ENVIRONMENTAL AND HUMAN COSTS OF COMMERCIAL AGRICULTURAL PRODUCTION IN SOUTH ASIA[1]

Abstract

Modern commercial agricultural practices involving chemical inputs such as fertilizers and pesticides have been associated with huge increases in food production never witnessed before, and in the case of cereal production (especially wheat) under Green Revolution technology, recorded spectacular growth. As statistics show, production and productivity have increased. However, the high chemical usage of fertilizers and pesticides used to bring about these spectacular increases in food production are not without problems. A visible parallel correlation between higher productivity, high chemical input use and environmental degradation and human health effects is evident in many countries where commercial agriculture is widespread. In this paper, I discuss the environmental and health effects/costs arising from the high use of chemical inputs to increase production and productivity in South Asia with a field study carried out in Sri Lanka to show the health costs arising from direct exposure to pesticides during pesticide handling and spraying on farms by small-scale farmers.

1. INTRODUCTION

Modern commercial agricultural[2] practices involving chemical inputs such as fertilizers and pesticides have been associated with huge increases in food production never witnessed before, and in the case of cereal production (especially wheat) under Green Revolution technology, recorded spectacular growth. As statistics show, production and productivity have increased. However, the high chemical usage of fertilizers and pesticides used to bring about these spectacular increases in food production are not without problems. A visible parallel correlation between higher productivity, high chemical input use and environmental degradation and human health effects is evident in many countries where commercial agriculture is widespread.

In this paper I discuss the environmental and health effects/costs arising from the high use of chemical inputs to increase production and productivity in South Asia with a field study carried out in Sri Lanka to show the health costs arising from direct exposure to pesticides during pesticide handling and spraying on farms by small-scale farmers. The first section of this paper briefly discusses commercial agriculture (high yielding and hybrid varieties) including the Green Revolution technology in South Asia[3]. In section two, the large-scale use of chemical inputs to bring about large increases in production and productivity is shown. Section three outlines the environmental and human effects/costs of continuous high chemical input use in South Asia with section four showing the costs of health effects based

[1] I wish to thank Professor Clem Tisdell, Alan Duhs and Stuart Corbridge for helpful comments on an earlier draft of this paper. However, all remaining errors are mine.

[2] Modern commercial agriculture does not necessarily mean large-scale agriculture. It could involve small-scale farming as well.

[3] In this paper, we avoid Bhutan in the discussion because of data constraints. Furthermore, Bhutan has been slow in adopting HYV's and hybrid varieties unlike the other countries in South Asia.

on a field study carried out in Sri Lanka. The last section summarizes the conclusions of this paper.

2. COMMERCIAL AGRICULTURE IN SOUTH ASIA

The introduction of high yielding varieties under the Green Revolution technology[4] and the high yielding and hybrid varieties of commercially grown vegetables and other cash crops in the 1960s and in the early part of the 1970s have no doubt increased food production and productivity in the South Asian region during the last few decades. This is especially so in the case of wheat (Farmer, 1986). The productivity of paddy, other cereal, cash and vegetable crops, too, has also increased (FAO production yearbooks, various issues, 1961-1998). Much of this spectacular increase in food production is clearly attributable to the continuing gains of the Green Revolution, especially the development of new rice varieties suited to regional conditions (WRI, 1990, p.84). At a time when famine seemed imminent, hybrid varieties of wheat and rice introduced to Asia along with other inputs, dramatically increased harvests (Wolf, 1987, p.139; Pinstrup-Andersen and Hazell, 1987, p.108). Over the last few decades the total area planted to modern varieties in South Asia has spread rapidly (Lipton and Longhurst, 1989, p.1). Wheat shows the largest increase. In India for instance, the percentage of high yielding varieties area to total area under wheat increased from 3.9% in 1966/67 to 90% in 1992/93 (Government of India, 1993, p.21)[5]. In rice, too, new varieties have spread rapidly (Barker et al, 1985, p.62). The largest percentage increase in area brought under HYVs in rice has occurred in India, Pakistan and Sri Lanka (Barker et al. 1985, p.63). By 1993 the area of rice under HYVs had grown by more than 50% since the mid 1960s. In India alone the percentage of area under HYVs grew to 68% (Government of India, 1993, p.121). In Sri Lanka the percentage of irrigated area under HYVs was almost 100% (Department of Census and statistics, Sri Lanka, 1990). The cultivation of high yielding and hybrid varieties of vegetable and cash crops, too, has increased.

If cereal production in South Asia is disaggregated into individual cereals, wheat shows an impressive growth (Pinstrup-Andersen and Hazell, 1987, p.107; Farmer, 1986, p.186). In India, wheat production grew more than six fold between 1961 and 1998 (FAO production yearbooks, various issues, 1961-1998). The other three South Asian countries producing wheat, too, have also shown a phenomenal increase (ibid). In terms of productivity [yield (kg's) per hectare], both wheat and rice have shown a sharp increase (FAO production yearbooks, various issues, 1961-1998). Wheat productivity has more than doubled or even trebled (as in India and Bangladesh) in the region since the 1960s, though with downward fluctuations in certain years (see *Figure 1*).

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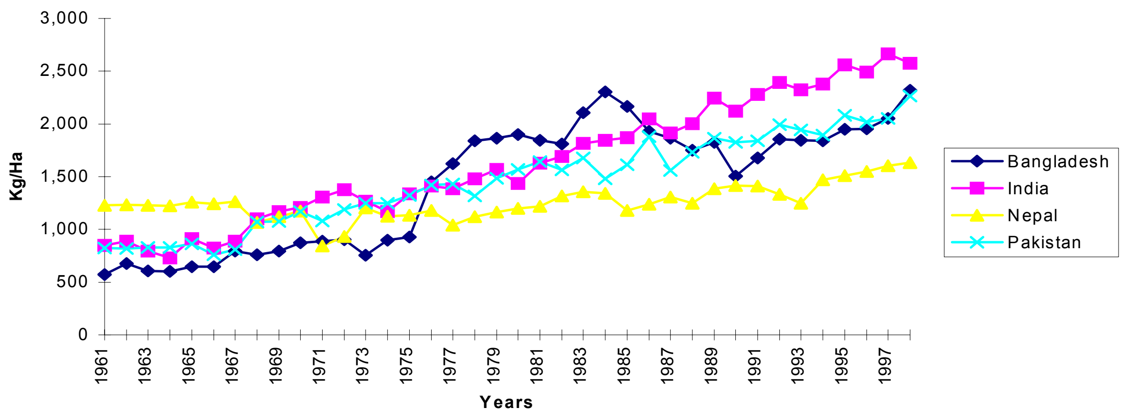
[4]This new technology comprised of new high yielding varieties (HYVs) of cereals, especially dwarf wheats and rices, in association with chemical fertilizers, pesticides, controlled water supply (usually involving irrigation) and new methods of cultivation, including mechanization (Farmer, 1986). The Green Revolution varieties were introduced to a large number of cereal crops including wheat, rice, maize, sorghum, jowar, bajra and ragi. The new varieties were introduced with the intention that the 'new technology' would not only increase production and banish hunger in food deficient Asia to feed the rapidly increasing population, but also assuage unrest and with it the danger of a red revolution (Farmer, 1986, p.176).

[5] According to Lipton and Longhurst (1989, p.4), although modern varieties spread to more than 70% of Indian Punjab's farmland (more than doubling its food yield), there may have been no improvement at all in human nutrition nor any reduction in average severity of their poverty.

