Rural Manufacturing in Cambodia: A Complementary Approach to Landmine Casualty Reduction

Steven Lim[a] and Bee Chui (Evelyn) Saw[b]

Abstract

Cambodia has one of the highest rates of civilian landmine casualties in the world. But with up to an estimated 4,500 square kilometres of Cambodian land still contaminated by landmines/UXO, the cost and time-consuming nature of clearance is a serious hurdle to rural development. The Cambodian Mine Action Centre, employing more than 2,000 deminers, has a current clearance capacity of only about 10-12km^2 per year. Thus, landmine/UXO research needs to be widened to encompass complementary activities that accelerate the current reduction in casualties.

We investigate the implications of partial landmine removal. Clearing landmines/UXO from transport routes facilitates infrastructural development, such as all-weather roads and new bridges, to link contaminated villages with previously inaccessible markets, including labor markets. Access to manufacturing jobs serves as a substitute for complete landmine removal in the village. Opening up safer income sources, such as factory work located away from landmines/UXO, may prove to be a quicker and more cost-effective way of reducing landmine/UXO casualties than relying solely on traditional humanitarian demining activities. We illustrate this proposition using a simulation model.

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[a]Corresponding author, Economics Dept, Waikato Management School, University of Waikato, Private Bag 3105, Hamilton, New Zealand; Tel: 64-7-838-4315; Fax: 64-7-838-4331; Email: slim@waikato.ac.nz

[b]Economics Dept, Waikato Management School, University of Waikato, Private Bag 3105, Hamilton, New Zealand; Tel: 64-7-838-4315; Fax: 64-7-838-4331

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1. Introduction

Landmines have been used in many war-torn countries, such as Cambodia, Laos, Angola and Mozambique, as part of military strategy or to terrorise civilians and control their movements. The widespread use of landmines, compounded by their relatively low cost of production, has created a protracted legacy of destruction. In 1995, the United Nations declared that 'mines were one of the most widespread, lethal, and long lasting forms of pollution' the world has ever known (Anonymous 2004). Landmines continue to isolate large, poor civilian populations from access to farm and grazing land (Anderson, Palha da Souza, C and Paredes 1995), roads, drinking water and firewood, worsening the already devastating effects of injury and deaths.

Since landmines/UXO are seen as a physical problem, engineering and technical solutions to clearing landmines/UXO feature heavily in casualty reduction programs worldwide and command the bulk of mine action funding (see ICBL 2003). Field surveys, marking of contaminated areas, village-level risk education and actual clearance usually form the core of demining practice. Where economic analysis is brought to bear, it is typically in identifying and evaluating locations for demining. Separating the physical act of clearing landmines/UXO from a wider economic perspective cements the landmine/UXO issue ultimately as an engineering or technical problem.[1]

We suggest that the current emphasis on engineering issues in demining restricts the options facing policy-makers. The appropriate research question, in our view at least, is not how to remove landmines/UXO at least cost, but how to most effectively reduce casualties. Landmine/UXO clearance is only one of several key issues in casualty reduction. With an estimated 4,500 square kilometres of Cambodian land claimed by some to be contaminated by landmines/UXO[2] (CMAC 2002), the scale of clearance is a serious hurdle to casualty reduction. The Cambodian Mine Action Centre (CMAC), the largest demining organisation in Cambodia (ICBL 2003), has a current clearance capacity of only about 10-12km^2 per year,[3] suggesting that direct removal efforts are slow relative to the total size of the problem. From a wider, social perspective, expenditure on landmine/UXO clearance is likely to exhibit much lower benefit-cost ratios than other welfare-enhancing activities. Lives saved per dollar spent on the distribution of condoms to combat HIV/AIDS, for example, may be much larger than an equivalent expenditure on complete landmine/UXO removal. For these reasons, we suggest that landmine/UXO research needs to be widened to encompass explicit economic alternatives to complete clearance of contaminated areas, alternatives that may produce faster and more cost-effective results at the margin. To date, much effort, financial resources and risk have been applied to the removal of landmines/UXO. But much less attention has been directed at finding complementary strategies to reduce casualties. It is this gap that our research seeks to address.

We investigate the implications of targeted or partial landmine/UXO removal in a village or region.[4] By 'partial' we mean complete removal in priority areas within a given geographical unit, with landmines/UXO remaining in non-targeted areas of the unit. Within a village, for

[1] Although economists have also contributed to the development of more efficient methods of landmine/UXO clearing, eg see Marsh, Boe-Gibson and Gibson (2002).
[2] This estimate is disputed; for example, see ICBL (2003).
[3] To give an idea of the number of mines and UXO yet to be removed, from the total of 90+ square kilometres of land that it cleared of landmines/UXO from 1992-2001, CMAC found 148,820 anti-personnel mines, 2,930 anti-tank mines and 667,160 items of UXO (CMAC 2002).
[4] See Paterson (2001) for further aims of targeting.

example, only some of the contaminated fields might be targeted. We shall consider two priority areas for clearance: fertile agricultural land and transport routes.[5] Clearing landmines from transport routes facilitates infrastructure development, such as all-weather roads and new bridges, to link contaminated villages with previously inaccessible markets, including labor markets. Access to manufacturing jobs, in particular, serves to some extent as a substitute for complete landmine/UXO removal in the village. By opening up alternative, safer income sources, such as factory work located away from landmines/UXO, villagers can remove themselves from the landmine/UXO dangers in their farms and forests. This may prove to be a quicker and more cost-effective way of reducing casualties than relying on traditional demining activities alone. This approach is underpinned by the view that the cause of landmine/UXO casualties is not solely the landmines/UXO themselves, but the economic conditions that induce people to risk injury or death by living or working in landmined/UXO-contaminated areas. Thus our approach differs from others, such as Bier (2003), that integrate basic social and economic development programs with demining to achieve a desired end, namely effective and sustainable post-conflict reconstruction. In this paper, economic rehabilitation and infrastructure construction are a means; the end is to reduce casualties.

Our focus on demining farmland and roads permits a more rigorous examination of the role of manufacturing growth in landmine/UXO casualty reduction. Agriculture and industry often co-exist symbiotically: agriculture supports the growth of industry and *vice versa*. Transport routes provide the physical link between the two, facilitating the beneficial (and at times competitive) interactions. We examine the wider economic benefits of partial landmine/UXO removal in terms of agriculture's contribution to manufacturing growth,[6] the resulting increased manufacturing jobs and the alternatives to complete landmine/UXO removal that the job opportunities make available.[7] Hence, in analyzing the impact of clearing landmines/UXO from farmland and roads, it will be useful to consider competing feedback from manufacturing, using a general equilibrium system.

The paper proceeds as follows. The next two sections introduce the dimensions of the Cambodian landmine/UXO problem and highlight the rationale for demining key farmland and transport routes. Given an initial expansion in farm output, we then develop a simple simulation model of economic interactions between agriculture and manufacturing. Workers base their decision to shift between sectors on relative profits or net wages, where the net returns from manufacturing work depend among other things on farm production. As we shall see, incentives to switch labor allocation between sectors can be complicated. The simulation model will present an illustration of the processes underlying partial landmine/UXO removal, inter-sectoral labor supply and casualty reduction. Most of the parameters of the simulation

[5] Cambodian mine-clearing organizations such as CMAC are currently shifting their priorities from an emergency or humanitarian clearance, roughly based on casualties per unit area, to development criteria in which the priority for landmine/UXO clearing is determined by the community itself. At the community level, road and agricultural land clearance seem to be important priorities (interview with Ouk Ratanak, Deputy Director of Operations and Planning, CMAC, Phnom Penh, 2003). But see also Demex and Scanteam (2004) for adverse issues associated with targeted road demining.

[6] The contribution of agriculture to the growth of the manufacturing should be included in an assessment of the benefits from rural landmine/UXO clearance. Yet analysts often limit the economic gains from landmine/UXO removal to the direct increase in farm production. By failing to recognize the positive spillover effects on manufacturing, the economic impact of landmine/UXO removal may be underestimated.

[7] We have suggested that farmland and transport routes be considered priority areas for landmine/UXO removal. But determining the actual priorities is complicated in practice. In the field we encountered village leaders who rejected efforts to remove landmines/UXO from their villages. The government has removed mines from farmland, only to find that outsiders expropriate the newly-valuable land by taking advantage of unsettled property rights, sometimes with the collusion of corrupt village leaders.

model are based on data obtained from field research in Cambodian villages in Kampong Speu Province surveyed by the authors in 2003 and 2004.

