Literature Review: Occupational Accidents and Economic Cost

Agricultural Work Related Injury and Ill-Health and the Economic Cost

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Abstract

This paper contains a literature review of the occupational injuries and ill-health in agriculture world-wide and a survey of the attempts that have been made to estimate the resulting economic and social costs.

Agricultural workers suffer a wide variety of disorders as a result of their occupation. These range from minor (cuts, bruises) to more severe (deep wounds, fractures), permanent (amputation, spinal cord injury) and fatal injury. Ill-health as a result of contact with animals, micro-organisms, plant material dusts or chemicals are associated with certain types of agriculture. There is an underlying but unquantified incidence of pain, stress and injury as a result of ergonomic problems due to poor working procedures and conditions. Statistics from many countries or regions show that agriculture consistently has one of the highest accident and injury rates of the industrial sectors.

There are many causes for the work related injury and ill-health in agricultural workers. In developed countries, tractors and other machinery cause a significant proportion of the accidents and are a major cause of occupational deaths. In less developed countries, accidents due to hand tools such as hoes, sickles and cutting instruments are most prevalent. Animals are a significant cause of injury and ill-health in many countries. Debilitating allergic reactions in the respiratory tract or the skin are caused by exposures to organic dusts, or by contact with allergenic plants in the field respectively. Where comparative data are available, occupational pesticide poisoning in agriculture is a small proportion (< 1-4%) of the total work related disorders.

Because of the wide variety of occupational risks to agricultural workers, it is emphasised that if one type of agricultural practice is replaced by another then the risks from the alternative procedure need to be considered. If, for example, agrochemical pest control practices are replaced by methods involving the increased use of machinery, draught animals or manual operations, then an assessment of the resulting risks should be taken into account.

Some of the economic costs of occupational injury and ill-health in agriculture can be quantified directly, such as medical costs, the cost of rehabilitation and loss of earnings. Other costs are more difficult to estimate such as loss of opportunity and income foregone for permanent and fatal injury and for the effect on a victim's family. The estimation of the overall economic costs to farming communities and national agriculture requires further development. When one agricultural practice is replaced wholly or partly by another, for example agrochemical pest control by alternative control methods, then it is necessary to take into account the occupational health costs of the alternative procedure for realistic comparative assessment.

There are a number of issues which require continued or increased attention by the relevant national and international authorities and by the agricultural industry. These include the improved collection and collation of occupational health statistics, a better understanding of the extent of ergonomic problems in agriculture, more realistic assessments of the cost of occupational injury and ill-health and the continued need to reduce occupational health disorders by appropriate training and education in agricultural practices and the use of agricultural equipment.

Keywords: Agricultural workers; economic cost; ergonomics; injury and illness; occupational accidents

1 Introduction

Agricultural activities cover many operations both manual and mechanical and include hoeing, digging, cutting, tending animals, driving tractors, applying pesticides and storing materials. Each activity has its risks to agricultural workers resulting in injuries and illnesses which have been described in the relevant literature. The most prominent risks are due to accidents leading to injuries such as severe cuts or bruising, loss of limbs and, in the worst cases, fatality. Agricultural workers also experience a number of illnesses and diseases due to their occupation as a result of contact with animals, plant materials, pesticides and other sources. A recognised but less cited risk arises from poor work practices, for example from repetitive action or incorrect body postures, which can lead to a variety of disabilities. The numbers of agricultural workers affected by these injuries and illnesses are reported by many countries world-wide. However as discussed later (*section 3*), it is difficult to make direct comparative assessments with these statistics because of the different reporting procedures for individual countries. In this paper the emphasis is upon data obtained from well defined geographical areas or agronomic activities and where the different types of work-related disabilities and their causes are well described. The impact of the causes of agricultural accidents and the relative severity of their effects can be assessed from this information.

The economic cost of the temporary or permanent disablement of farmers and other agricultural workers has been given more attention recently. The cost can be manifest in several ways such as the cost of medical treatment, loss of

personal and farm income or loss of productivity. At present, there is no universally recognised procedure for estimating the cost consequences to the agricultural community of the results of occupational health risks. There needs to be agreement on the fundamental parameters which have to be taken into account. This is particularly important if one type of agricultural activity is substituted by another so that the consequent reduction or increase in risks and costs can be properly assessed. For example, there is the current emphasis on reducing or eliminating the use of agrochemicals and utilising alternative pest control practices. The Agrochemical Industry is concerned that important products and pest control practices could be curtailed or eradicated without proper regard for the risks and costs of the alternative procedures. The control of pests (weeds, insects, fungi) is one of many activities required to produce plentiful and wholesome food. The risk of using agrochemicals has to be placed in the context of other occupational health risks in agriculture and if alternative pest control measures are advocated then the associated risks and their costs must be quantified.

This paper is a review of the occupational risks to farmers and agricultural workers together with a survey of studies estimating the economic costs. The factors needed for making appropriate estimations of changes in risks and costs as a result of changing agricultural practices are highlighted.

2 Types and Causes of Injury and Ill-Health

A survey was undertaken to ascertain the main types of occupational injury and ill-health experienced by agricultural workers and the causes. This was carried out by means of a search of the more recent relevant scientific literature using appropriate key words. Enquiries were also made from a number of informed individuals and organisations in a range of countries in order to supplement the information from the search. The survey produced sufficient information to show the extent of the problems in geographical terms and for a range of agricultural practices. The references, upon which this survey is based, are shown in the accompanying list [1-72].

The information has been grouped into 3 categories as follows:

1) Injuries as a result of accidents.
2) Ill-health as a result of contact with animals, plant materials, micro-organisms or chemicals.
3) Ergonomic problems as a result of poor work practices or conditions.