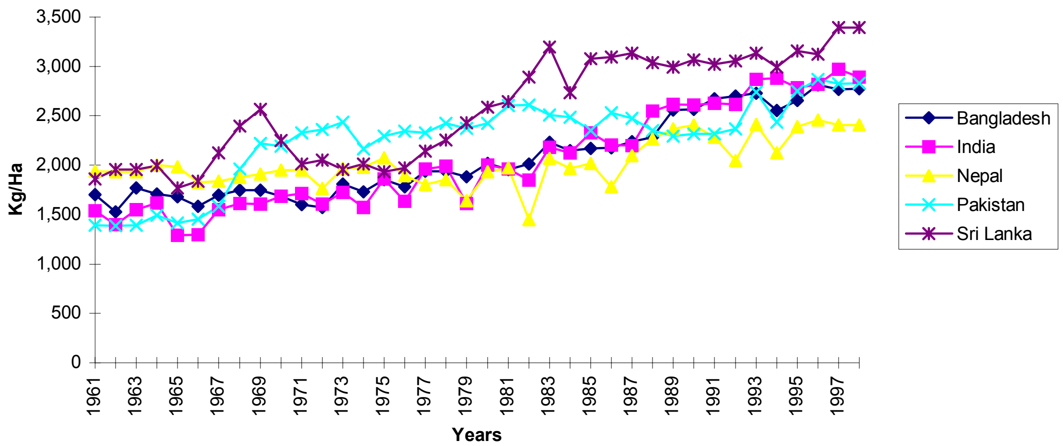
Figure 1: Wheat Yields in South Asia



Source: FAO production yearbooks, various issues, 1961-1998

Rice, too, shows a success story but the output increases are not as large as the output increases in wheat production (Farmer, 1986, p.177). In almost all the South Asian countries, rice production has more than doubled (FAO data, various issues, 1961-1998), though with downward fluctuations in years of bad harvests. Yield increases have doubled with Sri Lanka showing the largest yield increase (see *Figure 2*). In Sri Lanka, yield increased from 1,862 kilograms per hectare in 1961 to 3,392 kilograms per hectare by the end of 1998 (FAO production yearbooks, various issues, 1961-1998).

Figure 2: Rice Yields in South Asia



Source: FAO production yearbooks, various issues, 1961-1998.

Increases in food production and productivity[6] have enabled these countries in the region to reach self-sufficiency or near self-sufficiency in many food products, including cereal production, reduce imports, meet the food needs of a rapidly expanding population and

[6] The impact of the Green Revolution on wheat and rice production is a function of both the area sown with the new wheat and rice varieties and the increase in yields per unit of land.

perhaps avoid a possible Malthusian crisis. As Lipton and Longhurst (1989, p.1) point out, food production (per acre, per season) has doubled or tripled since the 1960s, outpacing population growth. They further point out that “history records no increase in food production that was remotely comparable in scale, speed, and duration” (ibid.). According to Wolf, 1987, p.137 “this agricultural strategy, which transformed the lives and prospects of hundreds of millions, is considered the most successful achievement in international development since the Marshall Plan and reconstruction of Europe following World War II. India, whose food prospects formerly seemed bleak, today holds grain reserves that provide insurance against famine”.

The high yielding and hybrid varieties of the Green Revolution technology and commercial crops are, however, only one component of the new technology(Rigg, 1989, p.381). If the full benefits of this “miracle technology” and other high yielding and hybrid varieties are to be harnessed, it is essential to apply large quantities of agro-chemicals such as fertilizers and pesticides[7]. Hence, the spectacular increases in cereal production and other food crops have been accompanied by huge increases in the use of fertilizers, pesticides, irrigation water and agricultural machinery. This is evident in every country/area that has adopted commercial agriculture including the Green Revolution technology. In this paper, we discuss only two of the commercial agricultural inputs, namely fertilizers and pesticides, in keeping with the theme of this paper [for a full discussion on other inputs used such as irrigation and agricultural machinery, see Wilson (1994, ch. 2)].

3. USE OF GREEN REVOLUTION INPUTS

As discussed in the last section, the introduction of new seeds was only one part of the total package. If the full benefits of the new ‘technology’ were to be harnessed, it was absolutely necessary to apply large quantities of chemical fertilizers, pesticides and other inputs. The increases in yields as pointed out by (Wolf, 1987, p.139) rested on a simple formula of fertilizers, pesticides and other inputs in combination with newly bred crop varieties. As a result, increases in food production and productivity have followed increases in the use of fertilizers, pesticides, irrigation and agricultural machinery (WRI, 1990, p.84; Pinstrup-Andersen and Hazell, 1989, p.107). For example, the average annual fertilizer use in Asia increased from 42 kilograms per hectare of cropland in 1975-77 to 93 kilograms per hectare in 1985-87 (WRI, 1990, p.281). In the 1990s too, this trend is continuing (for e.g. see WRI, p.99, 1994). As Byres (1972) points out, the genetic character of the new varieties is such that they have fewer leaves and more grain, requiring a higher level of inputs, mainly inorganic chemicals such as fertilizers, pesticides, better irrigation, etc. if their potential benefits are to be fully realised[8]. High yielding varieties and inputs have a complementary relationship. Therefore, the adoption of high input commercial farming has been a cause in increasing agricultural production and has led to an even greater production of fertilizers and pesticides to fuel that increase (UNEP, 1991, p.142). Shown below is the phenomenal growth in the use of fertilizers and pesticides[9] that have accompanied the spectacular increases in food production, especially cereal and vegetable crops.

3.1 Fertilizer Inputs

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[7] Adequate irrigation and agricultural machinery are also important inputs.

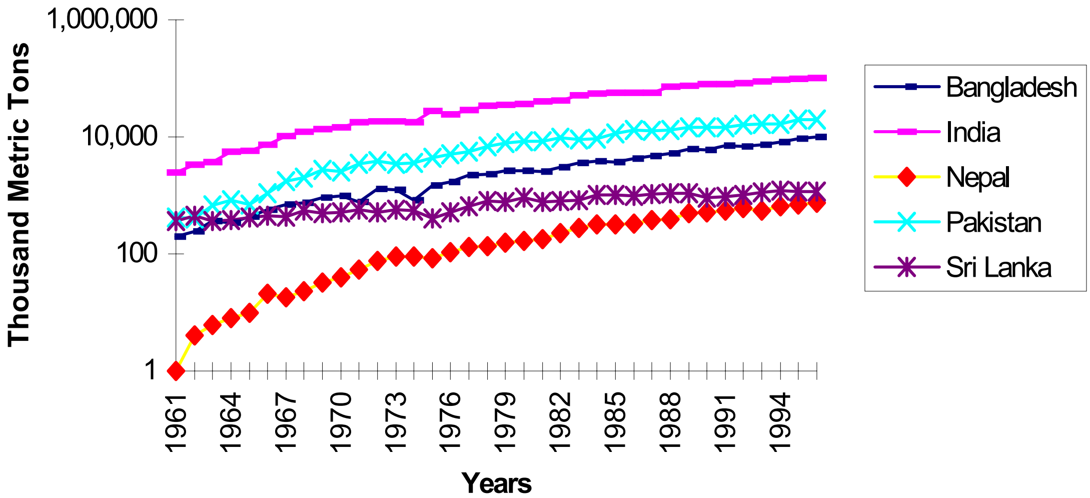
[8] Hence the reason for HYVs to be also called "High Responsive Varieties".

[9] It must be noted that phenomenal increases in irrigation and agricultural machinery have also been recorded (See Wilson, 1994, ch. 2).

Since the introduction of HYV's and hybrid varieties, the use of fertilizers, has shown a phenomenal increase (Wen and Pimentel, 1984). The world-wide use of fertilizer increased by almost 250% in the 20 years between 1966-1968 and 1986-1988 (UN Environmental programme, 1991, p.142). These relationships suggest that much of the increase in world food production can be attributed to the response of crops to increases brought about by fertilizers (ibid, p.142). In South Asia, since the introduction of Green Revolution and hybrid varieties, fertilizer use has shown an explosive increase. Prior to this period, for example, Asian rice farmers produced little surplus and used few purchased inputs. In the 1950s, farmers had little incentive to apply fertilizers. As Barker et al. (1985, p.75) point out, the development of fertilizer responsive tropical cereal varieties, together with installation of fertilizer production capacity and improved systems, led to a virtual explosion of fertilizer use in Asia. Between the early 1960s and the mid 1970s, fertilizer consumption in rice alone increased sevenfold in South Asia (Barker et al., 1985, p.74). In the 1980s and 1990s, too, a similar pattern is observed, not only for cereals, but for other crops as well.

The use of all three NPK fertilizers shows a rapid increase[10] (FAO production yearbooks, various issues, 1961-1998). However, the largest increase has been in the use of nitrogenous fertilizer, which has been most responsible for yield increases. According to Barker et al. (1985, p.76) nitrogen fertilizer has made a substantial contribution to rice output increases achieved by many Asian counties, including South Asia. *Figure 3* shows the consumption of nitrogenous fertilizer in South Asian countries from 1961-1996. The graph shows a very rapid growth from the 1970s to the1990s, still rising in almost all the countries. In India, for instance, nitrogen fertilizer consumption increased more than 41 fold from 1961-1996. Bangladesh, Pakistan and Nepal, show even larger increases. In Sri Lanka, however, it has

Figure 3: Nitrogenous Fertilizer Consumption in South Asia



Source: FAO production yearbooks, various issues, 1961-1996

only trebled (FAO production yearbooks, various issues, 1961-1996). However, it must be pointed out that Sri Lanka had been using some measurable levels of chemicals in rice

[10] For example, in India, fertilizer consumption increased from 69,000 tones in 1950-51 to 127.28 lakh tonnes by 1991-93 (Government of India, 1993, p.383).

cultivation as early as the 1950s coinciding with the introduction of HYVs (Barker et al. 1985, p.76).