2. Dimensions of the Cambodian landmine/UXO problem

The Cambodian Level One National Survey,[8] issued in May 2002, suggests that landmines/UXO affect 6,422 villages (46.2 percent of the villages surveyed), covering an area of 4,466 km^2 and putting an estimated 5.1 million people at risk. Of this, 2,776 villages are classified as contaminated by minefields and/or cluster bomb areas having a severe, adverse socio-economic impact on the community. Other remaining villages are contaminated by spot landmine/UXO contamination or have cluster bomb areas, but do not suffer adverse socio-economic impacts on the community. 7,486 villages were identified as non-contaminated (53.8% of the total villages surveyed).

Although the landmine impact survey (LIS) provides valuable information on affected areas and the impacts of landmines/UXO on communities, the size of the claimed contaminated areas is still under debate. According to the Landmine Monitor Report (2003), the LIS may overstate the problem by as much as 90 percent. The practice of surrounding contaminated areas with large buffer zones, plus the possibility of land already cleared being recorded as contamination-suspected, contribute to the overestimation problem (Landmine Monitor Report 2003). Some demining organisations therefore use a planning figure of 10 percent of the Level One National Survey estimates; e.g. the Cambodian Mine Action and Victim Assistance Authority (CMAA) estimates that 425.17 km^2 of land require clearance (Anonymous 2004).

Even with the use of a 10 percent planning figure, the land to be cleared of landmines/UXO is still vast. CMAC, with a total staff of 2,400[9] is capable of clearing only 12 km^2 per year.[10] The demining organisation HALO has 1100 staff deployed in Siem Reap province alone, with a reported demining rate of 25 km^2 per year.[11] The cost of demining is not cheap. HALO estimates demining cost per square meter to be US$0.67, while the cost per mine removed is US$160.[12] In November 2004 alone, HALO spent US$2,929,923 on demining. It thus appears that the process of demining is painstakingly slow and expensive. CMAC, demining at the rate of 12km^2/year, would take 37.5 years to completely demine 10 percent of its estimated contaminated areas. Even at a higher rate of demining (25 km^2/year), it will take 18 years to complete demining. With the prediction of funding from NGOs coming to an end in 10 years time,[13] there is a need for a faster approach to reducing landmine/UXO casualties, namely the partial clearance and creation of off-farm employment that are the focus of this paper.

3. Priority Clearance: Case studies from Kampong Speu Province

Our choice of clearing agricultural land and transport routes (as opposed to forests, mountains/hills, footpaths and rivers) needs some explanation. Nationwide statistics from recent landmine/UXO incidents suggest that most casualties occur in forests (Table 1).

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[8] A landmine impact survey, providing a database of landmine/UXO contamination and socio-economic impacts in Cambodia.
[9] Of which 92-93 percent work in the field.
[10] Interview with Mr Him Vandy, December 2004.
[11] Interview with Mr Tim Turner, December 2004.
[12] Tim Turner, December 2004.
[13] Tim Turner, December 2004.

Table 1: Terrain of Landmine Incidents

TERRAIN	Percent
Forests	45
Paths	13
Rice Field	10
Mountains/Hills	7
Near Rivers	7
Grazing Fields	5
Near Military Positions	4
Roads	3
Villages	3
Other	3

Source: Cambodian Red Cross 2003

Forest casualties outnumber rice field casualties by more than four to one, ostensibly suggesting that the demining of forests be given priority over farmland. Yet the reverse may hold: that first clearing farmland of landmines/UXO may be the more effective way to reduce total casualties. Constraints on the supply of arable land, imposed by landmines/UXO, reduce household farm size to such an extent that many households move into food deficit for several months each year. To cope the households divert labor to logging and harvesting of forest products.[14] The result is an increase in forest-related landmine/UXO casualties, such as from cutting wood, collecting food and clearing land (see Table 2). By helping to meet subsistence food needs and generate a marketed food surplus, clearing landmines/UXO from farmland would reduce the pressure for villagers to work in forests.

Table 2: Activities during Landmine Incidents

ACTIVITIES	Percent
Travelling	31
Farming	20
Cutting/Collecting Wood	18
Clearing New Land	8
Collecting Food	7
Nothing - exploded beside Victim	4
Tampering with Mine	3
Demining	2
Herding	2
Military Activity	2
Construction	1
Other	1

Source: Cambodian Red Cross 2003

[14] In such situations, the burdens often fall heavily on the poor (Roberts and Williams 1995).

Assigning priority to demining farmland is supported by field research in mined and demined villages in Kampong Speu Province. In July 2003, as part of a Waikato Management School research team, one of the authors interviewed a number of Cambodian government, NGO, business and village representatives, as well as villagers, to gather background information and data on landmine/UXO activities and impacts. The field research was undertaken in Phnom Penh and in two districts (Oral and Phnom Srouch) in Kampong Speu Province, lying west of Phnom Penh.

Kampong Speu Province ranks ninth out of Cambodia's 24 provinces in terms of landmine/UXO casualties over a recent survey period (Cambodian Red Cross 2003). It was the scene of much fighting between government and Khmer Rouge forces due to its strategic position between Phnom Penh and the port of Sihanoukville (Kampong Som). Phnom Srouch District was held by the Khmer Rouge from 1988-1995. By 1996 the refugee population that had been displaced by the fighting had begun to return. The Mines Advisory Group (MAG) cleared landmines/UXO from the district in 1997-2000,[15] yet one village is still contaminated: Pring Village in Treng Trayoeung Commune. Over an approximate period of 5-7 years, the village suffered at least six landmine/UXO casualties. Given the size of the village, this gives a casualty rate of at least 0.2 percent per year, well above the current average for Kampong Speu Province as a whole. The village is relatively poor, with more than half its households suffering food shortages for 2-6 months each year. An average household might be in food deficit for three months per year (typically September-November).[16] According to the leader of the village development committee, landmines/UXO are the most significant cause of the poverty in the village. (Nearby villages that have been demined appear to be doing much better, given their ability to increase the amount of crops grown.) Pring villagers respond to the food deficit by making money from the production of charcoal, firewood and bamboo.

[15] Interview with Khem Sophal, Lutheran World Federation (LWF), Phnom Srouch District, Kampong Speu Province, July 2003.
[16] Interview with Group Leader, Pring Village, July 2003.

Landmined land, Pring Village, Treng Trayoeung Commune, Phnom Srouch District

Of the households that sell fuel wood, an average household might earn around 50,000 riel (approx. USD12.50) per month, its only source of farm income during the food deficit periods. Rice production tends to be only for subsistence needs. A representative of the village claimed that villagers would cut back on wood-cutting if they could expand rice production after their fields were demined.

A preference for farming over forest-related work was also expressed by villagers in Oral District. Oral District is now free of landmines/UXO.[17] During fighting in 1990, most of the population of more than 10,000 from Oral District left their villages to move to government camps or to join the Khmer Rouge.[18] Under the 1996 reconciliation pact the Khmer Rouge withdrew from Oral District, beginning the return of the displaced population and the clearing of landmine/UXO from roads and community areas by MAG. Despite the clearing, villagers are still vulnerable to income shocks. Between 1999 and 2002 the area was hit continuously by droughts and floods. In Sangker Satop Commune, for example, natural disasters on the farm sent villagers into the forests to log and harvest forest products. With family sizes ranging between 5-10 people and farm sizes of no more than 2ha (with some latecomers to Oral District settling on farms of only 0.5ha), poverty from low rice production has meant that now 60 percent of families resort to selling charcoal to supplement their livelihoods.

Within a closed, farming/forestry production system subject to landmines/UXO or natural disasters such as in the two districts above, the scope for income generation is slight. Secure roads need to be built if such a system is to be opened to outside market and job opportunities. As late as 1998/early 1999, the only access between Kampong Speu town and Oral District

[17] Interview with Ung Sokchamroeun, community development officer, LWF, Oral District, Kampong Speu Province, July 2003.

[18] This and the following information were provided by Chamnap Houn, community development officer, LWF, Oral District, Kampong Speu Province, July 2003.

was by foot or motorbike. The 60km trip took roughly eight hours by motorbike. In 1999, the Lutheran World Federation upgraded the road, allowing the trip to be made in one-and-a-half to two hours. But flooding could add another two-three hours to the trip. By early 2003 the road was further upgraded to render it all-weather, and bridges were constructed to mitigate the impact of floods. The key to the continual upgrading of the road was to clear it of landmines/UXO first, an activity undertaken by MAG in 1996.