The outcome of this survey is summarised in **Table 1** and described in more detail in the following sub-sections 2.1 - 2.3.

2.1 Accidental injury

The main types of injuries suffered by agricultural workers from a variety of work-related causes are shown in **Table 1**. The frequency of accidents from a particular cause differs according to the type of agricultural operations and the agricultural status of the country or area involved. In countries with more developed agricultural practices, mobile and static machinery are a leading cause of injury amounting to 30-70% of the total cases reported [1,4,5,11,16,21,29]. A serious concern is the high proportion of fatalities due to tractor accidents. For example, a survey of fatal farm accidents in the USA showed that 31-51% were due to tractors [20]. A similar survey of 257 farm fatalities in Australia showed that 71% were caused by tractors and other mobile machines [1]. In this case, 34 of 257 fatalities were children, a source of concern shared by other countries such as Ireland and the USA [11,18]. In the less developed countries there is usually a wider range of causes with injuries from the use of hand tools being more prominent. In a survey in 1987-8 in Haryana State, India a review of 576 agricultural worker injuries showed that 23% were due to sickles and 24% to spades [9]. Similarly, in a survey of agricultural accidents in 8 states of Brazil in 1985-6, 39.5% were due to the use of hand tools [35]. In sugar plantation work in Africa, cane cutters caused 80% of the reported injuries [36]. Where mechanical devices are used in these countries, they can be the cause of a significant proportion of agricultural worker injury. For example, in Punjab, India a review of 397 patients with hand injuries showed that 88 were due to mechanical wheat threshers resulting in lesions such as loss of fingers or amputation to the forearm [7]. A notable finding for most countries is the number of injuries caused by animals, used either for livestock or for draught purposes. The proportion of total injuries from this cause (kicks, trampling, crushing, bites) is often about 10% and can be as high as 35% [1,4,5,13,16,21,35].

2.2 Occupational ill-health

Perusal of the relevant literature shows that agricultural workers are exposed to a wide range of illnesses and diseases as a result of their work and working conditions. There are many sources of information describing these ailments

Table 1: Main causes and types of occupational injury and ill-health in agriculture

Cause	Main injuries/ill-health
Tractor and other mobile machines	Fatality, crushing, internal injury, ergonomic problems
Combined harvesters, conveyors	Fatality, crushing, amputation, internal injury
Fodder cutters, wheat threshers	Deep wounds, loss of fingers/toes
Farm animals	Crushing, fractures, heavy bruising, bites, allergy
Hand tools	Cuts, bruising, strain, ergonomic problems
Lifting	Strain, sprain, distortion, ergonomic problems
Hit by objects	Contusions, cuts
Farm chemicals	Skin and eye irritation/skin allergy, internal poisoning
Plants/dusts	Skin or respiratory allergy
Poisonous animals	Bites, stings

although their incidences are not given in such detail as those for accidental injury above. The ailments arise from a variety of sources, mainly from contact with animals, plant materials and chemicals including pesticides (→ *Table 1*).

For diseases originating from animals, a ILO/WHO Committee on occupational health [65] categorised them as viral (e.g. viral encephalitis), rickettsial (e.g. Q fever) or bacterial (e.g. anthrax, brucellosis, leptospirosis, tetanus). In some cases, these can lead to fatalities in farm workers [43,44]. Poisonous animals can be the cause of a significant proportion of occupational adverse reactions (1% or more) in agricultural workers in tropical regions [3,8,10,36]. Research in Brazil, for example, indicated that a significant number of snake bite victims had been engaged in a variety of agricultural activities, including weeding, in coffee, maize and sugar cane crops [35].

Agricultural operations may lead to an increased risk for farm workers from vector borne diseases and infections such as cholera, typhoid fever, schistosomiasis and malaria [41]. For example, irrigation schemes to help expand rice production in areas of S.E. Asia, Africa and South America increased vector borne disease incidence and prevalence [66].

A variety of lung diseases can arise when workers come into contact with dusts from plant materials such as mouldy hay, grain, straw and wood chips [48-53]. The best known of these diseases is Farmers Lung (allergic alveolitis/hypersensitivity pneumonitis). The incidence of these lung disorders varies widely. In a Swiss alpine valley, the incidence of chronic bronchitis in farmers exposed to mouldy hay was 43% compared to 5% in an unexposed control population [48]. A survey of 2866 farmers in Finland showed that 13.6% suffered one or more attacks of organic dust toxic syndrome due to exposure to grain, hay and animals [53]. In the less developed countries there is a wider range of sources of allergic dusts in agriculture including several types of grain, tea, coffee, spices and vegetable fibres [41,67]. Allergic skin reactions, some of them extremely painful and debilitating, arise from direct contact with plants in the field. Examples of allergenic plants, found in temperate and tropical regions, include poison ivy, Euphorbia and some types of nettles [41,65,87].

Exposure during the use of pesticides in agriculture is mainly via skin contamination during product handling and preparation and when spraying the diluted formulations. In some cases, this may lead to localised effects on the skin and eyes and, in cases of overexposure, to systemic disorders. The best known of these is the effect on cholinesterae activity by organophosphate compounds. The incidence of occupational pesticide poisoning is low in developed countries (71,72) and is generally higher in less developed countries, a topic covered in more detail in Section 3.2.

