give the examples of deforestation and landmine effects on animal migration. Deforestation has been accelerated by extensive use of landmines. Where arable and pasture lands have been mined to such a degree that forests become the only source of livelihood, the long-term consequences of selling old forests and fruit trees gives way to immediate survival pressures. Cascading effects from deforestation can affect the surrounding areas. Moreover, minefields in migratory paths of some terrestrial animals can cause more harm than just death or injury. As one participant in the study noted, after a large number of elephants perished in the minefield of Southeast Asia, others learned to avoid that area, instead moving into agricultural areas they previously avoided—causing crop damage along their newly acquired migratory paths, which has led to local people hunting the animals to prevent further damage. This landmine-induced cycle of degradation continues by triggering socio-economic problems including: loss of income, poverty, migration, and social marginalization of affected populations.

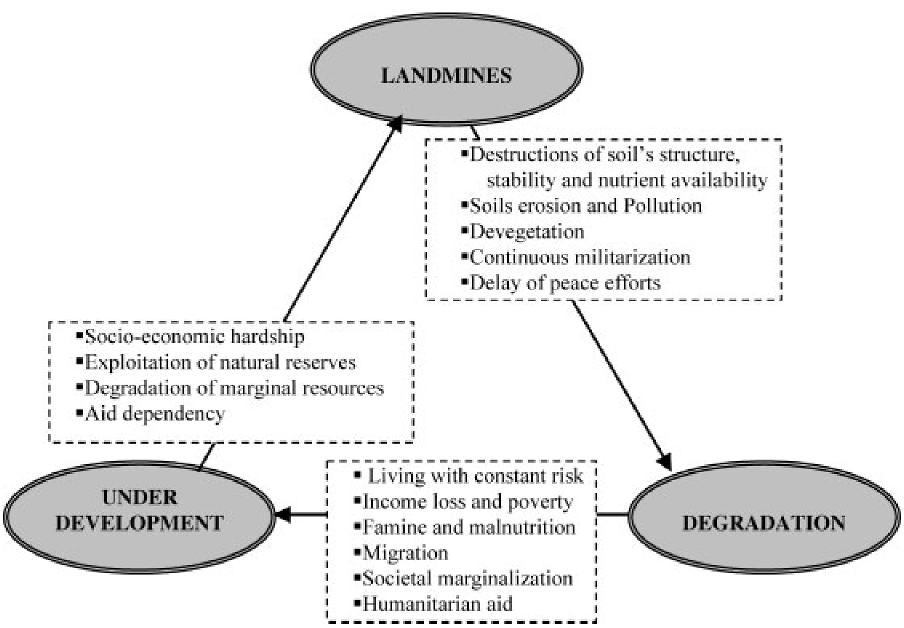

Figure 3. Triangular relationships between landmines, ecological degradation and underdevelopment.

Communities usually receive international humanitarian aid for de-mining and rehabilitation. But if the aid is provided in ways that fail to consider the real causes of the problem and the needs of the society it has tendency to foster aid dependency. In more extreme situations, landmines then drive populations to mine cleared areas in order to attract aid, or resource limitations leads to conflicts that reintroduce mines to the area, thus maintaining the triangular link between landmines, ecological degradation and underdevelopment.

In most cases, land users and managers are aware of the inherent potentials and constraints of their land, and they do develop appropriate systems of management that suit the quality of their resources. However, when these populations are forced to move to other areas (that may have different qualities and constraints) their traditional resource-management systems can become unsuitable or inadequate leading to inappropriate land use (excessively intensive cultivation, overgrazing and deforestation in the mine-free lands). Moreover, refugee populations usually have the dream of returning home and the settlement areas are perceived to be temporary; they strive to make the best out of the time they stay there. Refugee populations, more often than not, do not consider long-term investments or the effects they have. Desperation, not ignorance or stupidity, leads to abandonment of rational, sound resource management bringing about a collective disorder—tragedy of the commons (Hardin, 1968).

Regardless of who laid the mines and for what purpose they were placed, landmines promise to be impediments to development for a long time to come. Landmines change the natural environment in so many ways and make it hard, if not entirely impossible, for societies to achieve sustainable development that they might otherwise have attained.

SUMMARY AND CONCLUSION

Landmines cause multifaceted and interconnected ecological and socio-politico-economic problems. Landmine use is at best unchivalrous, but is a practical necessity (Croll, 1998). Landmines threaten the fragility of the natural environment by changing the quality and cover of land, and through abuse of biotic resources and habitat destruction. Landmines pose a lose-lose situation because they will cause land degradation whether landmines are left in the ground or detonated. Moreover, it is clear that there can be no blueprint for sustainable development in mine affected regions.

ACKNOWLEDGEMENTS

I thank Eckhart Dersch for his guidance throughout the research process. I also thank Michael Thomas, Larry Leefers, Arthur Westing, Ananda Millard, Karen Troll, and two anonymous reviewers for their help during the research process and/or valuable comments on earlier versions of this manuscript.

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