Roadside charcoal selling, Oral District

The all-weather road to Kampong Speu town, upgraded in late 200

Bridge on the Kampong Speu-Oral District road, completed in April 2003

The road and bridges have benefited farmers as new markets have emerged for their produce, including bananas and sugarcane. Prior to the infrastructure, villagers had difficulty in selling surplus production outside their area, resulting in local oversupply and price problems.[19] Perhaps an even more significant gain from the original demining of transport routes is the opportunity for villagers to diversify their income sources. The all-weather road has dramatically cut travelling time to Kampong Speu town, near which garment factories are located (primarily on the highway between Phnom Penh and Kampong Speu town). The garment industry is Cambodia's largest industrial employer. Garment manufacture in Cambodia is dominated by labor-intensive processes, making the industry suited to tapping rural surplus labor. If villages could shift their work from landmine/UXO-contaminated farm and forest areas to the relative safety of factories, then casualties would likely fall. Manufacturing jobs would become a partial substitute for complete, time-consuming and expensive demining of villages and nearby forests.

4. Modelling Framework

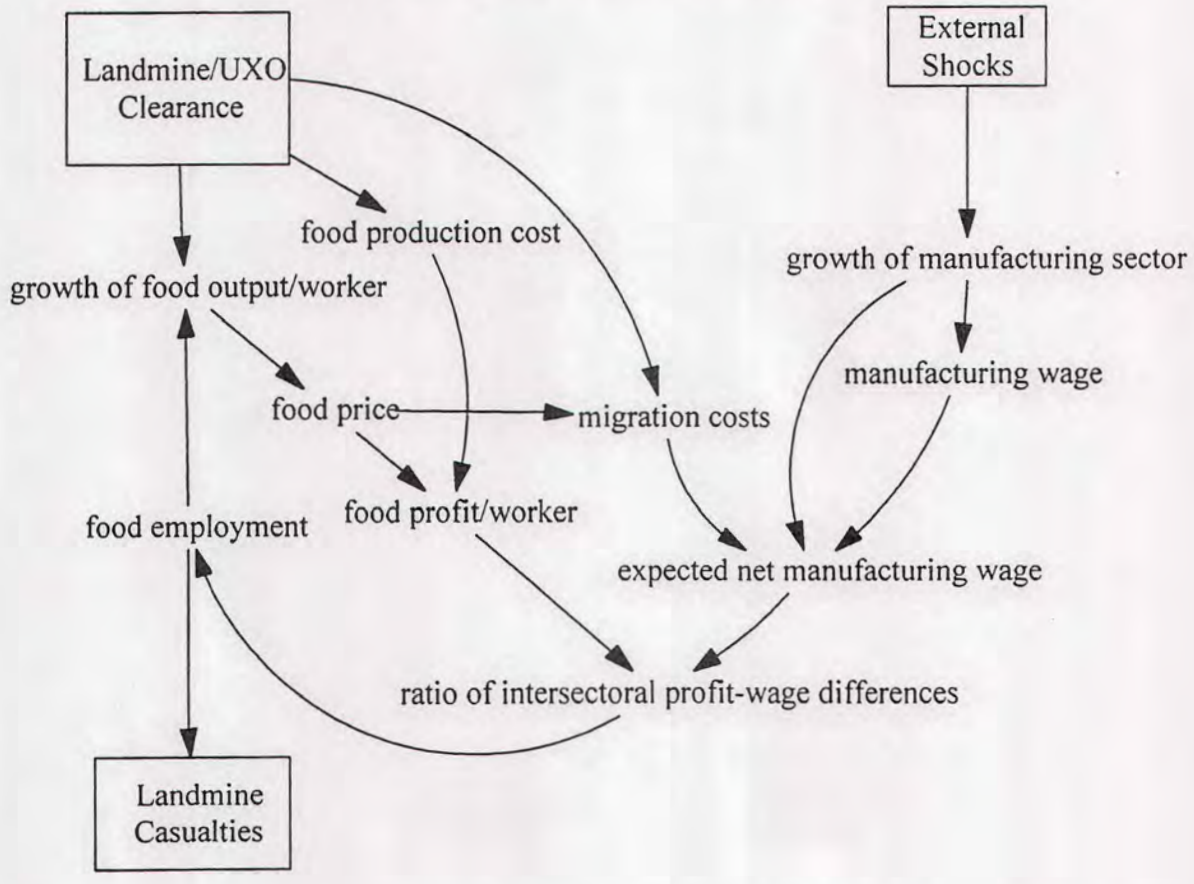
We turn to a model of inter-sectoral interactions that highlights salient issues associated with landmine/UXO removal from farmland and transport routes. To simplify the model, we consider only two sectors: the safe sector, manufacturing, and the unsafe sector contaminated by landmines/UXO, broadly denoted 'food'. The food sector spans a range of village-based

[19] Interview with Chamnap Houn, July 2003.

production activities that relate to food inputs or outputs, including farming, forestry, herding, land clearing and food collection. While demining some village farmland makes farming safer and may lessen the incentive to undertake other risky village-based work, the breadth of casualty sources in Table 2 nonetheless suggests that food-related activities are likely to continue to claim lives, at least under the scenario of partial demining. We assume, then, that food-related work in the village remains 'unsafe' overall. As workers leave the unsafe sector (i.e. as food employment falls), landmine/UXO casualties also fall.

The model focuses on three broad issues: changes in labor allocation between the two sectors as landmines/UXO are removed from farmland and transport routes, the impact of food production on the net incomes of workers in the manufacturing sector, and the reduction in landmine/UXO casualties should labor shift out of food production. Consider the basic model, summarized in Figure 1, in which deminers undertake partial landmine/UXO removal. Key farmland (and roads) are decontaminated, resulting in the initial growth of food output per worker as more arable land becomes available to villagers. There may be downward pressure on food prices, but this is offset somewhat by a lower imputed cost of food production, primarily related to reductions in the risk of death and injury as landmines/UXO are cleared. Per farmer food profits, broadly defined, may rise or fall depending on the relative sizes of the food price and cost effects.

Figure 1. The Labor Allocation Model



The decontamination of roads attracts factories to the countryside as businesses seek cheaper labor and land. The factories establish themselves along the main highways, sometimes near small towns. Decontaminating roads affects the migration expenses incurred by workers as

they migrate to off-farm jobs. In particular, the imputed cost of travel time may fall sharply as suggested in the case study above. Other items of migration expense include payments for transportation to and from the village to the factories and rent paid by workers in the factory townships. (Given disguised unemployment on farms, we impute a zero value of the subsistence food output foregone as farm labor shifts to the manufacturing sector.) Deducting migration expenses from the manufacturing wage leaves the net manufacturing wage. But given the constraints on finding manufacturing work, it is the expected net manufacturing wage that is relevant (i.e. the net manufacturing wage times the probability of getting a job, with the probability of getting a job increasing with the number of manufacturing firms). Workers compare net food profits per worker with the expected net manufacturing wage in allocating their labor between the two sectors.

Landmine/UXO removal has a direct positive impact on food production, akin to a productivity shock to farmland. But the increase in farm output per worker, and therefore farm worker income, is tempered by a decline in the price of food. Landmine/UXO removal reduces the total cost of producing food, but also lowers food expenses incurred when working off-farm. Without knowledge of the relative sizes of these impacts, the direction of intersectoral labor movement in response to landmine/UXO clearance is indeterminate. Conceivably, removing landmines/UXO from farmland could reduce the incentives to produce food (although the enhanced productivity of farmland has the potential to increase food supplies). If employment in the food sector declines, then so too will landmine/UXO casualties. Nevertheless, should the manufacturing sector be hit by adverse external or trade shocks, such as a fall in foreign demand for Cambodian garments, the closure of factories could initiate flow-on effects that may ultimately increase landmine/UXO casualties.

5. Simulated Outcomes

The preceding section highlighted the complex relationships between landmine/UXO clearance and a range of economic variables, including input and output prices, and intersectoral wages, profits, production levels and labor allocation. We now illustrate the time paths of the variables under different scenarios, using Vensim PLE32. Vensim PLE32 is a modelling tool that facilitates the simulation of dynamical systems. Relationships between variables in the system are entered as causal links to build stock and flow diagrams that collectively form the system to be simulated (a fuller description of the Vensim modelling software is available at www.vensim.com).

The following simulations are based on Figure 1, which we seek to model for a hypothetical Cambodian district heavily contaminated by landmines/UXO. Our reference districts for the simulations are Oral and Phnom Srouch, based on field data collected in July 2003, and Samroeung Tong, based on data collected in November-December 2004. All three districts are in Kampong Speu Province.

As discussed earlier, Pring Village in Phnom Srouch is relatively poor, barely meets subsistence food requirements, is heavily contaminated with landmines/UXO, and has a high casualty rate. By contrast, the villages sampled in Samroeung Tong, which have better access to factories, are on average richer than Pring Village, have many more migrant workers and suffer fewer landmine/UXO casualties. Thus, our simulations use data from Phnom Srouch and Oral to set the initial simulation parameters, such as farm size and food output per worker, to represent a community whose proximity to landmines/UXO retards access to output and labor markets and stifles economic development. We then use data from the higher

income Samroeung Tong villages to derive parameters that relate more closely to trade in food markets and to off-farm migration, given targeted demining.