2.3 Ergonomic problems

Agricultural workers experience a variety of disorders when their work activity causes a bodily reaction as a result of a repetitive operation (→ *Table 1*). The commonest example is back pain arising from poor body posture during operations such as hoeing or tractor driving. Ergonomic studies have been undertaken for a number of industrial operations but are not common in agriculture. Those that have been reported in the scientific literature, usually deal with the types of problems and how they can be corrected but give little information on the severity or frequency of the disorders. The papers covered in the present survey [54-64] give some information on these aspects, i.e. the site, cause or prevalence of pain and injury. In a study in India, agricultural workers planting rice seeds while standing in muddy stagnant water suffered back pain, accumulation of fluid in lower limbs, cardiovascular stress, skin irritation and infection of feet [61]. In Tanzania, the heat stress limit in workers was exceeded 90% of the time during heavy agricultural work such as deep hoeing and sugar cane cutting in the hottest season [63]. In a study of 1155 tractor drivers in Italy, more than 80% were affected by low back disorders due to tractor vibration and/or awkward posture during driving activities [64].

It is evident that there is a lot of underlying pain and injury in agricultural workers as a result of their working practices and conditions. The problems are present in both the developed and less developed countries and arise from mechanical and manual operations. In many cases, workers continue to work but with less effectiveness and productivity. The incidence of these disorders may not be reflected in accident or injury statistics even for the more severe cases. There is general agreement that ergonomic problems in agriculture have not received sufficient attention [41,54,68].

3 National or Regional Statistics

Statistics on agricultural work related injuries and ill-health are collected world-wide. However, meaningful and consistent data are difficult to collate in practice. National statistics for persons injured and work days lost, under the heading of agriculture, hunting, forestry and fishing are listed in the Yearbook of Labour Statistics by the International Labour Office (ILO). However, The ILO emphasise the caution needed to interpret these findings, particularly when making national comparisons [69]. For example, there are variations in national definitions of occupational injury and in sources of collecting and reporting procedures. Coverage may be limited to certain types of workers or to establishments employing more than a certain number of workers etc. Some countries include employee injury and fatality as a result of commuting accidents. The under-reporting of occupational injuries and illnesses is a universal problem. Thus, it would require a great amount of effort and knowledge to make useful comparisons of the national statistics presented in the ILO Year Book. For this reason, the approach taken for the present survey was to collect data from reports in countries or regions where the population at risk was defined and the types of injury and ill health identified [1,2,5,15,21,22,23,24,25,26,27,28,30,31, 32,33,36,39]. For the purpose of this paper, bearing in mind the health and economic consequences of changing agricultural practices covered in Section 4, the issues here are covered under total occupational agricultural statistics and those due to pesticide poisoning only.

3.1 Numbers of work-related disorders

A selection of the studies covered in this survey serve to illustrate the extent of the problem in different countries or regions.

In a study of 13835 people in full time work on 7922 farms in one county of West Jutland Denmark in 1992, there were 257 injuries requiring medical treatment of which 4 were fatal [5]. In Western Australia, the number of lost time injuries and diseases in agriculture, forestry and fishing was 1600 per year over the period 1988-1996 [2]. A survey by the Swedish Farmers Safety and Preventative Health Association and the National Board of Occupational Safety and Health in 1987 showed that there were 7520 accidents involving people off work for more than one day in a variety of farming operations [27]. In the USA the non-fatal injury and illness rate in 1995 was 9.7 per 100 full-time workers in agriculture, forestry and fishing [22]. In Zimbabwe in 1985-6, accidents in agriculture resulted in 53 fatalities and 2425 non-fatal injuries [33]. A breakdown of the UK statistics for 1995-6 showed 44 fatalities, 530 serious non-fatal accidents and 1364 accidents resulting in people away from work for 3 or more days in agriculture, forestry and fishing [32]. Farming has one of the highest fatality rates for all industries. Annual death tolls in agriculture range from 28 in Ireland in 1995 to 855 in the USA in 1993 [26,30]. In Australia, work related agricultural fatalities, obtained from the lists of all deaths in the period 1982-4, totalled 257, which included 34 children [1].

It is evident that the overall numbers of work related fatalities, injuries and ill health in agricultural workers is a significant problem world-wide. In many countries the rates of occupational injuries, illnesses and fatalities in agriculture are among the highest of the industrial sectors [5,20,22,40,70].

3.2 Proportion of disorders due to pesticide use

In several of the studies reviewed in this survey, there is a breakdown of the causes of agricultural work-related disorders. The proportion of disorders due to pesticide use in crop protection for various countries or regions is shown in **Table 2**. It is evident that pesticide poisoning in agricultural workers in developed countries is a very small proportion, < 1 - 4%, of the occupational injuries and ill-health recorded. The comparisons for fatalities is even more marked, for example in the UK in 1995-6, there were no work related fatalities due to pesticides, whereas deaths due to other causes in agriculture numbered 44 [32,71].

The position with the less developed countries is not as clear because statistics for all types of occupational disorders in agriculture are not well recorded. However, for some types of agriculture where pesticides are used, the proportion of disorders due to their use is similar to that stated above. Thus, in a survey of rural accidents in several Brazilian states in 1985-6, the use of pesticides represented 1.6% of the causes [35]. In sugar plantations in Africa, the Caribbean and Latin America, where the range of occupational injuries included cuts, falls, injuries from animals and snake bites, the proportion due to pesticide use was about 1% or less [35,36]. In banana plantations in Costa Rica in 1994, 4% of occupational accidents were caused by pesticide use resulting in about 4% of workdays lost [37]. The ILO [70] has made an estimate, based upon limited data, that pesticide poisoning could account for about 14% of all occupational injury and ill-health in agriculture. Since this estimate is based upon an extrapolation from the incidence of pesticide poisoning in one country, Costa Rica, in one year, 1986, it cannot be considered representative of the position world-wide.