Potassium and phosphorous fertilizer, too, have shown increased use (FAO production yearbooks, various issues, 1961-1998). In India for instance, phosphate fertilizer consumption increased more than 49 fold between 1961-1996. Potash consumption increased by almost 37 fold during this period. In Pakistan, consumption of potash has recorded a more than 31 fold increase during the period 1961-1996. Phosphate fertilizer consumption has increased by 839 fold during this period. Bangladesh, Nepal and Sri Lanka show similar trends (FAO production yearbooks, various issues, 1961-1996). Apart from the increasing use of fertilizers, especially nitrogenous fertilizers, the use of pesticides, too, has shown a phenomenal increase from the 1960s coinciding with the Green Revolution and other high yielding and hybrid varieties. We next discuss the use of pesticides in the South Asian agricultural fields to control pests and diseases in the last few decades.

3.2 Pesticides

Unlike fertilizers, pesticides have a somewhat different effect on crops. The initial application of fertilizers almost always adds to crop yields, while on the other hand, pesticides are applied to prevent pest attacks and diseases whenever they occur. Since the Green Revolution and other high yielding and hybrid varieties are less resistant to pests and diseases (Pimentel and Pimentel, 1991, p.329) pesticides, too, have become part of commercial agriculture where pesticide usage on crops is a common occurrence[11]. In addition to poor resistance to pests and diseases, high yielding varieties and hybrids meant intensive cultivation (usually both seasons), and involving monocultural crops. These factors would have also contributed significantly to the widespread increase in pests and diseases in agricultural fields. Furthermore, the importation of seed varieties, mainly vegetable with little resistance to local pests and diseases, too, has no doubt contributed to the increase and spread of pests and diseases. Another reason for the increase in pests could be due to the decimation of natural predators of pests by chemical pesticides as witnessed in Indonesia during the last few decades[12].

Data on pesticides, unlike for fertilizers, are less easy to obtain (UNEP, 1991, p.142). Data sources (example, FAO, UN) that give statistics on agricultural production, fertilizer use, etc have incomplete and inadequate[13] time series data on pesticides. However, the available data again show a rapid increase in the use of pesticides in all the South Asian countries since the introduction of high yielding and hybrid varieties[14]. In India, pesticide consumption increased from 31,361 metric tons in 1972 to almost 84,700 metric tons by 1988 (UN, statistical yearbooks, various issues). Dinham (1993, p.158) points out that in India, pesticide usage has been growing at the rate of 12% per annum during the last two decades. In

[11] Subramaniam et al. (1973) point out that pesticide use in Green Revolution rice production is sevenfold more than in traditional rice production.

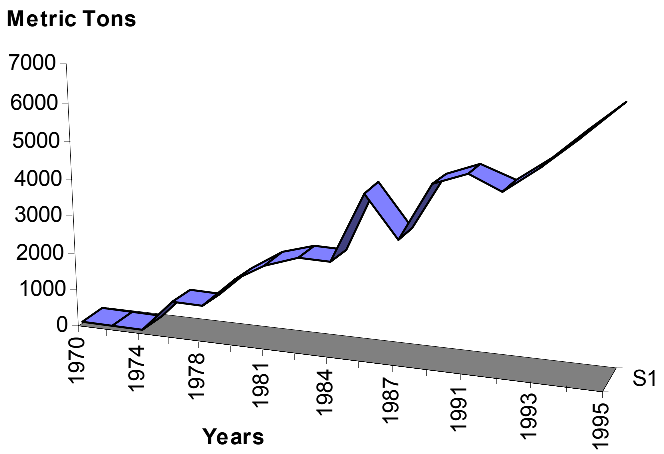
[12] For a discussion on the damage done to rice by the brown planthopper, see for example, Conway and McCauley (1983); Oka (1991); Cook and Perfect (1989); Teng (1990); Whalon et al. (1990).

[13] It is interesting to examine why time series data on pesticides are not freely available. Companies that manufacture pesticides, according to the author's experience, are reluctant to divulge their pesticide production statistics while the same company is happy to divulge their fertilizer production statistics. Hence, data sources (e.g. FAO, UN) are inadequate on the production and use of pesticides in the respective countries.

[14] According to Postel (1988, p.119) pesticide usage in Asia increased by 261% between 1972 and 1985.

Pakistan, after an initial increase in 1970s, a decline is shown in the early 1980s and an increase towards the end of the 1980s. Sri Lanka, too, has recorded a phenomenal increase in the use of pesticides during the last few decades[15]. Since it is difficult to obtain yearly national time series data on the use of pesticides for the entire set of South Asian countries, in this section, we discuss only the patterns of yearly pesticide use in Sri Lanka from the 1970s to the mid 1990s. These data give an idea of the extent of pesticide use in South Asia. Data available in Sri Lanka from various sources from the 1970s show that the amount of pesticides (this includes, insecticides, herbicides and fungicides) used has increased from a few metric tons in 1970 to more than 6,500 metric tons in 1995. This is shown in *Figure 4*. The available data show that the amount of pesticides used has increased almost 110 times during the last few decades.

Figure 4: Pesticide Consumption In Sri Lanka



Data Sources: 1970-1978-Pesticides imported to Sri Lanka taken from (Weeraratna (1983, p.11)[16]. 1980-1982-Domestic supply formulations, RENPAF Gazette, 1985. 1984-Agricultural Economics and Projects/Department of Agriculture, Sri Lanka, 1988. 1986-1987-Pesticide Registration Office, Peradeniya, Sri Lanka, 1988. 1990-1995-Annual sale of pesticides-pesticide Registration Office, Peradeniya, Sri Lanka, 1995.

Since the 1980s, the increase has been more than four fold. From 1987, the use of pesticides has doubled, while the data available on the extent of land cultivated do not show a significant increase[17]. Hence, the quantity of pesticides used per acre of land has increased confirming studies (Chandrasekera et al. 1985; Sivayoganathan et al. 1995) that show that farmers use pesticides more than the recommended level.

As shown in the above discussion, the huge increases in agricultural inputs during the last few decades have no doubt brought about large increases in crop yields. This is the successful side of the high yielding and hybrid varieties technology. However, there is a negative aspect to this technology as well. The huge increases in chemical inputs that were

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[15] Abeysekera (1988, p.21) points out that since the introduction of the Green Revolution varieties to Sri Lanka in the early part of the 1960s, the use of pesticides in agriculture has grown rapidly.

[16] The amount of pesticides manufactured in Sri Lanka in the early 1970s would have been negligible given the size of the total market.

[17] For data on the extent of land cultivated in Sri Lanka, see FAO production yearbooks, various issues, 1961-1998.

required to bring about the large increases in yields, have at the same time brought about another parallel growth; i.e. environmental pollution and deterioration, affected agricultural land, other production processes, increased pest and disease proliferation, affected wildlife and human health. There is increasing evidence to show that the large increases in production with chemical inputs have impacted on the environment and human health. In the next section, we discuss such damage to the environment before going on to deal with the health impacts resulting from agricultural chemicals.

4. ENVIRONMENTAL AND HEALTH EFFECTS OF AGRICULTURAL POLLUTION

The large quantities of chemical inputs used to produce record levels of output are not without problems. The use of chemical inputs has also impacted on the environment such as agricultural land, other production processes, increased the proliferation of pests and diseases, affected wildlife, in addition to affecting human health. In this section, we discuss the environmental impacts caused by the excessive use of fertilizers and pesticides.