Villages in the sampled Samroeung Tong area tend to comprise 100 or more households, with 4-5 people per household. Rice is the main crop. In a village with 55ha of arable land, for example, 52ha might be devoted to rice fields, with the remaining three used for vegetable growing, although there is some variation across villages, including in hectares farmed per household. In our 2004 survey, paddy sold at a farm gate price of R300-500/kg (US$0.75-1.25 /kg), or up to US$125/tonne.

Most of the Samroeung Tong villages have migrant workers, often in the garment industry and also in construction. In the sample of seven villages in Samroeung Tong district, migrant workers in the garment sector ranged from 3-50 percent of the village population. Our village surveys indicate that the per worker migration costs to work in factories include $5-7/month for accommodation, usually in dorms or shared rental dwellings; $7-8/month for transport to and from the village to the factories (such as for a minibus to a factory one hour away); plus around $10/month for other miscellaneous expenses. Clothing expenses usually amount to very little.[20] The village respondents stated that farm output did not fall when surplus labor migrated to factory jobs – other family members simply worked more. In calculating the costs of migrating to manufacturing, we thus impute a zero opportunity cost of food output foregone.

Small Cambodian garment factories typically employ around 500-1,000 workers, paying a base wage of US$45 per month,[21] although some factories pay $40 per month. We do not know whether the migrant workers consider the lifestyle associated with working in the factories to be more or less desirable than living in the village. In determining the intersectoral allocation of labor, then, we assume that the sole criterion for workers is net financial remuneration.[22] In manufacturing the key wage is the net expected wage, i.e. the actual nominal wage adjusted for migration and other expenses, multiplied by the probability of finding a manufacturing job. (We model the probability as a constant times the number of firms in the locality.) Given the risk attached to working in the unsafe food sector, we arbitrarily discount the prospect of a dollar earned in food production by a third relative to a dollar earned in a factory. We further assume that worker skill levels are roughly the same between sectors – most garment workers coming from the farms are illiterate (labor brokers are used for recruitment, since most job applicants cannot read the job advertisements),[23] although some of the village headmen interviewed stated that factories also imposed literacy tests on job applicants.

We begin the simulations with an outline and discussion of the key assumptions underpinning the simulation equations. Where possible, the assumptions and resulting equation parameters provide an approximate representation of the economic and demographic environment in the villages outlined earlier in this section. We initially assume that food is the dominant sector, both by production and employment. Let the total labor force in our simulated district be fixed at 5,000 workers out of a total population of 8,000. In contrast with the current situation in Kampong Speu Province overall, the simulated district is assumed to start with heavy landmine/UXO contamination. At 14-15 casualties per year, the district faces a very high

[20] Ms Chi Socheat, CARE, Phnom Penh, 2004.
[21] Mr Chea Sophal, ILO, Phnom Penh, 2004.
[22] Following Grasso (1998).
[23] Anonymous informant, Garment Manufacturers Association of Cambodia, 2004.

annual casualty rate of around 0.18 percent.[24] Each household has five members, of which three are able-bodied workers. Households have one hectare of land each. Initial food production (t/ha/worker/year) is 0.3, giving a fairly low initial annualised household output of 0.9 tonnes, a figure similar to that given by households reporting tonnage for a moderately poor harvest year. The initial price of paddy is set at $118/tonne, consistent with our field survey of prices.

At the outset of the simulation, assume that there are two factories employing 1400 migrant workers in total.25 The remaining workers in the district work in the food sector. The growth rate of food production is driven by a combination of exogenous and endogenous factors. Landmine/UXO clearance is one of the exogenous factors, as is also the intrinsic growth rate of food output,[26] determined by technology and the macroeconomic environment. We assume that food output per worker grows logistically. Growth in the number of manufacturing firms is also logistic[27] and is determined exogenously, e.g. by the world trade environment. The food and manufacturing sectors are constrained to not exceed some potential or maximum level. We let potential food output/worker be one tonne per year, slightly more than three times the initial output of 0.3 tonnes/worker/year, given the reduction in production constraints associated with targeted landmine/UXO removal.[28] The potential or maximum sustainable number of factories is initially set at 6.

Growth in the number of manufacturing firms drives up the manufacturing wage. In the list of simulation equations below, the monthly manufacturing wage is given by $W = 40 + 0.2M$. The intercept relates to the afore-mentioned US$40/month wage, with wages rising with growth in M, the number of manufacturing firms in the locality. (Note that, in reality, total hires in the factories are typically not constrained by the population of the district. In practice, labor can be drawn from outside the district as well but, as modelled here, there will still be a slight upward pressure on wages.)

As food output rises due to targeted demining, the price of food falls,[29] leading to changes in food profits per worker. Food profits per worker per month (π_F) are given by food output (tonnes) per worker per year, divided by approximately 12 months, all multiplied by the price of food/tonne, P_F, less the cost/tonne of making the food, C_F (see the equation list below). We have modelled the food price equation based on calculations derived from actual price-quantity relationships reported by farm households. The food production costs relate to fertiliser and other direct input costs (assumed to total $20/tonne), less the assumed

[24] Approximating the 5-7 year casualty average for heavily-contaminated Pring Village, Treng Trayoeung Commune, mentioned earlier.

[25] Most of who are likely to be young women, given the dexterity and sewing skills required in garment factories.

[26] Set arbitrarily at 0.0001 in the simulations.

[27] The logistic function has been chosen because it exhibits similarities with observed growth in actual sectors or industries. E.g., when the number of firms in an industry is initially small, new firms can enter and industry growth accelerates, but eventually the growth rate declines as the industry becomes saturated (when reaching the upper limit to the number of firms that the industry can sustain).

[28] For example, without landmines/UXO, agricultural production could be increased by 135% in Cambodia as a whole (Walsh and Walsh 2003). With less than half the country's villages suspected of landmine/UXO contamination according to CMAC – see above – the production increase in a contaminated village could be more than 270%. (And presumably this refers to average land; targeted decontamination focuses on clearing the most productive land first.)

[29] Note the functional form of the food price equation. Due to simultaneity problems in the simulation, we cannot multiply food output/worker by the number of food workers to determine total food production. We have resorted to scaling output per worker to derive total food production.

production benefits accruing from landmine clearance. Changes in food profits per worker impact on the decisions of villagers to continue working in the food sector or to migrate to factories.

Manufacturing sector or migration-related expenses likewise fall with food prices, further influencing the net returns from migrating. The equation C_M = 45 - 0.017(118-P_F) - 0.0065*Clearance* highlights the impact of food prices (and landmine/UXO removal) on costs incurred by migrant workers. The US$45 relates to monthly transportation, accommodation and miscellaneous expenses. As food output expands due to demining, food prices fall below the initial price of US$118 per tonne. To derive the impact on per capita food expenditure, we assume that a migrant consumes the equivalent of 200kg of paddy per year, or approximately 17kg per month. The latter figure determines the coefficient 0.017 in the equation.

Based on the relative net returns, the workers then determine their intersectoral labor allocation, namely whether to work more in the food sector (N_F) or in manufacturing (N_M). The allocations are based on the following equations: $N_F = \frac{N}{2}(1+d)$, $N_M = \frac{N}{2}(1-d))$, and $N = N_F + N_M$, where N is the total labor force of 5000 workers. The term d refers to the ratio of difference in remuneration per worker across the two sectors. Here, $d = (0.67\pi_F - W^E)/\pi$, where W^E is the expected wage in manufacturing, and the prospect of a dollar earned in food production has been adjusted or discounted arbitrarily by a third relative to a dollar from factory work to account for the risk involved in the food sector.[30]

Once workers have re-allocated their labor across sectors due to the changes in remuneration attending the food output increase, the changes in employment levels will impact on sectoral growth rates. In the case of the food growth rate, for example, a shift of workers from food to manufacturing is modelled as having a relatively small impact due to the low marginal product of departing food workers, as discussed above.

5.1 Scenario 1: The Baseline Model

The key simulation equations for Scenario 1 are given below.

Food Sector

Output/worker/yr: $F = \int \dot{F} dt$

Growth of output/worker/yr: $\dot{F} = \left(r_F - r_F F/\overline{F} + 0.000005 Clearance + 0.00005 P_F\right)F$

Intrinsic growth rate of F: $r_F = 0.0001$

Potential output/worker/yr: $\overline{F} = 1$

[30] For example, from the labor allocation equations, if $d = 0$ (where the adjusted returns from each sector are the same), then the 5000 workers are split evenly, ie, 2500 workers in each sector.