4 The Economic Cost of Agricultural Work Related Disorders

Work-related disorders in farmers and other agricultural workers not only has adverse physical consequences for the individuals concerned but also impinges upon their earning capacity, income and productivity. This also has adverse economic consequences for the agricultural industry and farming communities in the broader context. Increasing attention is being directed at estimating the economic costs of agricultural work related disorders and some of the more recent literature on the subject is included in the present survey [73-85].

A cost-risk approach for estimating the expected cost of farm related injuries was constructed by Zhao et al. [77,78]. This was expressed at the Expected Injury Cost (EIC) index per farm worker per year. This combines the probability of an injury from a particular risk factor with the severity of the economic losses from the injury. Risk factors included employment status, gender, hours of work, type of farm operation and the hazards which exist. The major costs of farm accidents include medical treatment, loss of income and productivity, replace-

Table 2: Pesticide poisoning incidence as a proportion of overall work-related injuries and illnesses in agriculture

Country/Region	Proportion as pesticide poisoning	Reference
W Australia (1995-6)	2.2%[a]	2
USA, New York State (1984-6)	2%[a]	16
USA (1993)	3.9%[a]	22
California, USA (1965-71)	4%	24
California, USA (1989)	2.3%	23
Sweden (1984-8)	1.3%	27, 72
UK (1970-1980)	<1%	15
UK (1995-6)	<1%	32, 71

[a]Described as 'chemical exposure' or 'poisoning'

ment labour and rehabilitation. Injury severity classification is an important part of the index and was defined as slight, severe, permanent or fatal. The cost of permanent injury can exceed that of a fatality. Estimated costs, in 1992 $US, were $50 for a slight injury, $1000, for a severe injury (eg. broken bone), $2 million for permanent injury (e.g. amputation) and $1.5 million for a fatality. The severity of injuries can have more economic impact than the frequency of injuries.

Similarly, Tormoehlen and Field [76] designed a computer program, ICE (Injuries, Cost, Economics), to derive the costs associated with farm related permanent disabilities. A total of 16 cost items were identified including those for ambulance service, hospitalisation, rehabilitation, productivity loss and loss of earnings. To test the program, an estimate was made from a case study of a vegetable farmer who had been paralysed from the waist down as a result of a spinal cord injury. The actual cost was $266,770 compared to the computer calculation of $446,590 (1994 $US). The broader issues of agricultural fatalities was shown by the work of Kelsey [75] who interviewed surviving family members of workers killed on New York State farms in 1985-7. A formula of Discounted Future Earnings was constructed to estimate income foregone and opportunity cost of a fatal accident. This took account of the age and earning power of the person killed. Thus for a male farm owner aged 49, this amounted to $362,000, while the comparable value for a hired farm worker aged 31 was $351,000 (1987 $US). Although other costs beyond these indices were not considered, it was noted that 67% of families who operated a farm where a fatality occurred, no longer operated them, and 44% no longer lived on a farm.

In contrast to the studies described above, Sauerborn et al. [79] investigated the position in a less developed country. This involved a study of a rural community in Burkina Faso where the main economic activity was subsistence farming (millet, sorghum, maize and cotton as a cash crop). Illness costs were divided into financial costs for health care and time cost. Healthy household members caring for an injured person lost almost as much time for production as a sick member. Therefore the entire household has to be included in the analysis for this type of agriculture. Time costs consistently exceed direct financial costs. The total cost per accidental injury was calculated to be approximately $10 (average daily wage is about $1; 1993 $US).

The above studies indicate the common components to be taken into account when estimating the costs of agricultural injury and ill-health. These include not only the direct medical and rehabilitation costs but also those due to loss of income and productivity. A severe disability produces greater costs than more frequent minor ailments. Wider economic and social costs are also to be expected such as the effect on family life in both developed and less developed countries.

There have been some studies specifically addressing the economic costs of ill-health arising from pesticide use. In making a case for a 50% reduction of pesticide use in the USA, Pimental et al. [80,81] took account of the effect on a variety of factors including human health. The replacement of agrochemical pest control would involve a number of alternative methods such as ridge tilling, deep tillage, mechanical cultivation, crop rotation and field sanitation and numerous additional activities involving field monitoring, biological control, water and fertilisation management. It was indicated that these alternative methods would also cause social and environmental problems and that the added costs of non-chemical alternatives would approximately offset the reduced environmental and public health costs due to reduced pesticide usage. It was not clear, however, if occupational injury and ill-health costs were addressed in this scenario.

In an attempt to estimate pesticide related occupational health costs, the health of two small groups of 56 & 57 Philippine rice farmers and pesticide operators was compared with a group of 39 farmers from an area considered to be generally pesticide free [83]. The adverse findings in the two exposed groups included increased eye, skin, respiratory, cardiovascular, gastrointestinal, and neurological problems. An estimation of health costs included treatment costs for medication and physician fees, opportunity cost and time lost for recuperation. These costs were estimated to be 2890 Philippine pesos for an exposed worker and 1790 Philippine pesos for an unexposed. A model was developed integrating this health data with rice production data to measure the impact of farmer health on rice production in the Philippines [84]. The total active ingredients applied in a season and the number of applications was used as a surrogate for pesticide exposure. The model showed that reduced insecticide use had a small net effect on productivity because productivity loss would be offset by gain from improved farmer health. Herbicide use, however, had little adverse health impact but increased productivity. The difficulty in appraising the usefulness of these estimates is in deciding, which of the adverse heath effects seen in these workers were due to pesticides. The eye, skin and respiratory changes for example could have arisen from a variety of causes unassociated with pesticide use. The authors indicate that such ailments may or may not have been related to pesticide exposure [83]. Pesticide exposure was not measured directly so the actual intake and which pesticides were involved could not be determined. Because of these doubts it would be difficult to assess the economic costs of ill-health due to pesticides in this case.