4.1 Agricultural Impacts

There is increasing evidence to show that during the last few decades, the agricultural environment has been affected due to agricultural pollution, especially from nitrates and pesticides, leading to declining productivity[18]. Continuous increase in chemical inputs results in a build up of ‘stock’ pollution on agricultural land. Soil damage has occurred in many agricultural lands with heavy use of inorganic chemical fertilizers[19], and pesticides resulting in a reduction of essential soil nutrients such as zinc and boron (IAD, 1983, p.17; Shiva,1991, p.114; Pingali and Rosegrant, 1994, p.16-17). Micro nutrient deficiencies in the Punjab soils have been recorded. Zinc is the most widespread of all micro nutrient deficiencies in Punjab. Such deficiency has reduced yields in rice, wheat and maize (Shiva, 1989, p.77). Furthermore, with increased fertilizer application, acidification of soils has increased (IAD, 1993, p.16-17; IAD, 1994, p.7; Conway and Barbier, 1990, p.21). According to Baker (1993, p.16), intensively grown monocultural systems with chemical fertilizers and water throughout the year can exhaust organic matter in soils. Furthermore, it has been pointed out that there is a potential for pesticides to adversely affect paddy soils (Greaves, 1984, p.14). Declining soil fertility not only affects productivity, but also increases the need to apply larger quantities of chemical inputs, thus further increasing the costs to farmers. For example, IRRI scientists point out that farmers have to apply up to 40% more nitrogenous fertilizer than they did ten years ago to produce the same amount of rice (IAD, 1994, p. 8). For a detailed discussion, see Wilson (1998, ch. 2). For a discussion on the effects/costs of pesticides on soils, microorganisms and invertebrates, see Pimentel et al. (1992).

Apart from decreasing yields resulting from fertilizer contamination of the soils, pesticides, too, affect yields indirectly. Increases in pesticide use to control the pests that easily attack high yielding and hybrid varieties have led to an increase in the virulence of rice, wheat and other crop pests (IAD, 1990, p.6; Shiva 1991, p.88-89) due to the destruction of non-target

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[18] For other adverse effects of commercial agriculture, including the Green Revolution, see Shiva (1989, 1991); Wilson (1994); Pimentel et al. (1987); Alauddin et al. (1995); Tisdell and Alauddin (1989); Alauddin and Tisdell (1991a); Alauddin and Tisdell, (1991b); Conway and Barbier (1990); Pingali and Rosegrant (1994).

[19] According to Nortcliff (1993, p.16-17) ‘inorganic fertilizer is partly responsible for declining yields, but there may be other factors, such as decline in soil structure’. Baker (1993, p.17), states that when chemical fertilizers have been applied over long periods, yields have eventually declined.

species, which include natural predators of pests and parasites (Litsinger,1989, p.235; Bramble 1989, p.229; Teng 1990; Pimentel, 1992, p.752; Pimentel, 1993)[20]. The best examples that can be cited are the brown planthopper and rice gall midge. There are many more species that have proliferated with the destruction of natural predators which earlier were not serious (Litsinger, 1989, p.235; Kenmore et al. 1984; Way and Bowling, 1991; Sogawa, 1982; Rola and Pingali, 1993, p. 15-19; Heong, 1991). Kenmore (1980) reported that nearly every outbreak of BPH in the tropics has been associated with prior use of insecticides. Reissig et al. (1982) found that 16 of the 39 insecticides tested caused BPH resurgence. Hence, a pesticide treadmill has been created. Severe outbreaks of the brown planthopper occurred on rice in the 1970s, 1980s and in the 1990s in Asia with losses running into millions of hectares of rice destroyed[21]. Planthoppers are naturally controlled by wolf spiders and a variety of other natural predators and parasites which are destroyed by many of the pesticides commonly used on rice (Conway and Barbier, 1990, p.22; Conway and McCauley, 1983, p. 288). According to Way and Bowling (1991, p.237) “as the Green Revolution varieties became more widely accepted and grown, more insecticides were applied to protect high yielding crops requiring greater inputs. The increased use of insecticides decimated natural enemies and led to secondary pest outbreaks and the resurgence of planthoppers”. This connection is also shown by Heinrichs (1979); IRRI, 1979; Chelliah and Heinrichs (1980); Krishnaiah and Kalode (1987); Teng (1990). Pimentel (1971) points out that the use of 2, 4-D herbicide has increased the level of attacks of insects on rice. Numerous outbreaks of pests have occurred during the last few decades. These outbreaks of pests are, however, not restricted to Green Revolution varieties, but affect other high yielding and hybrid varieties as well. Wilson (1998, p. 25) shows some of the natural predators of pests that have been decimated by the continuous use of pesticides.

Insect resistant varieties of (both Green Revolution varieties and non Green Revolution varieties) have not been able to prevent these outbreaks as the pests rapidly select new biotypes (Litsinger,1989, p. 235). Outbreaks of BPH and tungo virus vectored by the green leafhopper have proliferated after their natural enemies were destroyed by insecticides (Litsinger, 1989, p. 235; Kenmore et al. 1984; Way and Bowling, 1991; Sogawa, 1982). Furthermore, the white backed planthopper (WBPH) which was earlier considered a minor pest has now become a serious pest to rice production in several Asian countries including Pakistan, India, Bangladesh and Nepal. Serious outbreaks have been reported from Madhya Pradesh, Orissa, Tamil Nadu, Kerala, Andhra Pradesh and West Bengal (Chatterjee et al. 1976) Haryana (Kushwaha et al. 1982), Punjab (Sidhu, 1979), Uttar Pradesh (Verma et al. 1979) and Nepal (Pradhan et al. 1983). The damage caused to grain yields by this species and its allied species, the brown planthopper is estimated between 10 and 100% in various states/areas (Kushwaha et al. 1986, p.21). Pathak and Dyck (1993) show that 25% of the Philippine rice crop is lost to insects. Other studies that show crop damage from insects include: Pathak and Dhaliwal (1981); Walker (1990); Teng et al. (1990); Pingali and Rosegrant (1994, p. 17-18). For a detailed discussion on crop losses, see Rola and Pingali

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[20] Pesticide resistance by pests and weeds is ranked as one of the top four environmental problems in the world (UNEP, 1979). Today more than 500 insect and mite species are immune to one or more insecticides (WRI, p. 113, 1994).

[21] The best example of crop damage from brown planthopper can be taken from Indonesia. From 1977 to 1979, over two million hectares of rice were lost due to brown planthopper damage. Again from 1984 and 1986 BPH outbreaks reduced rice yields nation wide (Whalon et al. 1990, p.156). The estimated loss in just a two-year period was 1.5 billion US dollars (FAO, 1988). Pimentel et al (1992, 1993) show the costs of decimation of natural enemies in the USA which run into millions of dollars each year.

(1993, ch. 2). In Sri Lanka (for example, Matale District), land has also been abandoned because pesticides have been ineffective in protecting crops[22].

Furthermore, in recent times, rice scientists have, established a link between increases in nitrogenous fertilizer and proliferation of pests in rice. When fertilizer applications increased, the amount of pests and diseases in rice has also simultaneously increased (Pimentel, 1977; Chakraborty et al. 1990, p.167; Litsinger, 1989; Conway and McCauley, 1983, p. 288). It has also been shown that increased nitrogen is often associated with more leaf disease, because it provides a micro climate more conducive to fungal growth. Among the diseases that have increased in South Asia are bacterial diseases, sheath brown rot, narrow brown leaf spot (Estrada et al. 1981), tungo and grassy stunt (Mew, 1991). Hence, through crop damage, yields could decrease. These problems are also not restricted to the Green Revolution varieties but also to all commercially grown food crops requiring the use of chemical inputs. Soil pests, especially root nematodes, have also increased with agricultural intensification (Prot et al.,1992). Fischer (1985, p.208), Pimentel et al. (1992), state that pollution not only affects yields and the quality of crops but also increases the susceptability of vegetation to damage by insects and diseases. In addition to these effects, other adverse effects have also been recorded which are discussed below.

4.2 Eutrophication and Algal Blooms from Nitrate Pollution

Excessive use of fertilizers has caused other environmental impacts too. Nitrates act as fertilizers for aquatic plants (Saull, 1990, p.2). Nitrates seeping out of soil into streams, rivers
and lakes in excessive quantities can boost the growth of algae and other aquatic plants. This enrichment is called eutrophication. The increase in the growth of aquatic plants and algal blooms in certain areas has clogged up rivers and lakes (IAD, 1989, p.2), as well as killed fish, shrimps and other beneficial organisms (Pimentel, 1989) due to de-oxygenation. Waterways in Asia provide a valuable form of water transport and when rivers and lakes are clogged up, the impact on water transport can be considerable. Fertilizers have also increased weed growth in rice fields and provided breeding grounds for the malaria mosquito. The increased weed growth has led to an increase in the use of herbicides, further increasing the level of pesticide pollution and aggravating the environmental effects of pollution. The spread of insecticides into aquatic ecosystems has also increased the resistance of mosquito's resulting in the spread of Malaria (ICAITI, 1977; NAS, 1991; Pimentel, 1992, p.754). Research carried out by ICAITI (1977) shows that malaria mosquito has increased three fold after the use of pesticides. Weeds have also developed resistance to herbicides and hence a proliferation of weeds has been recorded (Alauddin et al. 1995, p. 243; Pimentel et al. 1992).