Price/tonne: $P_F = 130 - 40F$

Cost/tonne: $C_F = 20 - 0.001\,Clearance$

Profit/worker/month: $\pi_F = 0.08(P_F - C_F)F$

Manufacturing Sector

Number of firms: $M = \int \dot{M} dt$

Growth in number of firms: $\dot{M} = (r_M - r_M M/\overline{M})M$

Intrinsic growth rate: $r_M = 0.1$

Potential number of firms: $\overline{M} = 6$

Monthly wage: $W = 40 + 0.2M$

Migration expenses/worker: $C_M = 45 - 0.017(118 - P_F) - 0.0065Clearance$

Net expected wage: $W^E = (W - C_M)0.1M$

Total remuneration/worker $\pi = \pi_F + W^E$

Ratio of difference in

remuneration/worker $d = (0.67\pi_F - W^E)/\pi$

Employment (N)

Total: $N = N_F + N_M = 5{,}000$

Food: $N_F = \frac{N}{2}(1+d)$

Manufacturing: $N_M = \frac{N}{2}(1-d)$

Landmine/UXO Impacts

Casualties: $Casualties = 0.004N_F$

Initial Conditions

Food output (t/worker/yr): 0.3

Manufacturing firms: 2

The figures below illustrate time paths for production, employment and casualties for Scenario 1. The initial monthly food profit per worker is around $2.40. This may seem low,

but accords with consumption data for surveyed villages in Phnom Srouch, 2003. (In Beng Village, Chambok Commune, annual cash spending per head ranged from zero to $125. Spending of $25/year was not uncommon.) Food production rises with landmine/UXO decontamination, with food contributing to an expansion of manufacturing via decreases in migrant food expenses. Worker remuneration increases in both sectors, but at a faster rate for manufacturing. Labor shifts to manufacturing, with attendant changes in rural out-migration. Landmine/UXO casualties fall in accord with our expectations.