A detailed survey was made by Naylor [85] on the use of herbicides in Asian rice production which included an appraisal of the social (economic) costs. Countries surveyed ranged from Bangladesh where herbicide use is low, to countries such as Japan and Korea with high herbicide use. The social costs included a number of non-market factors such as the impact of herbicides on the health of labourers and residents on and off the farm. Any negative effects were weighed against the benefits of herbicide use, to determine the true social (economic) perspective. For example, the replacement of hand weeding by herbicide use was indicated as a favourable change, i.e. less drudgery and more leisure time. An analysis of the social costs was undertaken for the differing inputs of a) no weeding, b) hand weeding and c) herbicide control, utilising case studies from Indonesia and the Philippines. Overall, the use of herbicides is probably socially profitable in Asian rice production, particularly in regions with higher rates of economic growth and rising labour costs. The issue of injury or ill-health due to hand weeding did not appear to have been

addressed, however, and, if so, it would presumably have provided further evidence for the case for herbicide use.

5 Discussion and Conclusions

The occupational injuries and ill-health in farmers and other agricultural workers and the attempts to estimate the resulting economic costs have been reviewed in this paper. Although the survey cannot be regarded as exhaustive, several outstanding points are evident. Farm workers in all countries face a number of risks to their physical well-being due to the nature of their work and this is well recognised. Resulting injuries and ill-health range from slight to serious to fatal. The major causes are due to mechanical operations in developed countries and to a variety of manual and mechanical operations in less developed countries. There are a variety of other underlying causes due to falls, contact with animals, organic dusts, and chemicals and to repetitive action. The amount of pain and injury due to ergonomic problems is still largely unquantified and requires particular attention.

The collection of meaningful and consistent data on the numbers of accidents and the incidence and severity of resulting disorders is often difficult to achieve. In particular, under-reporting and the lack of consistent reporting procedures between countries means that national comparisons of agricultural occupational injury and illness statistics have to be analysed with great care. That is why, in this review, most attention has been placed on the data from studies where the population at risk is identified and the types, causes and incidence of the disorders clearly presented. The collation of this data shows that certain activities, for example tractor driving, give rise, proportionately, to the greater number of injuries and to the more severe effects. It also shows that farm animals consistently cause a significant number of injuries and illnesses in countries world-wide. In the context of pesticide use, the data collation shows that the resulting disorders represent less than 4% of the reported agricultural occupational injury and ill-health.

Where agricultural-occupational health statistics are collected and presented in this way, then meaningful conclusions may be drawn from the data. For example, pest control procedures with agrochemicals are often portrayed as one of the more dangerous agricultural practices, leading to calls for alternative pest control measures. The data compiled from this review shows that this view is incorrect. It also has to be realised that if an agrochemical pest control procedure is replaced by another type of practice, the risks of the alternative control measures need to be taken into account. For example, if weed control by herbicides is replaced by methods involving machines or draught animals or by hand weeding, then this can result in health problems ranging from back pain to fatality. Similarly, the replacement of insecticide use for insect control would result in a number of activities such as ridge tilling, contour ploughing, crop rotation, field sanitation, inter-cropping and crop monitoring. Apart from the direct risks from these activities, the increased labour requirements mean that more people are at risk. In tropical countries, more workers in the field would be exposed to venomous reptiles, rodents and biting insects and to a range of vector borne diseases and infections. The replacement of one agricultural practice by another replaces one set of risks by another set and does not necessarily result in less risk.

This review has drawn attention to the attempts to assess the economic impact of occupational injury and health in agriculture. Some common factors in the analyses have been highlighted. There are costs which can be directly quantified such as the cost for medical treatment, rehabilitation and the loss of personal or farm income. Other economic costs are more difficult to assess such as loss of opportunity and income foregone, and the effect on the victim's family. The overall cost to national agriculture and to farming communities also has to be considered. In some studies, the economic impact of occupational disorders from agrochemical pest control have been estimated and alternative control methods advocated. In most cases, it appears that the health costs of proposed alternative methods have not been taken into account. This is necessary if a realistic comparative economic impact is to be estimated. As indicated earlier in this discussion, the alternative control measures pose risks for injury and ill-health and hence involve economic and social costs. The attempts to assess occupational health costs in agriculture, at this time, may be seen as a prelude to the development of more exact appraisals where all relevant factors are included.

The final point is to emphasise the role of accident prevention and training and education in agriculture. Although these measures involve costs of their own, the rewards in terms of reducing occupational injuries and ill-health and the resulting decreased economic costs, more than outweigh the inward investment. The Agrochemical Industry has been well aware of the need for this input and has actively promoted the principles of product stewardship and integrated pest management (IPM) via relevant guidelines, posters, monographs, media sources and farmer training and education schemes over many years [86]. Increased efforts of this type are required in all sectors of agriculture in order to help reduce overall numbers of occupational accidental injury and ill-health and, consequently, to reduce the economic and social costs in agricultural communities.

6 Summary of Recommended Actions

It is evident from this review that there is room for improvement in all areas surveyed. The following proposals are put forward for consideration by the relevant authorities and organisations.

1. The improvement of the collection of statistics for occupational injury and ill-health in agriculture and identification of the major causes of these disorders. The estimation of their overall incidence in geographical or agronomic terms and the estimation of relative incidence and severity due to specific causes.
2. Particular attention is required to identify disorders due to ergonomic problems and to the estimation of their incidence and severity in agricultural workers.
3. The creation of realistic assessments of the economic costs of occupational injury and ill-health in agriculture. These should take account of all the relevant factors when making comparative assessments for different types of agricultural practices.
4. Continued and increasing effort devoted to training and education to help improve safety in agriculture including those activities involving mechanical, manual and agrochemical methods for crop protection.