4.3 Wildlife Impacts from Pesticide Use

No one knows for certain the extent of the damage done to wildlife from the use of pesticides. This is because no detailed study has been carried out in Asia to determine the real damage to fauna. However, many species have been affected, especially animals[23] at the top of the food chain, and according to Bramble (1989, p.228), the natural balance of

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[22] For a similar problem in Mexico, see Adkisson (1972).

[23] For pesticide poisoning of mammals in Britain and elsewhere, see Mason et al. (1986, pp. 656-66); Blackmore (1963, pp. 391-409).

predators and prey has been disrupted, particularly in the insect world[24]. Birds, too, have been a casualty from pesticide poisoning[25]. According to Urfi (1994, p.35) cranes and storks have been affected due to Green Revolution agricultural toxins. It is believed that agricultural toxins have decimated water insects and invertebrates in the agricultural lands that constitute up to 75% of Uttar Pradesh, India. As a result, Sarus Cranes, the world's largest flying bird, began to disappear due to the disappearance of their specialized food. Storks, too, have been affected. The numbers of Black Necked Storks have shown a visible decline and among the many factors responsible, have been the thinning of the shells of their eggs due to pesticides (Urfi, 1994, P.35). A study conducted in Karnataka state (India) of 338 wetlands by IWRB (1992, p.49) has shown that pesticide and fertilizer pollution threatened 17 of 338 wetlands. Beasley and Trammel (1989) point out that farm animals and pets are also affected by the use of pesticides. For a discussion on the effects/costs of pesticides on wild birds populations in North America and Europe and for relevant references, see Pimentel et al. (1992).

4.4 Impacts On Other Production Processes

In addition to the damage caused to the environment and agricultural land, these pollutants also impact directly on other production processes. One such process that has been directly affected is the fisheries sector. We discuss briefly the impact of pesticides on the fisheries sector below.

4.5 Shrinking Fish Production

Another major negative externality arising from chemical pollution, in addition to the damage caused to the environment, has been a decrease in fish production (Bull, 1982, pp. 63-65; Bangladesh, Ministry of Finance, 1992, p.32; Conway and McCauley, 1983, p. 288; Pimentel et al. 1992, p.756), both in paddy fields and fresh water lakes and rivers. Many of the pesticides used are highly toxic to fish at normal rate of application (Grist, 1986, p.318)[26]. There is increasing evidence for this from India as well as Bangladesh. In Kuttanad, the rice bowl of Kerala, since the 1980s, fishing has become practically extinct (IAD, 1990). In Bangladesh, fish production over the years has shown a noticeable decrease. Among the many factors that have been cited as a cause for decline in fish production is the presence of pesticides in fresh water as well as in crop fields (Bangladesh, Ministry of Finance, 1992, P.32). Alauddin et al. (1995, p. 242) point out that in Chittagong and Durgapur districts (Bangladesh), fish production in paddy fields has declined by 60-75% over the last decade following the Green Revolution. In addition to fish, shrimps, prawns, crayfish and crabs are also known to suffer from pesticides, but detailed studies of pesticide poisoning are not available. Greaves (1984, p.15) states that there is evidence that pesticides, particularly insecticides, can cause mortality in crabs and fish. Pesticides, not only affect the quantity but also contaminate the harvests of fish, shrimps, etc. posing a serious health hazard to consumers (ICAITI, 1977). For a discussion on the effects of pesticides on fishery losses and

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[24] For a discussion on the impact in bees see Shries (1983, pp. 118-20); Murray (1985, pp. 560-64). For a discussion on costs resulting from a decline in bee populations in the USA, see Pimentel et al. (1992, p. 754).

[25] For evidence of pesticide poisoning of birds in UK and North America see Lundholm (1987, pp.1-22); Peakall et al. (1976, pp.392-4); Newton and Bogan (1978, pp. 105-116); Lincer (1975, pp.781-93).

[26] In the Philippines and Malaysia farmers have linked declining fish yields in rice fields to pesticide poisoning (Dinham, 1993, p.69; Sudderuddin and Kim, 1979).

their costs in the USA, see Pimentel et al. (1992, p.756). The increased use of pesticides has also depleted the frog and toad populations (Alauddin et al. 1995, p.243). Other externalities have also been observed. For example, Wilson (1998, p.156) notes that herbicides used on onion plots to destroy weeds when spread to neighbouring farms due to strong winds affected other crops which were not resistant to the herbicides used. In Australia, Endosulfan (a very toxic organochlorine insecticide) used on cotton crops has contaminated beef production and has affected exports in recent times (Williams, 1999, p.11). Rural water supplies, too, have been affected (Callinan, 1999, p.1). Furthermore, Quinnell (1997) points out that pyrethroids are known to have impacted on aquatic ecosystems in Australia (e.g. in Moreton Bay). In the USA, too, beef, milk and eggs have been affected (Pimentel et al. 1992). For a discussion on similar externalities and their costs in the USA, see Pimentel et al. (1992, p. 755)

In addition to the above mentioned adverse effects, the health effects arising from fertilizer and pesticide pollution are also very large as will be shown below.

4.6 Health Effects

Agricultural pollution generated from chemical inputs, not only has affected the quality of the environment but as will be shown in this section, has also impacted on human health, leading to numerous morbidity and mortality effects. The health effects are from both nitrogenous fertilizers and pesticides. We first discuss the health effects of nitrates in water in South Asia and then discuss the effects of pesticides especially on farmers with special reference to Sri Lanka.

Fertilizers used in agriculture are a major source of water contamination, especially shallow aquifers (Tivy, 1990) in rural areas. Many diseases, including cancers have been linked to nitrates in drinking water (Pretty and Conway, 1988a, p.1; Conway and Pretty, 1988). Theoretical models describing the chain of events from nitrate pollution to cancer appear fairly complete. The carcinogens in this chain are N-nitroso compounds (ibid.). Many of these compounds tested have been found to cause cancers in many species of animals, especially of the stomach, liver, oesophagus and bladder. However, despite these findings there is no direct evidence to show that these compounds cause cancer in humans (Muia and Thomas, 1990, p.93). Gastric, bladder, and esophageal cancers have been suspected to be caused by high levels of N-nitroso compounds in water (Pretty and Conway, 1988a, p.1). However, the current evidence for a relationship between nitrates and cancers is mixed[27]. Despite all these, some parts of India and Sri Lanka show increasing incidence of these cancers, most of which come from agricultural areas.

Nitrogenous fertilizer has been identified as one of the causes of methaemoglobinaemia, commonly referred to as the Blue-Baby syndrome in agricultural areas (Pretty and Conway, 1988b, p.1; Conway and Pretty, 1988). Although many deaths have been reported from agricultural regions in USA and Hungary, there are very few records of the Blue-Baby syndrome in tropical countries (ibid.). So far no one is certain as to what the real risks are in South Asia from high nitrate levels. This could be attributed to lack of studies conducted in the region. High nitrate levels in drinking water in developing countries are known to occur. According to various surveys in India, some 20-50% of wells contain nitrate levels greater

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[27] Despite the suspicions that high nitrate levels could cause gastric cancer, available information suggests that the incidence of gastric cancer is declining in many developing countries including Sri Lanka and Bombay, India (Pretty and Conway, 1988a, p.3).

than World Health Organization (WHO) limits and in some cases, as high as several hundred mg/1[28] (Pretty and Conway, 1988b, p.4). However, not all nitrate contamination comes from fertilizers alone. Livestock waste and human excreta, too, have been identified as causing the high nitrates in water. The risk in South Asia from fertilizer contamination is obviously high. But the main problem has been the lack of studies to determine the seriousness of the problems arising from chemical pollution. The danger is magnified especially when most people in rural areas use untreated water straight from the source of origin. Furthermore, jaundice has been reported in the Punjab due to ground water being contaminated with fertilizer effluents (Singh, 1989, p.32).