Figure 2

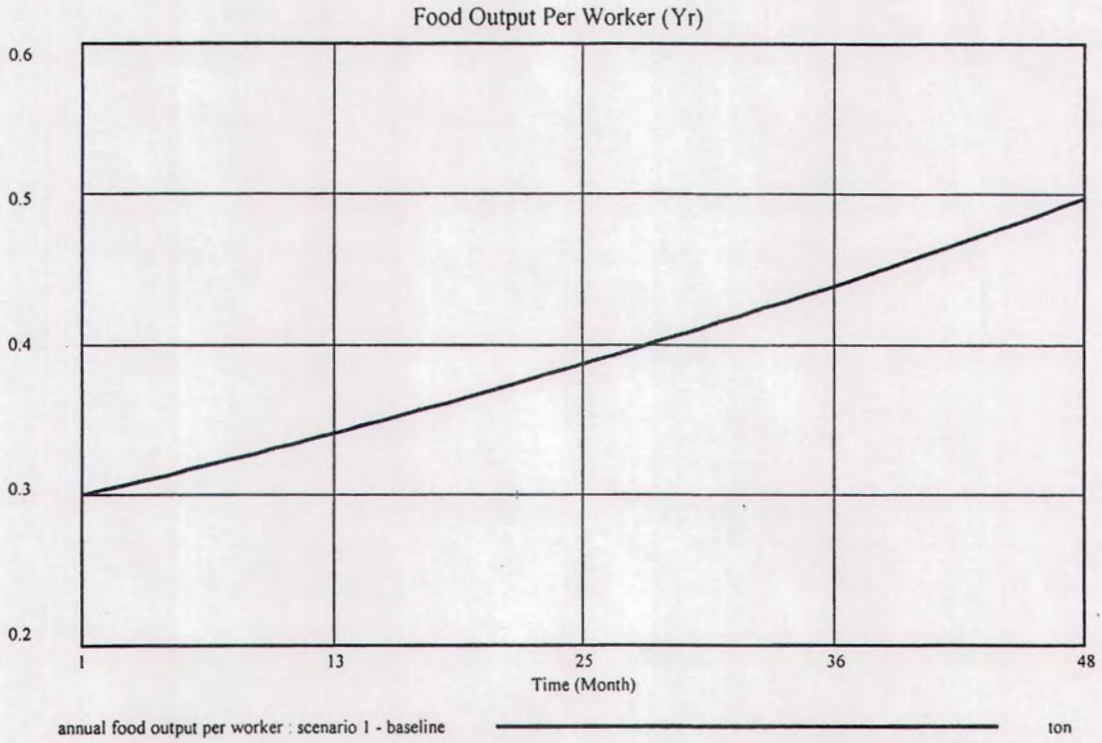


Figure 3

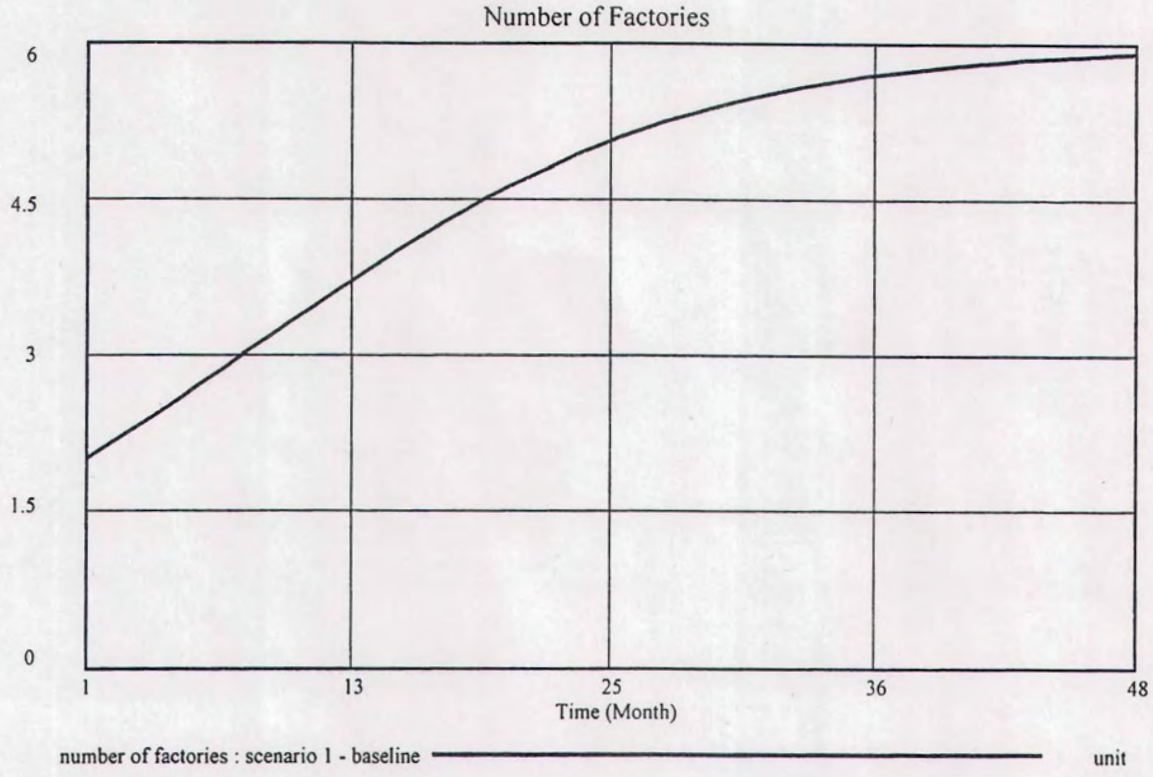


Figure 4

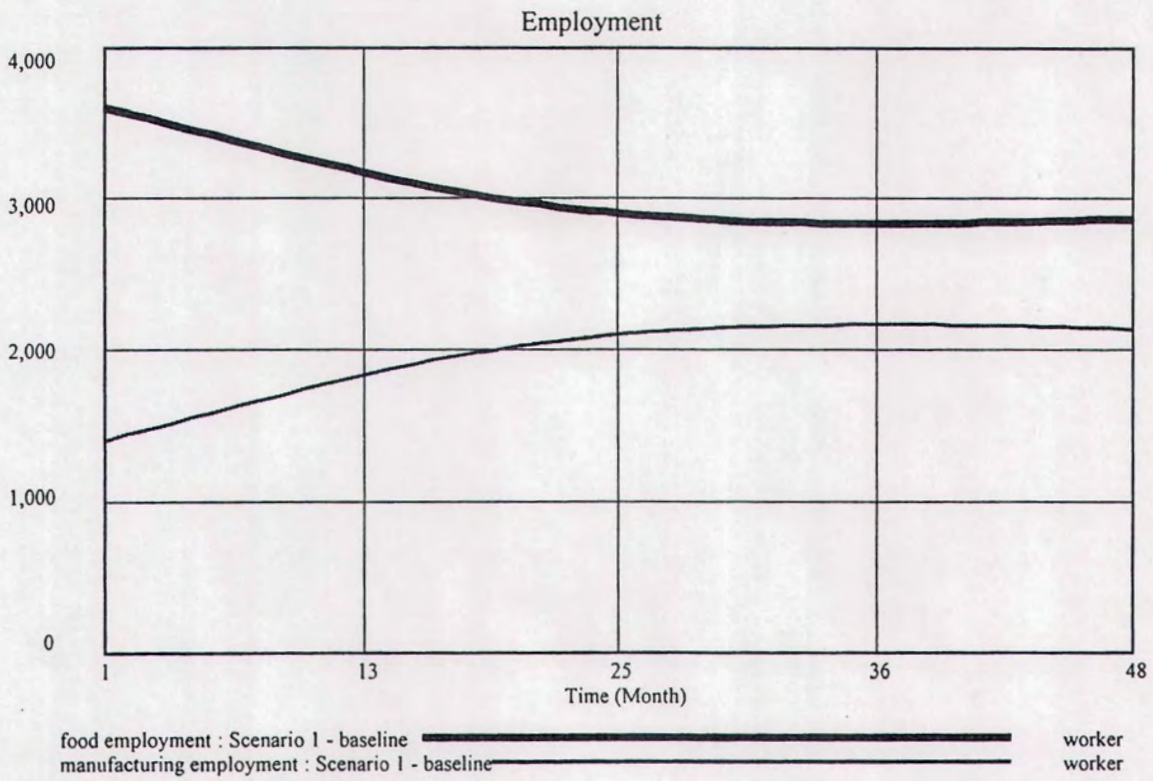
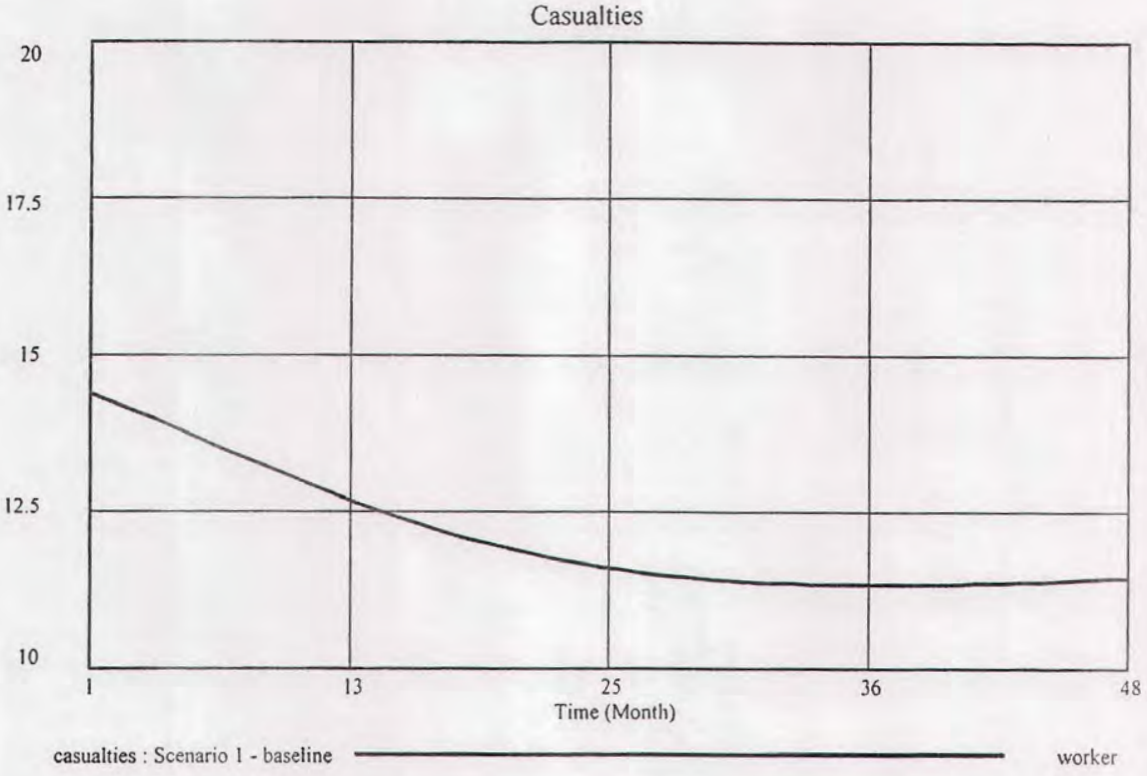


Figure 5



The overall simulation results seem reasonable. Given that the decontamination of farmland focuses on the most fertile or productive land first, we expect to see an increase in food output/worker. The other significant impacts relate to the decontamination of roads to link the villages with the newly-emerging factories and the provision of a safer working environment. Food employment falls from 3,600 to 2,861 after four years. Casualties fall by more than 20 percent within three years.

Nevertheless, the results obtained from the simulation depend on assumptions made about the timing of demining impacts across the food and manufacturing sectors. In the above, the demining activities have an instantaneous effect on the variables concerned. Roads are cleared as fast as farmland, allowing surplus farm produce to be sold in local and, if necessary, in more distant markets. In our simulation, the rise in food production results in only a relatively small decrease in food price (falling from US$118/t to around US$110/t) over the four year simulation period. Yet suppose that farmland was cleared first, with roads following much later. There would be a clear lag between the initial demining-induced increase in food output and the ability of localised markets to absorb the output. Faced with an inelastic demand for food, farm profits could fall. Given this unexpected shock, more households might resort to collecting fuel wood in landmine/UXO contaminated forests, worsening the casualty problem.

5.2 Scenario 2: Trade Shock

The manufacturing sector may be buffeted by shocks, such as Cambodia's entry into the WTO and adverse changes to the foreign investment environment. In Scenario 1, significant and rapid increases in Cambodian manufacturing exports may do more to benefit households in landmined/UXO areas than waiting for the government and NGOs to fund more demining. Yet as a result of WTO membership, Cambodia has now lost its favored access to US garment

markets. Given the stern competition from China, Cambodia's garment industry is currently bracing itself for widespread factory closures.

Scenario 2 differs from Scenario 1 only in terms of manufacturing growth. Now the intrinsic growth rate of the manufacturing sector falls to 0.067 and the maximum number of firms is set to four, reflecting the view that at least a third of Cambodia's garment factories may close.