7 References

[1] ERLICH, S.M.; DRISCOLL, T.R.; HARRISON, J.E.; FROMMER, M.S. & LEIGH, J. (1993): Work-related agricultural fatalities in Australia, 1982-1984. Scand. J. Work Environ. Health 19: 162-167

[2] Work Safe Western Australia (1997): Work Safe Statistics, Agriculture, Forestry & Fishing Industry. January 1997 Bulletin (4 pages)

[3] NOGUEIRA, D.P. (1987): Prevention of accidents & injuries in Brazil. Ergonomics 30: 387-393

[4] BRISON, R.J. & LAWRENCE, C.W. (1992): Non-fatal farm injuries on 117 Eastern Ontario Beef and Dairy Farms: A one-year study. Am. J. Ind. Med. 21: 623-636

[5] CARSTENSEN, O.; LAURISTEN, J. & RASMUSSEN, K. (1995): The West-Jutland study on prevention of farm accidents, Phase 1: A Study of work specific factors in 257 hospital-treated agricultural injuries. J. Agric. Safety Health 1: 231-239

[6] VAYRYNEN, S. (1984): Safety & Ergonomics in the maintenance of heavy forest machinery. Accid. Anal. & Prev. 16: 115-122

[7] CHARI, P. S.; KHARSHING, W. & BALAKRISHNAN, C. (1975): Wheat thresher hand injuries. Indian J. Med. Res. 63: 829-832

[8] DATTA, S.P. & VERMA, P.S. (1969): A study of rural accidents in Pondicherry, South India. Indian J. Pub. Health XIII: 25-29

[9] MOHAN, D. & PATEL, R. (1992): Design of safer agricultural equipment: Applications of ergonomics & epidemiology. Internat. J. Indus. Ergonom. 10: 301-309

[10] GORDON, J.E.; GULATI, P.V. & WYON, J.B. (1962): Traumatic accidents in rural tropical regions: an epidemiological field study in Punjab, India. Am. J. Med. Sciences 243: 158-178

[11] DOYLE, Y. & CONROY, R. (1989): Childhood farm accidents: A continuing cause for concern. J. Soc. Occup. Med. 39: 35-37

[12] LARSSON, T.J. (1990): Severe hand injuries among Swedish farmers. J. Occup. Accidents 12: 295-306

[13] JANSSON, B.R. (1987): The yield of systems for continuous & periodic injury surveillance in emergency care with emphasis on farm-work-related accidents. Scand. J. Soc. Med. 15: 247-252

[14] MILLER, K. (1992): Causes of accidents with post-drivers & their remedies. Applied Ergonomics 23: 101-104

[15] UNDERWOOD, J.G. (1984). Pesticides & Health. The Insurance Technical Bureau, London, UK

[16] PRATT, D.S.; MARVEL, L.H.; DARROW, D.; STALLONES, L.; MAY, J.J. & JENKINS, P. (1992): The dangers of dairy farming: The injury experience of 600 workers followed for two years. Am. J. Indus. Med. 21: 637-650

[17] LAWRENCE, T.J. & BEAN, T.L. (1992): Rewards and regulations: Motivating farmers to adopt ROPS. The American Society of Agricultural Engineers meeting, Nashville, Tennessee, 15-18 Dec. 1992

[18] RIVARA, F.P. (1985): Fatal & non-fatal farm injuries to children & adolescents in the United States. Paediatrics 76: 567-573

[19] ISAACS, L.K. & BEAN, T.L. (1995): An overview of the Ohio migrant farmworker safety needs assessment. J. Agric. Safety & Health 1 261-272

[20] PURSCHWITZ, M.A. & FIELD, W.E. (1990). Scope and magnitude of injuries in the agricultural workplace. Am. J. Indus. Med. 18: 179-192

[21] HOSKIN, A.F.; MILLER, T.A.; HANFORD, W.D. & LANDES, S.R. (1988): Occupational injuries in agriculture: A 35-State survey. National Safety Council, Chicago, Illinois, USA

[22] US Bureau of Labor Statistics (1996): a) Table R.64. Number of non-fatal occupational injuries & illnesses involving days away from work, 1993. b) Table 1. Non-fatal occupational injury & illness incidence rates per 100 full-time workers, 1995. c) National Census of fatal occupational injuries, 1995 Bureau of Labor Statistics, US Department of Labor. 8 August 1996

[23] SUTTER, S.R. (1991): Farmworker injury & illness: statistical guides to prevention. California Agriculture 45: 13-15

[24] Whiting, W.B. (1975): Occupational illnesses & injuries of California agricultural workers. J. Occup. Med. 17: 177-181

[25] California Division of Labor Statistics (1995): Table 4. Number & percent distribution of fatal occupational injuries by industry, California 1993-94. Census of Fatal Occupational Injuries

[26] Health & Safety Authority, Dublin, Ireland (1997): Health & Safety at Work (Ireland), Statistics. Reported accidents

[27] LUNDQVIST, P. & GUSTAFSSON, B. (1992): Accidents & accident prevention in agriculture. A review of selected studies. Internat. J. Indus, Ergonom. 10: 311-319

[28] MYERS, J.R. (1990): National surveillance of occupational fatalities in agriculture. Am. J. Indus. Med. 18: 163-168

[29] SKROMME, A.B. (1990): A farm safety program sponsored by farmers. The American Society of Agricultural Engineers meeting, Chicago, Illinois, 18-21 Dec. 1990