In addition to fertilizers, pesticides, too, have affected human health. Pesticides once used can remain active in soil and water for a long period of time. Furthermore, the potency of insecticides used, especially organoclorines and organophosphates can be very high. All this has increased the risk of pesticide use. What is frightening is that the human and environmental impact in South Asia are under-documented and that the few studies carried out point out to high levels of contamination. Since the introduction of Green Revolution and other high yielding and hybrid varieties, pesticide usage has been growing[29] as shown in the last section. As Postel (1988, ch. 7, p.12,) points out chemicals were part of the inputs package used to boost Third World food production during the Green Revolution[30]. In India, for example, in the 1980s, some 80 million hectares of India's cropland received treatment with chemical pesticides compared with just 6 million in 1960 (Gupta, 1986). In Ludiana district, for example, according to Sidhu and Byerlee (1991, p.A-160), two thirds of the wheat area is treated with herbicides. Although the use of pesticides has helped to reduce crop losses, their effect is becoming quite evident now. Incidentally, most if not all pesticide poisonings have been recorded from states/areas where the Green Revolution and other high yielding and hybrid varieties have been adopted [31].

Farmers handling and spraying pesticides on their farms are those who are most affected. Incidents of direct exposure to pesticides and the resulting illnesses are well documented[32]. Jeyaratnam (1982), as far back as the early 1980s, showed that as many as five out of 1,000 agricultural workers in Sri Lanka are hospitalized each year due to 'pesticide use' poisoning (which is around 24.8% of all hospitalized cases due to pesticide poisoning) and that occupational health effects from pesticide poisoning are numerous. Since then, not only have the incidences of all cases of pesticide poisoning increased, as many sources of data/studies show, but the extent of pesticide poisoning due to direct exposure during handling and spraying has also remained inadequately documented. For example, many farmers take treatment from private physicians. Furthermore, the out-patient treatment of direct pesticide exposure cases has not been recorded nor studied. It is also known that a very large number of farmers take self-treatment (home made). Hence, the real extent of the problem is not highlighted and the seriousness of the health hazards remain undetected. Several field studies

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[28] The WHO guideline for safe levels in drinking water is 45 mg nitrate/litre.

[29] According to Dinham (1993, p.159) the Green Revolution turned India into a major pesticide consumer.

[30] Experiments carried out at the International Rice Research Institute (IRRI) in the Philippines between 1964 and 1971 have shown that rice plots protected by insecticides yielded an average of 2.7 tons per hectare more than unprotected plots - almost double the yield. The use of rodendicides, too, can result in rice yields two or three times higher than those of untreated plots (Lim and Ong, 1977, extracted from Bull, 1982, p.50).

[31] In India the states include; Andhra Pradesh, Karnataka, Uttar Pradesh, Haryana, Punjab, Gujarat, Tamil Nadu and Maharashtra.

[32] See Wilson (1998, chapter 3) for a discussion on studies carried out on pesticide poisoning in Sri Lanka.

carried out have shown that farmers suffer numerous morbidity effects during handling and spraying of pesticides. These studies have also noted the various symptoms that arise due to direct exposure to pesticides. Sivayoganathan et al. (1995, p.436) point out in a study carried out in Sri Lanka, that the majority of those interviewed (62%) had at least one morbidity effect arising from direct exposure to pesticides. The morbidity effects ranged from headaches, dizziness, nausea to blurred vision. They list 17 illnesses that arise due to direct exposure to pesticides during handling and spraying (usually during or within four hours of spraying) on a typical pesticide spraying day[33]. Chandrasekera et al. (1985), too, show from a field study in four districts in Sri Lanka, that more than 50% of those interviewed suffered from many pesticide related symptoms during or soon after the application of pesticides. A study carried out by Dharmawardena (1994), too, shows that the incidence of direct pesticide poisoning is high among farmers in Sri Lanka and points out that the true incidence of pesticide poisoning is likely to be more than that shown by the hospital morbidity figures. Hoek et al. (1997) in their work state that "many cases of intoxication due to occupational exposure may not require admission to a hospital and are therefore not included in routine health statistics" (p.8). They go on to point out that many minor poisoning cases due to occupational exposure are not seen at the government hospitals. As Dinham (1993, p.50) comments "where figures on pesticide poisonings exist, they frequently come from hospital poisons units, which tend to receive very acute cases of poisonings-predominantly, though not exclusively, cases of suicides or attempted suicides. These figures skew the overall statistics relating to pesticide poisoning and may give the impression that suicides are the most significant problem". Some other studies that confirm morbidity effects on users include Jeyaratnam and Ponnambalam (1980); Gnanachandran and Siyayoganathan (1989); Jayathilake and Bandara (1989). These observations are confirmed by a field study conducted by Wilson (1998).

Other studies carried out, not only in Sri Lanka, but in other Asian countries too, confirm that many morbidity effects take place during application of pesticides in agriculture [Jeyaratnam et al. (1987), Rola and Pingali (1993, ch. 6); Loevinsohn (1987); Kishi et al. (1995); Antle and Pinali (1994a); Antle and Pingali (1994b); Lum et al. (1993).]. Jeyaratnam et al. (1987) in a study of four Asian countries (Indonesia, Malaysia, Sri Lanka and Thailand), also confirm morbidity effects of pesticides during handling and spraying on farms. Jeyaratnam and Ponnambalam (1980) list a number of symptoms, similar to those recorded among farmers in their study of health workers engaged in anti malaria and anti-filaria work in Sri Lanka. For a detailed discussion on the effects of pesticides on the users, see Wilson (1998, ch. 3).

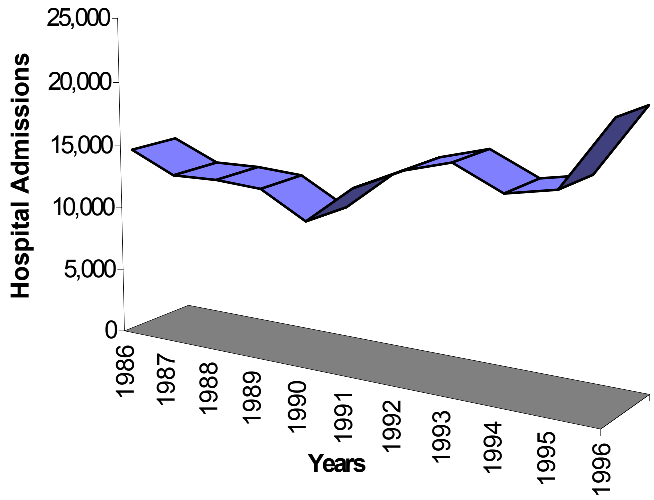
The above mentioned studies record the symptoms experienced by farmers either during handling and spraying or soon after spraying (usually during or within four hours of completing pesticide application). Some of these symptoms could also appear a day, or days later, after showing mild symptoms on the day of spraying.

In addition to the many field studies that show high morbidity effects from direct exposure to pesticides in Asia, hospital records, too, show very high levels of morbidity due to pesticide pollution. Hospital data in agricultural areas in all the South Asian countries show high levels of hospital admissions due to pesticide pollution. For example, in Sri Lanka, pesticide

[33] Fernando (1988, 1991) also describes the clinical symptoms of inhalation and skin contact of pesticides, as often happens during handling and spraying by farmers, especially when adequate precautions are not taken by the users.

poisoning has been a health hazard to users (both health workers and farmers) from the late 1950s and early 1960s and has been increasing at an alarming rate ever since. *Figure 5* shows the national hospital admission figures for Sri Lanka for the period 1986-1996.[34]

Figure 5: Hospital Admissions Due to Pesticide Poisoning in Sri Lanka



Source: National Poisons Centre, Colombo General Hospital, Sri Lanka, 1997.

As the national figures for Sri Lanka show, the total number of hospital admissions has on average remained around 14,500 from 1986-1996 (see Appendix 1 for hospital admission figures from 1975-1996). It must be pointed out here that not all hospital admissions (shown in *Figure 5*) were due to occupational poisoning (i.e. due to handling and spraying on the farms) but include cases of self-ingestion (suicides), accidental ingestion and homicides as well[35]. However, the high hospital admissions point out to the free availability of pesticides in the agricultural areas where most of the hospital admissions of pesticide poisonings are recorded.