Figure 6

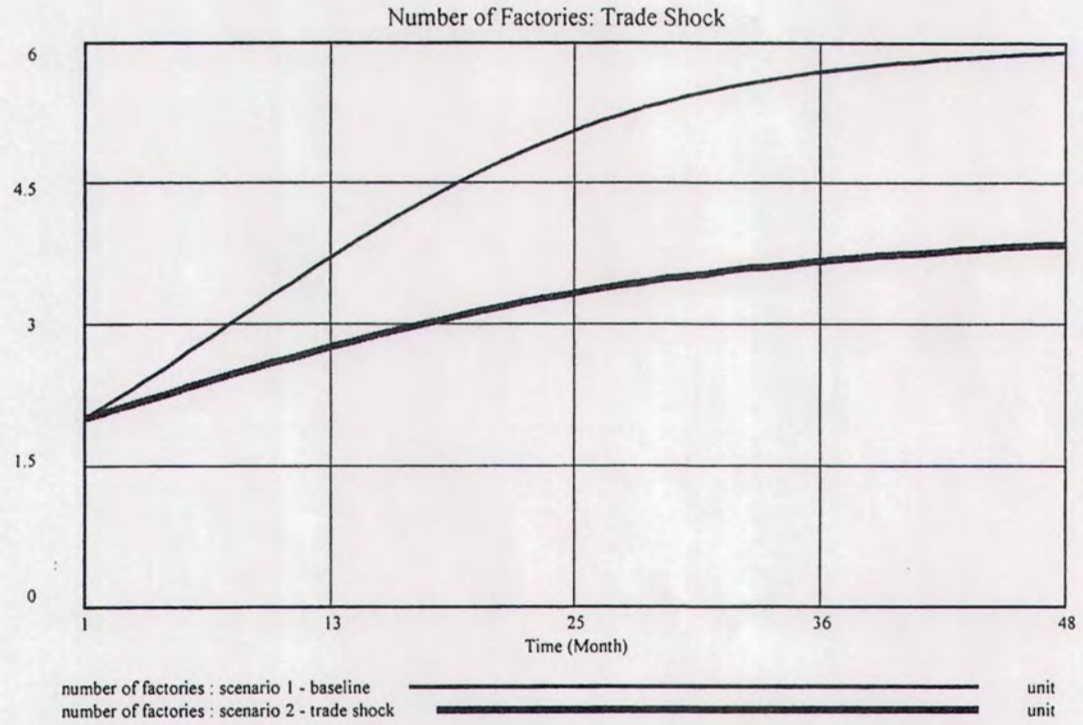


Figure 7

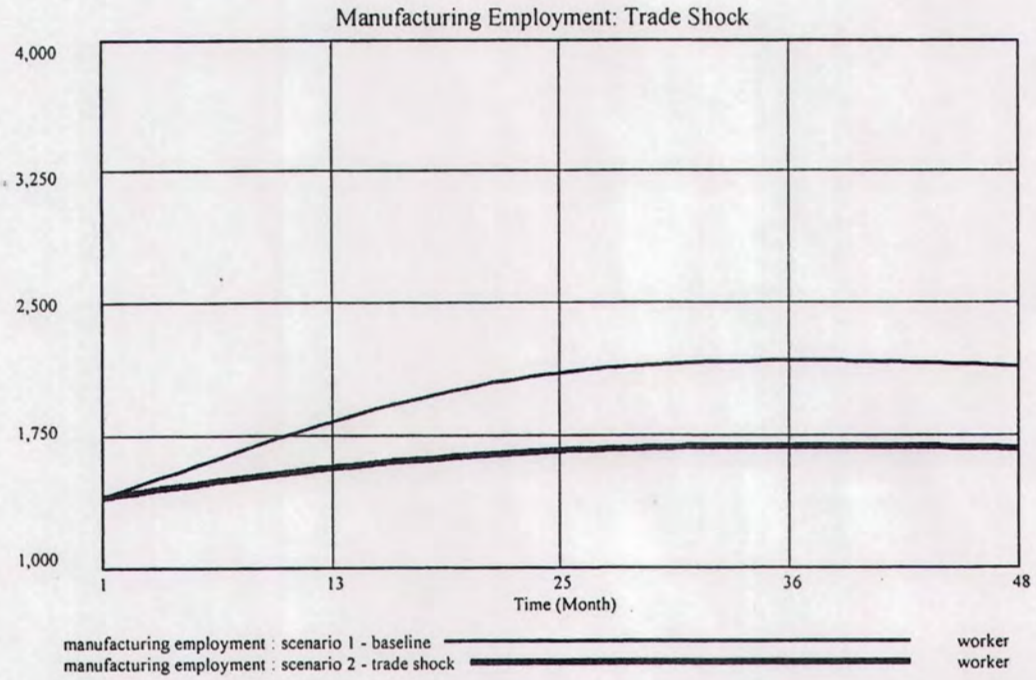


Figure 8

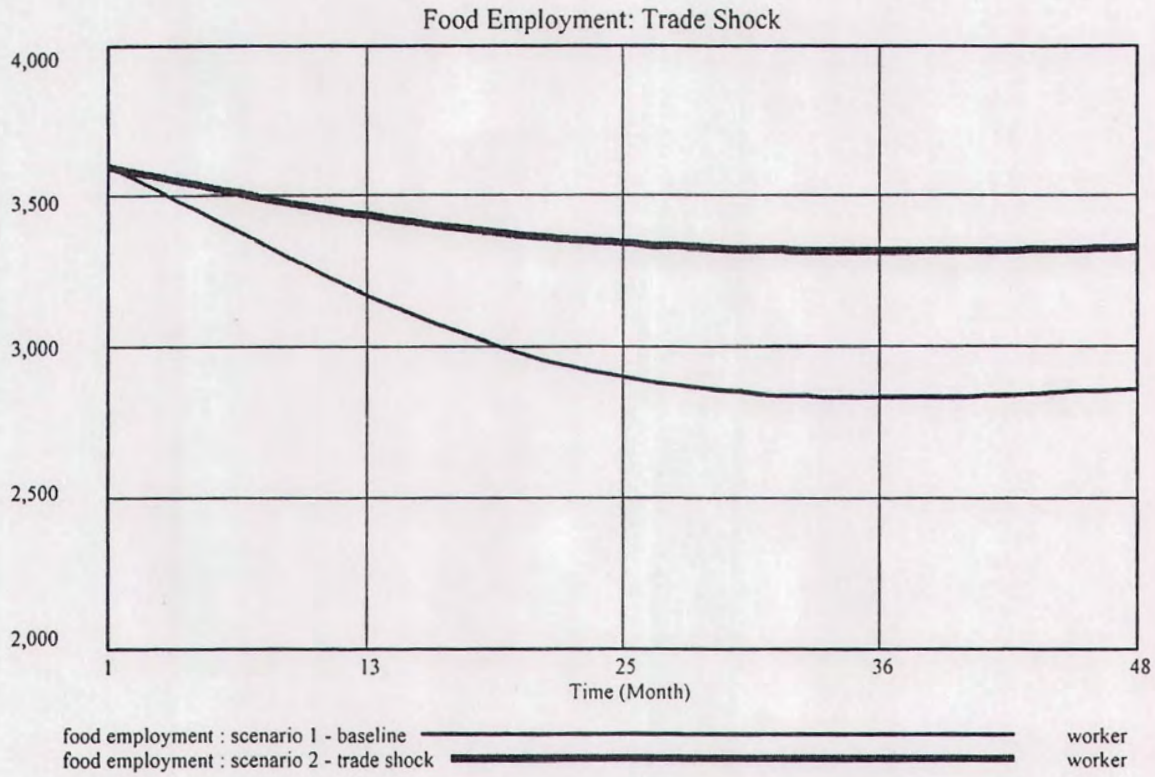
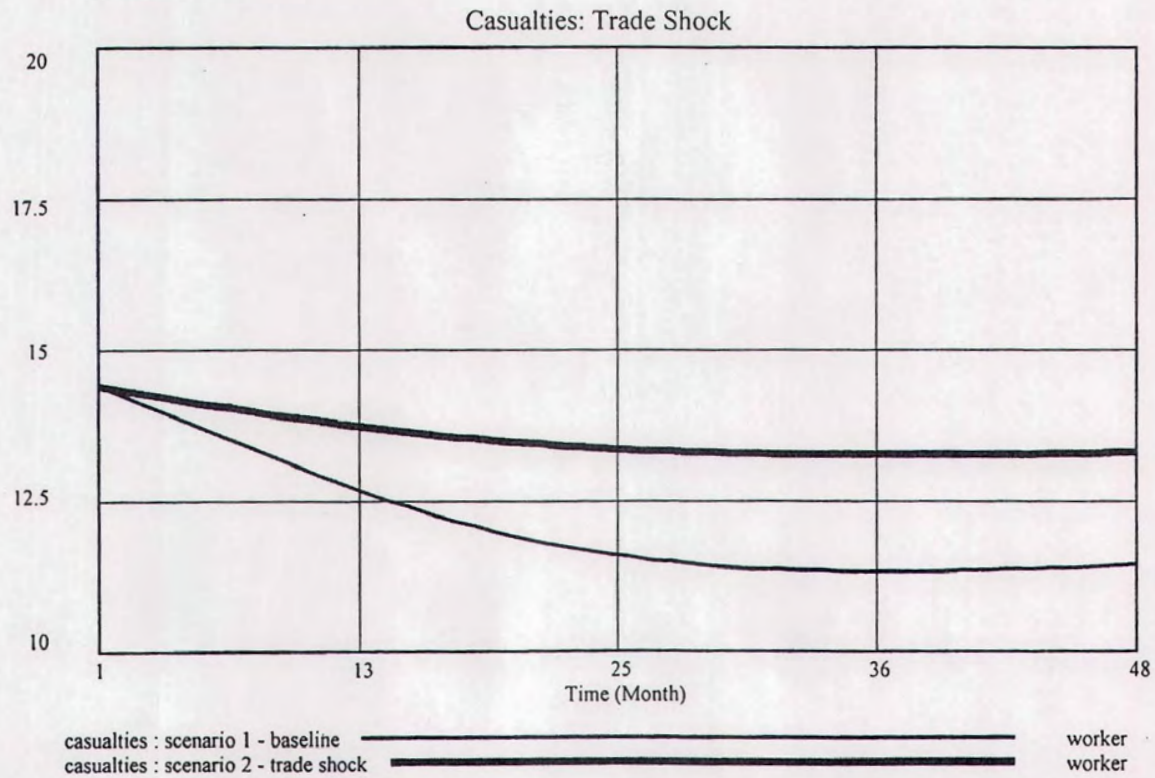


Figure 9



Again the results conform to our expectations. A reduction in the growth rate of the number of firms leads to a fall in manufacturing jobs, a fall in the expected net manufacturing wage, and more workers in the food sector. Landmine/UXO casualties rise commensurately. But the adverse impacts are confined not just to casualties, but also to community health. In the simulation the decline in manufacturing (garment) sector jobs is exactly matched by an increase in food sector jobs. But in reality job layoffs in manufacturing may translate into work in a third sector: the sex industry. In Cambodia the concern is that the fall in manufacturing employment may lead to displaced workers seeking employment in informal sectors, such as entertainment (karaoke singing, cigarette and beer selling in restaurants, etc) and commercial sex. In the country as a whole, garment manufacture employs more than 200,000 workers, more than 90 percent of whom are women.[31] A one-third drop in manufacturing employment translates into 70,000 or so unemployed workers, most of whom are young women. With HIV/AIDS rates at around 16 percent in the Cambodian entertainment industry and almost double that in the commercial sex industry, the potential for increased HIV/AIDS prevalence due to an adverse trade shock looms large in the eyes of policy-makers and health professionals.