[30] US Bureau of Labor Statistics (1997): US Table 17, Number of Fatal Occupational Injuries by Industry, 1993. US Bureau of Labor Statistics, Occupational Safety & Health Statistics

[31] Health & Safety Executive (1991): Agriculture: A students guide to legislation, guidance, films and forms 1991. Third edition: Health & Safety Executive, Library & Information Services, Sheffield, UK, March 1991

[32] Health & Safety Executive (1997): Accidents in agriculture, hunting, forestry & fisheries. UK HSE Infoline, February 1997

[33] LAITINEN, H. & VAHAPASSI, A. (1992): Accidents at work. In Occupational Health in Developing Countries. Ed: Jeyeratnam, J. Oxford Medical Publications 368-391

[34] DOYLE, Y. & CONROY, R. (1989): The spectrum of farming accidents seen in Irish general practice: A one-year survey. Family practice 6: 38-41

[35] MEIRELLES, C.E. (1996): The country under study. The primary production sector and work safety (English translation). Protecão, March 1996, 64-69

[36] Private communication (1997): Sugar Industry Agricultural Safety Statistics, 1996

[37] BALTODANO, J.M.A. & TOBAR, S.M.A. (1995): Analisis de la accidentabilidad laboral para la toma de decisiones en la prevencion y control de los factores de riesgo en la produccion de banano en Geest Limited Costa Rica. Universidad, Latinoamericana de Ciencia Y Tecnologia, San José, Costa Rica, 25 de Agosto 1995

[38] Private Communication (1997): Tea estate accident analyses, India 1994-1997

[39] Commission of the European Communities Safety & Health Directorate (1983): Safety Training for Agriculture Workers. Part One: Statistical analysis of accidents in agriculture. Module commissioned from the Institut National de Promotion Superieure Agricole in Dijon by the commission of the European Communities Safety & Health Directorate

[40] RUNYAN, J.L. (1998): Injuries & fatalities on US farms. Economic Research Service, United States Department of Agriculture, January 1998

[41] SEKIMPI, D.K. (1992): Occupational health services for agricultural workers. In Occupational Health in Developing Countries, Ed: Jeyaratnam, J., Oxford Medical Publications 31-61

[42] Private Communication (1998): Accident performance in CDC Industries 1995-7

[43] COGHLAN, J.D. (1981): Leptospirosis in man, British Isles, 1979-80. Brit. Med. J. 282: 2066

[44] Leptospirosis Reference Laboratory & Communicable Disease Surveillance Centre (PHLS) (1983): Leptospirosis in man, British Isles, 1982. Brit. Med. J. 287: 1365-1366