Apart from these acute short-term ill effects recorded, many long-term illnesses have also been recorded in South Asia. For example, long-term illnesses such as cancers, tumors, loss of memory, blindness, asthma, swellings in the body, weight loss, numbness of fingers, were recorded during a field study in 1996 (Wilson, 1998). These observations were made by farmers, based on their perceptions of ill health using pesticides which were confirmed by physicians. Comas and paralysis have also been recorded [Perera (1988, p.56)]. Prolonged exposure to pesticides could also lead to cardiopulmonary disorders; neurological and hematological symptoms and skin diseases (Davis et al. 1982; Smith et al. 1988; Rola and Pingali, 1993). Some other studies that show long-term illnesses from exposure to pesticides

[34] For data on pesticide related hospital admissions for the entire country from the 1970s and the field study area hospitals in Sri Lanka see Wilson (1998, ch. 3).

[35] No disaggregated data are available with the National Poisons Centre. Bed head tickets of all the government hospitals have to be examined in order to isolate cases resulting from direct exposure to pesticides from handling and spraying on the farms. However, the bed head tickets of a selected number of hospitals in the study area were examined and it was found that a considerable number of the cases were due to occupational poisoning, although the majority of the cases were due to self ingestion (suicides).

include: Hoar (1986); Nielson and Lee (1987); Blair and Zahm (1993); Balir et al. (1993); Boyle and Zardize (1993); Brown et al. (1993); Collins et al. (1993); Pingali et al. (1992). Fernando (1991), too, describes some of the long-term illnesses, but refer mainly to patients who have deliberately ingested pesticides or through accidental ingestion involving pesticides.

In India, there is concern among doctors that cancer is increasing among communities exposed to pesticides. For example, a study in India (Thiruvananthapuram Medical College) has tried to show the link between high pesticide use among farmers in Kuttanad area and frequent cases of cancer of lip, stomach, skin and brain as well as leukemia, lymphoma and multiple myeloma (Dinham, 1993, p.49). The Kuttanad area has around 52,000 hectares under rice cultivation and pesticide consumption has shown a steady increase from 200 tonnes in 1972 to a peak of 13,400 tonnes in 1980 which, in recent years has stabilised at 4,000 to 5,000 tonnes a year (The Hindu, 11/3/91). Another study conducted by an environmental toxicologist working in Tamil Nadu (Tanjore district) to determine a link between cancer and pesticide use[36] among 20 labourers (15 men and five women) has shown higher chromosomal aberrations and chromatid exchanges in the labourers which indicate increased carcinogenic risk. The study found that these measures were significantly higher in the study group, compared to the control group, indicating chromosomal anomalies, which increase significantly with duration of work (Dinham, 1993, p. 49). With hundreds of thousands of farmers using pesticides in South Asia carelessly and without adequate precautions taken, the dangers must be substantial as this small survey demonstrated.

In addition to the short-term and long-term illnesses described above, direct exposure to pesticides during handling and spraying on the farms also results in many deaths. Fernando (1991, p.98), for example, refers to cases of fatal poisoning due to skin contamination probably due to accidents during spraying on the farms. Chandrasekera et al. (1985) in their study show, that many deaths occur due to direct exposure to pesticides in Sri Lanka. Data collected from farmers during a field study in 1996 by Wilson (1998), too, show that deaths due to direct exposure to pesticides on the farms is not an uncommon feature. This was confirmed by hospital data in the study area (see Wilson, 1998, ch. 3) and national data available with the National Pesticide Poisons Centre, Sri Lanka. In other countries in South Asia, too, deaths have been recorded. For example, *Table 1* shows pesticide related deaths in India by state. Interestingly, all deaths have been recorded from agricultural states where Green Revolution technology is in widespread use.

Table 1: Reports of Pesticide-Related Deaths Notifiable Under the Insecticides Act 1968 (excluding occupational health hazards and illnesses which are not recorded)

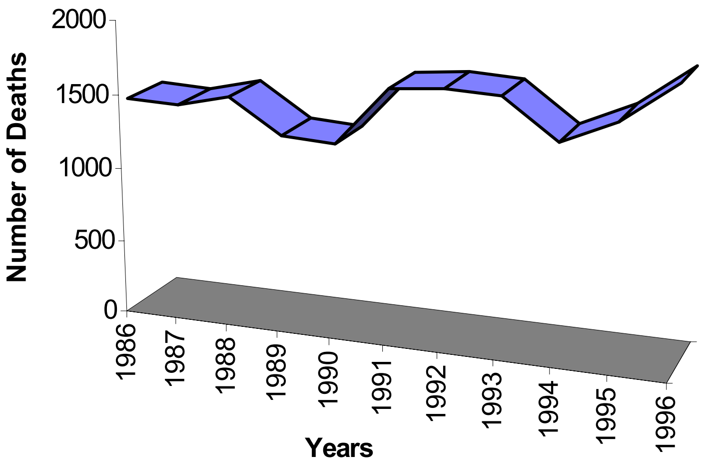
[36] Men spray from 4-20 acres for 8-10 hours a day to earn extra cash (Dinham, 1993, p.49, 167). Wilson (1998, p.114), too, records long hours of exposure to pesticides by farmers.

State	1987-88	1988-89	1989-90
Andhra Pradesh	Nil	n/a	34
Haryana	3 (animal deaths)	6	10
Himachal Pradesh	n/a	n/a	n/a
Kerala	Nil	n/a	237
Madhya Pradesh	772 cases of poisoning including a number of deaths from 1986-88	n/a	n/a
Orissa	2	Nil	2
Punjab	126	n/a	149
Tamil Nadu	4 (animal deaths)	n/a	1
Uttar Pradesh	54	78	100
Pondichery	Nil	108	131
Total reported deaths	**182+**	**192+**	**664+**

Source: Indian Government Answer to Parliamentary Question on 4.1.91 extracted from Dinham, 1993, p.165.

Apart from these deaths, thousands die each year due to deliberate and accidental ingestion of pesticides. A small number also die due to homicides. *Figure 6* shows the amount of deaths in Sri Lanka from 1986-1996. As shown, the amount of deaths from pesticide poisonings in

Figure 6: Deaths Due to Pesticide Poisoning in Sri Lanka



Source: National Poisons Centre, Colombo General Hospital, Sri Lanka, 1997

Sri Lanka is around 1,500 a year[37]. Appendix 1 also shows the mortality figures, deaths per thousand and their rankings for the whole country during this period 1975-1996. These national figures include all deaths due to pesticide poisoning, which includes occupational deaths (i.e. due to handling and spraying pesticides) among farmers and health workers as well. No disaggregated data are available to show only the deaths from occupational

[37] Hettiarachchi and Kodithuwakku (1989) from their study note a mortality rate of 22 per 100,000 population, all of which are from self poisoning (suicides).

exposure. However, data available from rural hospitals as shown in Wilson (1998); Chandrasekera et al. (1985) show that deaths due to direct exposure to pesticides is not uncommon.

In addition to the morbidity and mortality effects arising from direct exposure to pesticides, non users and consumers of food contaminated with pesticides are also at risk from pesticide poisoning. Not many studies have been undertaken to determine these risks. However, the available data show that third parties are affected from the use of pesticides. For example very high levels of pesticide residues have been detected in Indian food and high residues of persistent organochlorine found in the tissues, human milk and blood of Indians, including DDE, DDT and BHC residues in breast milk (Dinham, 1993, p.169; UNEP, 1987, p. 100/101). It has been estimated by the Punjab Agricultural University that, all milk samples of women around Ludhiana city were found to contain DDT residues, 73% of which had more than the tolerable limit (Singh, 1989, p.37). It is estimated that a three month old baby in the Punjab which feeds daily on milk, takes in nine times more DDT residues than is acceptable. All collected human milk samples were found to contain very high levels of DDT and BHC. Out of 980 samples of milk tested for the study in Andra Pradesh, 95% of them contained DDT with HCH in 90% and dieldrin in 1% (Dinham,1993, p.169). Another study carried out shows that DDT residues were found in 53% of the 1,651 tested samples of cereals produced in Punjab, Haryana, Uttar Pradesh and Andhra Pradesh (Dinham, 1993, p.169). The dangers of drinking water contaminated with pesticides have not been systematically studied even in the developed countries[38]. With a large percentage of rural people in South Asia dependent upon wells, streams and ponds for their water supplies, the dangers from pesticide contamination could be high. For a discussion on the costs of food and water contamination by pesticides in the USA, see Pimentel et al. (1992, p. 755/756).
The above discussion showed that the heavy use of agricultural inputs such as fertilizers and pesticides has impacted on agricultural land, other production processes, increased the proliferation of pests and diseases, caused eutrophication, affected wildlife and human health. The private and external costs of pollution are no doubt very high. The costs include direct, indirect and non use/intangible costs. To estimate all the costs of fertilizer and pesticide pollution is beyond the scope of this paper. However, we show some of the costs of pesticide pollution. Here, too, we only show the private costs arising from direct exposure to pesticides and not the public (external) costs or the costs to third parties from pesticide pollution. From these costs we can show the extent of the severity and the magnitude of the costs that are associated with agricultural pollution.