6. Conclusion

If the cause of landmine/UXO casualties is the landmines/UXO themselves, then the solution is to remove them. Around the world, large amounts of money and effort have been spent on this exercise. But if the casualties have their root in the adverse economic conditions that drive people into landmine/UXO-contaminated areas in the first place, then different solutions may be required. It is likely that the ultimate cause of injuries and death from landmines/UXO lies in the combination of the two. Landmines/UXO cause direct injury/death *and* reduce economic opportunities for people who have no choice but to live and work in contaminated areas. Thus our approach in this paper has been two-pronged, addressing landmine/UXO clearance directly and highlighting approaches such as alternative job creation that complement partial or targeted landmine/UXO clearance.

We have argued in favor of partial (over complete) landmine/UXO clearance based on two factors: the high cost of complete clearance and the slowness of landmine/UXO removal (recall CMAC's removal rate of 10-12km^2/year relative to the 450-4,500km^2 still to be demined). In terms of partial clearance, we have suggested that contaminated farmland and roads be assigned priority, despite forest-related landmine casualties currently running at more than four times the number of rice field-related casualties. We believe that the forest casualties are primarily the result of food shortages due to landmine/UXO constraints on household arable land, as suggested by national data and interviews with households in landmined villages.

But despite removal of landmines/UXO from farmland, communities can still be hit by natural disasters, including drought and flooding. In demined Tang Sroeung Village, Oral District, farmers still needed to work in forests. The prospect of random natural disasters strengthens our case for infrastructural work and the acceleration of off-farm employment opportunities. Without additional factory jobs, the loss of farm output from a natural disaster may lead to more landmine/UXO casualties as villagers' dependence on forestry increases. To help escape from rural landmine-low income poverty traps, we highlight the gains from clearing and upgrading major roads. This strengthens the beneficial links between agriculture

[31] This estimate conforms to garment industry employment ratios in neighbouring Thailand (see Lim and Cameron 2003).

and industry, adding value to the growth in agricultural production following landmine/UXO removal. To the extent that agriculture may contribute to the expansion of industry,[32] more industrial jobs are created to serve as a substitute for work in the remaining landmined/UXO areas and to act as an income buffer in the face of natural disasters. The ultimate result may be a faster reduction in landmine/UXO casualties than that obtained from an indiscriminate policy of complete landmine/UXO removal.

We have highlighted the complications associated with even simple landmine/UXO removal. For even apparently straightforward decontamination priorities, namely clearing of agricultural land and transport routes, the impact on intersectoral labor allocation is by no means clear. It cannot be assumed that landmine/UXO clearance will increase agricultural production as much as the initial increase in arable land suggests. Landmine/UXO removal can increase food supply, conceivably pushing down food prices to such an extent that the landmine/UXO removal adversely affects incentives to farm. If food acts a wage good in industry, then a drop in food prices contributes to the expansion of manufacturing and off-farm employment opportunities, further drawing labor out of agriculture. Demining roads can accelerate the labor transfer, as the better transportation infrastructure increases villagers' access to off-farm jobs. Policy makers may be interested in avoiding the unintended consequences of landmine/UXO clearance (if indeed labor loss from agriculture is considered a problem).

In practice, increases in food supply do not always translate into lower expenses for manufacturing workers. The government must consider breaking monopoly power within food distribution networks. Problems with the power of middlepersons who buy agricultural products from farmers and sell to others have been cited as continuing problems in Oral District.[33]

Earlier we mentioned the issue of insecure land tenure. Currently Cambodia has neither a tenure system in place that guarantees equitable land registration, nor a system to legally recognise land ownership rights (USAID Cambodia, 2005). Possession rights dominate in the rural areas, but there is no proper framework to guide the allocation of the rights. Certificates and receipts have been issued against land ownership claims, but they are neither legal titles nor documents that signify land ownership (Sophal, Saravy and Acharya, 2001). Thus, insecure land tenure in Cambodia remains a continuing obstacle to Cambodia's rural development and is likely to impinge on the benefits from landmine/UXO clearance. Some farmers may have little guarantee that, once their land is demined, they will have continued access to the land.

The search for a legal and equitable resolution of the land tenure conflict is gaining importance. Economic development in Cambodia has meant that access and secure rights to land are increasingly needed. A proposed method to resolve land tenure issues is land reform. Such a reform would focus on land distribution, land management and land administration (Oxfam, 2001). Land reform is slowly being implemented in Cambodia, but there are those who still question the system. USAID (2005) has suggested that, given the lack of a fair

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[32] With decontamination of farmland, farm incomes can rise. Farmers are then able to increase their expenditures on inputs, such as farm equipment, and on consumer goods, including garments, much of which is provided by industry. A virtuous circle emerges in which industry and agriculture can potentially expand in tandem. (For the seminal work on mutually-beneficial agricultural-industrial interactions, see Mellor (1986)).

[33] Interview with David Mueller, Director, LWF, Phnom Penh, July 2003.

judicial system and a clearly defined access to justice, the possibility of unfair practices in securing land tenure claims could be a major setback to land reform.

Further conflict could arise within village communities, as each villager seeks to have their land cleared first. Clearly, optimal landmine/UXO policy requires input from the villagers themselves. Villagers should be consulted in a transparent way, allowing them to identify and express their needs and priorities in landmine/UXO clearance. This will require village development committees taking more responsibility in decision-making, strengthened village solidarity, improved democracy at the village level and communities becoming more aware of their rights (LWF 2002). CMAC undertakes community-based landmine/UXO education activities. These include direct face-to-face discussions with villagers, house and field visits, specific target group education, and volunteer networks (CMAC 2004). Such activities could be employed to defuse potential conflicts with villages by explaining to households how demining priorities have been arrived at after consultation and assessment at the village level. The scope of conflict can be further reduced if villagers can agree on a fair allocation of landmine/UXO removal – CMAC's emphasis on targeting villagers at greatest risk and in greatest need (CMAC 2003) is likely to fall within most perceptions of fair.

By understanding the dynamics between the construction of roads and bridges and access to new off-farm product and input markets, villagers will be in a better position to evaluate the worth of infrastructural projects, some of which will come at the expense of an immediate decontamination of village forests and fields. The new factory job opportunities and rising consumer demand might absorb the greater agricultural output, helping to maintain agricultural prices and support farm incomes. As rural incomes rise overall, the financial returns to providers of health care, education services and further physical infrastructure will increase, attracting more resources to the countryside to assist in community development. If the factories are set up and funded by foreign investors, implying low domestic resource costs, the growth of labor-intensive manufacturing may be a more cost-effective way of reducing landmine/UXO casualties and initiating a broad-based pattern of sustainable and equitable economic growth than is currently the case.

7. Interviewees Cited

7.1 July 2003

Ms Chamnap Houn, Community Development Officer, Lutheran World Federation, Oral District, Kampong Speu Province

Mr David Mueller, Director, Lutheran World Federation, Phnom Penh

Mr Ouk Ratanak, Deputy Director of Operations and Planning, CMAC, Phnom Penh

Mr Ung Sokchamroeun, Community Development Officer, Lutheran World Federation, Oral District, Kampong Speu Province

Mr Khem Sophal, Community Development Officer, Lutheran World Federation, Phnom Srouch District, Kampong Speu Province

Village Development Committee Leader, Pring Village, Treng Trayoeung Commune, Phnom Srouch District, Kampong Speu Province

Group Leader, Pring Village, Treng Trayoeung Commune, Phnom Srouch District, Kampong Speu Province

7.2 November-December 2004

Mr John McAndrew, CCC, Phnom Penh

Ms Chi Socheat, CARE, Phnom Penh

Mr Chea Sophal, ILO, Phnom Penh

Mr Tim Turner, Deputy Manager, HALO Trust, Siem Reap.

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