[45] YANAGAWA, R. (1985): Farmworkers at risk. World Health, July 1985

[46] BARILE, F.; MASTROLONARDO, M.; LOCONSOLE, F. & RANTUCCIO, F. (1993): Cutaneous sporotrichosis in the period 1978-1992 in the province of Bari Apulia, Southern Italy. Mycoses 36: 181-185
[47] CASEMORE, D.P. (1990): Epidemiological aspects of human crytosporidiosis. Epidemiol. Infect. 104: 1-28
[48] DE HALLER, R., (1986): Respiratory symptoms and preventive aspects in farmers chronically exposed to mouldy hay. Am. J. Indus. Med. 10: 288
[49] DONHAM, K.J.; HAGLIND, P.; PETERSON, Y. & RYLANDER, R. (1986): Environmental & health studies in swine confinement buildings. Am. J. Indus. Med. 10: 289-293
[50] ROSE, C. & KING, T.E. (1992): Controversies in hypersensitivity pneumonitis. Am. Rev. Respir. Dis. 145: 1-2
[51] DO PICO, G.A. (1992): Hazardous exposure and lung disease among farm workers. Clinics in Chest Medicine 13: 311-328
[52] MALMBERG, P.; RASK-ANDERSON, A.; HOGLUND, S.; KOLMODIN-HEDMAN, B. & GUERNSEY, J.R. (1988). Incidence of Organic Dust Toxic Syndrome in allergic alveolitis in Swedish farmers. Int. Arch. Allergy Appl. Immunol. 87: 47-54
[53] HUSMAN, K.; TERHO, E.O.; NOTKOLA, V. & NUUTINEN, J. (1990): Organic Dust Toxic Syndrome among Finnish farmers. Am. J. Indus. Med. 17: 79-80
[54] BISHU, R.R.; CHEN, Y.; COCHRAN, D.J. & RILEY, M.W. (1989): Back injuries in farming - a pilot investigation. In Advances in Industrial Ergonomics & Safety, Ed. Mital, A. Taylor & Francis, London & Philadelphia pp. 791-798
[55] CONLAN, T.M.; MILES, J.A. & STEINKE, W.E. (1995): Static lower back stress analysis in citrus harvesting. Am. Soc. Agric. Eng., 38: 929-936
[56] THELIN, A. (1990): Hip joint arthrosis: An occupational disorder among farmers. Am. J. Indus. Med. 18: 339-343
[57] GUSTAFSSON. B.; PINZKE, S. & ISBERG, P-E. (1994): Musculoskeletal symptoms in Swedish dairy farmers. Swedish J. Agric. Res. 24: 177-188
[58] HAMMER, W. (1991): Safe access to farm tractors & trailers. J. Agric. Engng. Res. 50: 219-237
[59] AXELSSON, S-A. & PONTEN, B. (1990): New ergonomic problems in mechanised logging operations. Int. J. Indus. Ergonom. 5: 267-273
[60] VAYRYNEN, S. & KONONEN, U. (1991): Short & long-term effects of a training programme on work postures in rehabilitatees. A pilot study of loggers suffering from back troubles. Int. J. Indus. Ergonom. 7: 103-109
[61] NAG, P.K. & DUTT, P. (1980): Circulo-respiratory efficiency in some agriculture work. Appl. Ergonom. 11: 81-84
[62] NAG. P.K. & PRADHAN, C.K. (1992): Ergonomics in the hoeing operation. Int. J. Indus. Ergonom 10: 341-350
[63] HALL, S.A. (1971): Heat stress in outdoor manual workers in East Africa. Ergonomics 14: 91-94
[64] BOVENZI, M. & BETTA, A. (1994): Low-back disorders in agricultural tractor drivers exposed to whole-body vibration and postural stress. Appl. Ergonom. 25: 231-241
[65] WHO (1962): Occupational health problems in agriculture. Fourth report of the joint ILO/WHO Committee on Occupational Health. World Health Organisation Technical Report No. 246. WHO Geneva 1962
[66] HESPANHOL, I. (1996): Health impacts of agricultural development. In: Sustainability of Irrigated Agriculture, Eds: Pereira, L.S. et al.. Kluwer Academic publishers, Netherlands. pp. 61-83
[67] URAGODA, C.G. (1992): Occupational lung diseases - vegetable dusts. In Occupational Health in Developing Countries, Ed: Jeyeratnam, J., Oxford Medical Publications 304-313
[68] RAINBIRD, G. & O'NEILL, D. (1993): Work-related diseases in tropical agriculture. Silsoe Research Institute, Silsoe, UK
[69] ILO (1995): Yearbook of Labour Statistics, 54th Issue. Chapter VIII, Occupational Injuries. International Labour Office, Geneva, pp. 839-942
[70] ILO (1996): Wage Workers in Agriculture: Conditions of employment & work. International Labour Office, Geneva, pp. 73-77
[71] HSE (1996): Pesticide Incidents Report 1995/96. Health & Safety Executive, UK
[72] EKSTROM, G.; HEMMING, H. & PALMBORG, M. (1996): Swedish pesticide risk reduction 1981-1995: Food residues, health hazard & reported poisonings. Rev. Environ. Contam. Toxicol. 147: 119-136
[73] MARTIN, S.K. (1994): Risk perceptions and management responses to risk in pastoral farming in New Zealand. Proc. N.Z. Soc. Animal Production 54: 363-368
[74] MONK, A.S.; MORGAN, D.D.V.; MORRIS, J. & RADLEY, R.W. (1986): The Cost of accidents in agriculture. J. Agric. Engng. Res. 35: 245-257
[75] KELSEY, T.W. (1991): Fatal farm accidents in New York: Estimates of their costs. North-eastern J. Agric. Resources Econom. 20: 202-207
[76] TORMOEHLEN, R.L. & FIELD, W.E. (1995): Projecting economic losses associated with farm-related permanent disabilities. J. Agric, Safety & Health 1: 27-36
[77] ZHAO, W.; HETZEL, G.H. & WOESTE, F.E. (1992): Injury risk analysis as input to farm insurance ratings. Am. Soc. Agric. Eng. 35: 765-772
[78] ZHAO, W.; HETZEL, G.H. & WOESTE, F.E. (1995): Defining farm safety research priorities by a cost risk approach. J. Agromed. 2: 7-21
[79] SAUERBORN, R.; IBRANGO, I.; NOUGTARA, A.; BORCHERT, M.; HIEN, M.; BENZLER, J.; KOOB, E. & DIESFELD, H.J. (1995): The economic costs of illness for rural households in Burkina Faso. Trop. Med. Parasitol. 46: 54-60
[80] PIMENTEL, D.; MCLAUGHLIN. L.; ZEPP, A.; LAKITAN, B.; KRAUS, T.; KLEINMAN, P.; VANCINI, F.; ROACH, W.J.; GRAAP, E.; KEETON, W.S. & SELIG, G. (1991): Environmental & economic impacts of reducing US agricultural pesticide use. In CRC Handbook of Pest Management in Agriculture, Ed: Pimentel, D., CRC Press, Boca Raton, Florida, pp 679-718
[81] PIMENTEL, D.; ACQUAY, H.; BILTONEN, M.; RICE, P.; SILVA, M.; NELSON, J.; LIPNER, V.; GIORDANO, S.; HOROWITZ, A. & D'AMORE, M. (1992): Environmental & Economic costs of pesticide use. Bio Science 42: 750-760
[82] ANTLE, J.M. & CAPALBO, S.M. (1995): Measurement & evaluation of the impact of agricultural chemical use: A framework for analysis. In Impact of Pesticides on Farmer Health & the Rice Environment, Eds., Pingali & Roger, Kluwer Press, Boston, MA, pp. 23-57
[83] PINGALI, P.L.; MARQUEZ, C.B.; PALIS, F.G. & ROLA, A.C., (1995): The impact of pesticides on farmer health: A medical & economic analysis in the Philippines. In Impact of Pesticides on Farmer Health & the Rice Environment, Eds: Pingali & Roger, Kluwer Press, Boston, MA, pp. 344-360
[84] ANTLE, J.M., & PINGALI, P.L. (1994): Pesticides, productivity & farmer health: A Philippine case study. Amer. J. Agr. Econ. 76: 418-430
[85] NAYLOR, R. (1994): Herbicide use in Asian rice production. World Development 22: 55-70
[86] Global Crop Protection Federation (1998): List of Publications, February 1998
[87] NORTON, S. (1996): Toxic Effect of Plants. In Casarett & Doull's Toxicology. The Basic Science of Poisons, Fifth Edition. Ed: Klaassen, C.D., McGraw-Hill, New York pp. 841-853

Received: December 12th, 1998
Accepted: March 3rd, 1999