5. THE PRIVATE COSTS OF DIRECT EXPOSURE TO PESTICIDES

The costs arising from agricultural chemicals such as fertilizers and pesticides can be substantial judging from the adverse effects of pollution as shown in the last section. In this section, we show the extent of the private costs to farmers arising from mobidity effects as a result of direct exposure to pesticides during handling and spraying on the farms. For this purpose, the results of a field survey carried out in 1996 by Wilson (1998) in Sri Lanka are used. We estimate only the private costs since government hospital treatment and care in South Asian countries is free of charge or subsidized. These costs, too, are large, but we do not discuss these costs in this paper.

[38] In the USA, for example, GAO (1986) states that there is lack of public health data about pesticide effects.

As shown in the last section, farmers suffer numerous morbidity effects from direct exposure to pesticides during handling and spraying on the farms. The private costs alone are very high. These costs arise from illnesses on spraying days, non-spraying days and long-term illnesses. The severity of short-term illnesses experienced by farmers on spraying and non-spraying days can be grouped into three categories, namely severe, moderate and mild[39]. In all of these categories, respondents suffer private direct, indirect and intangible costs. The direct and indirect costs can be further subdivided into medical costs[40] which include doctor visits, hospitalization costs, laboratory costs, emergency room visits and medication/drug costs. These are categorized as direct costs. Other direct costs include dietary expenses resulting from illnesses, travel costs associated with medical treatment, hired labour due to inability to work and any other direct costs incurred due to inability to stay on the farm such as crop damage from pests and diseases due to inability to look after the crops from animals, theft, etc. The indirect costs are loss of work days on farm, loss of efficiency on farm, time spent on travelling/seeking treatment and leisure time losses. The intangible costs include pain, discomfort, stress and suffering[41]. In addition to these costs, farmers also incur costs on precautions taken to minimize exposure to pesticides in the form of protective clothing, masks, gloves, wearing shoes, hiring labour to spray the pesticides, building special storage units, etc.

In order to estimate these costs several techniques have been suggested. They include the cost of illness, avertive behaviour and the contingent valuation approaches. The cost of illness approach takes into account only the direct and indirect costs. This approach does not take into consideration the intangible costs such as pain, suffering stress and discomfort. The avertive behaviour approach takes into account all costs incurred on precautions taken to reduce direct exposure to pesticides. However, the results presented in this paper have considered only some of the costs of defensive behaviour due to data constraints. The third approach mentioned takes into consideration all the costs including intangible costs such as pain, suffering, stress and discomfort. These are important costs that need to be taken into consideration since those suffering from exposure to pesticides undergo considerable pain, stress, suffering and discomfort. The contingent valuation approach, unlike the other two approaches, involves asking the respondents the value to them of avoiding direct exposure to pesticides and the resulting illnesses. A respondent in giving a bid to avoid exposure to pesticides would take into account the costs of ill health, precautions taken to reduce direct exposure to pesticides, as well as all the intangible costs. Hence, the contingent valuation estimates are upper bounds while the cost of illness and the avertive/defensive approaches are lower bounds. For a detailed discussion on the three techniques used, see Wilson (1998).

Using these three techniques (Wilson, 1998) has estimated the private costs of direct exposure to pesticides in Sri Lanka. As the estimates from the three approaches used in the field study show, costs arising from direct exposure to pesticides are very high. The cost of

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[39] An illness is described as serious where the respondent was hospitalized, a moderate illness is where the respondent takes treatment from a physician but was not hospitalized and the mild case is where a respondent was neither hospitalized nor sought treatment, but took home made self-treatment and incurred other private costs.

[40] Although medical examination and treatment is free in Sri Lanka certain prescriptions may have to be purchased from a pharmacy and laboratory tests may have to be conducted in a private clinic. Furthermore, some farmers also seek treatment from private clinics.

[41] For a discussion on some of the economic costs of human pesticide poisonings in the USA, see Pimentel et al. (1992, 1993).

illness approach estimates that a farmer on average incurs a cost of around 5,465 Rs[42] a year or about a months income from direct exposure to pesticides. The avertive/defensive behaviour approach estimates the costs to be around 405 Rs a year or about 12% of a monthly income of an average farmer per year. The contingent valuation estimates, as expected, give a higher figure of 11,471 Rs or a cost of more than two and a half months income a year due to ill health resulting from direct exposure to pesticides. The contingent valuation estimates are large, because as mentioned earlier, respondents who give bids take into consideration all costs including tangible costs of ill health (both direct and indirect), avertive/defensive behaviour costs and the intangible costs. Cost scenarios estimated for the entire country using data from the three approaches run into millions of rupees each year as shown in Wilson (1998). The private costs arising from direct exposure to pesticides is all the more significant when farmers' incomes vary a great deal due to adverse weather conditions, crop price fluctuations, pests and disease attacks, damage caused by wild animals, etc. All these costs, while affecting the farmers, as well as the welfare of their families, also reflect the extent of the severity of the problem of pesticide pollution affecting those around agricultural land, other production processes, wildlife and the environment in general.

6. CONCLUSIONS

It is clear from the above discussion that the present agricultural practices, despite producing record yields using large quantities of chemical inputs are unsustainable and diametrically at odds with the definition of sustainable development espoused by the World Commission on Environment and Development (WCED). The Commission defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p.43). Current production practices are not only unsustainable, but also, as the high costs demonstrated, may well be a factor in explaining poverty (low incomes) among farmers, despite adequate food being produced all year around. This is due to the high costs that have arisen in terms of human and natural capital costs and the increased use of input costs due to pollution. The numerous health effects result in medical, as well as time costs both in the short and in the long-term. Wasting of human health also reduces the ability to work on farms. The precautions taken to avoid exposure to pesticides, though inadequate, also incur costs. Agricultural pollution also affects natural capital in the form of decimation of natural predators of pests (through the use of pesticides), increase in the proliferation of pests (due to decimation of natural predators/high usage of nitrogenous fertilizer), soil fertility decline (brought about due to continuous chemical use), thus affecting agricultural productivity. As a result of declining agricultural productivity and due to proliferation of pests and diseases, larger quantities of chemical inputs have to be used in the production process, not only thus increasing the level of pollution on the agricultural lands but also increasing the costs of input use. Furthermore, agricultural pollution affects other production processes, such as fisheries (which farmers engage in on a part time basis) thus depriving them of an additional/alternative source of income. Therefore, in conclusion, it can be said that the private and external costs resulting from agricultural pollution have not only made resource allocation inefficient, but as the available evidence suggests, the current agricultural practices are unsustainable, both in the short-term and in the long-term.

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[42]The exchange rate prevalent during the study period (June-September, 1996) was 1A$ = 37 Rs

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Appendix 1:

Hospital Admissions and Deaths Due to Pesticide Poisoning in Sri Lanka 1975-1996

Year	Total Pesticide Deaths	Total Pesticide Admissions	Deaths Per 100,000 Population	Rank Order[43]
1975	938	14,653	-	-
1976	964	13,778	-	-
1977	938	15,591	-	-
1978	1029	15,504	-	-
1979	1045	11,372	-	-
1980	1112	11,811	-	-
1981	1205	12,308	-	-
1982	1376	15,480	-	-
1983	1521	16,649	-	-
1984	1459	16,085	-	7th
1985	1439	14,423	-	4th
1986	1452	14,413	-	6th
1987	1435	12,841	8.8	6th
1988	1524	12,997	9.2	6th
1989	1296	12,763	7.7	6th
1990	1275	10,783	8.8	6th
1991	1667	13,837	11.3	4th
1992	1698	15,636	-	4th
1993	1682	16,692	9.5	5th
1994	1421	14,979	8.1	5th
1995	1581	15,740	9.5	6th
1996	1850	21,129	-	6th

Source: National Poisons Information Centre, General Hospital, Colombo, Sri Lanka, 1997.

[43] Rank order shows the leading causes of deaths in the country. As the rank order shows, pesticide poisonings is a major cause of death in Sri Lanka.