HEALTH EXTERNALITIES AND PESTICIDE USE IN THE ATLANTIC ZONE OF COSTA RICA: AN ECONOMIC EVALUATION

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Abstract

This paper represents a first step towards analyzing the extent of pesticide-related health externalities in the Atlantic Zone of Costa Rica. To assess the costs associated with health damage due to pesticide exposure, data obtained from Costa Rica's National Insurance Institute and the Pesticide Program of the Universidad Nacional on occupational pesticide intoxication of wage laborers in the counties Guácimo and Pococí in 1993 were linked to corresponding cost data from the National Insurance Institute. Health damage costs associated with pesticide use as calculated in this study included compensation payments to the victims for temporary disability and medical treatment costs. The results obtained for wage laborers were extrapolated to independent smallholder farmers by linking them to data regarding input use for cassava, plantain, palm heart, and maize. Most documented intoxication cases occurred in banana plantations where pesticide use (particularly fungicides) is very high. However, health costs associated with acute occupational pesticide intoxication constituted a negligible part of total production costs. Extensive research regarding optimal input levels ensures that levels of pesticide application in banana cultivation do not exceed economic thresholds. Moreover, safety measures for some pesticides have considerably improved in many banana plantations. On the other hand, long-term health effects, possibly resulting in reductions in future productivity of the victims, could not be taken into account. Costs of acute intoxications for the victims' families, in terms of care provided to the victims and human suffering, were not calculated either. In smallholder agriculture, health externalities may be quite significant and were particularly large for paraquat

in the cultivation of palm heart where they were valued at up to 35% of the cost of the pesticide itself. The feasibility and optimal level of a pesticide tax which depends on the toxicity level should be investigated. Besides further economizing quantities applied and inducing substitution towards less toxic chemicals, such a tax may generate revenues that could be used for the further development and dissemination of safety practices and research on alternative pest and disease control in both plantation and smallholder agriculture.

Keywords: Atlantic Zone, banana, Costa Rica, economic assessment, health, pesticide, smallholder

1. Introduction

Even though pesticides[1] are widely regarded as an indispensible ingredient of modern agriculture in both developed and developing countries, their use has become increasingly controversial in the light of increasing awareness of undesired side effects. For developing countries, such effects have been analyzed in terms of adverse health implications for both producer (Jeyaratnam, 1990; Antle and Pingali, 1994) and consumer (Seitz, 1994); elimination of natural predators and other beneficial organisms (Brader, 1979); groundwater contamination as a result of leaching (Pluimers, 1995); and soil contamination resulting from the accumulation of pesticide residues (Thrupp, 1991a). For developed countries, Pimentel et al. (1993b) claim that it should be possible to reduce pesticide use in the United States (U.S.) by 50% without significant changes in neither crop yields nor cosmetic appearance. At the same time, the estimated increase in food costs would be a paltry 1.5%. Pimentel et al. (1993a) estimate that the environmental and social costs of pesticide use in the U.S. amount to approximately $\$8.1 \times 10^9$ yr^{-1}, or about twice the annual cost of $\$4.1 \times 10^9$ of pesticide treatments themselves. A different view is the one held by Stroup (1991) who presents evidence from the U.S. to show that the use of chemicals in general (i.e., including both pesticides and chemical fertilizers) has significantly contributed to higher standards of living and healthier lives. Stroup's results suggest that the positive impacts of environmental and health regulations may be outweighed by the damage to health and safety that they cause by reducing income growth.

Compared to many other countries, the use of pesticides in Costa Rica is high. Yearly

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[1] In this paper, the term pesticides is used in a wide sense and includes insecticides, nematocides, herbicides and fungicides, but excludes disinfectants.

per capita use of pesticides in Costa Rica amounts to about 4 kg active ingredients (a.i.), compared to 2.1 and 0.6 kg a.i. in Central America and the rest of the world, respectively (Wesseling et al., 1993). On a per hectare (ha) of cultivated arable land basis, annual use is estimated at 19 kg (6 kg on an a.i. basis; von Düszeln, 1990), or nearly double that in Japan (Castillo et al., 1997) though only about one-third to one-fourth of the average use in the highly intensive agriculture practiced in the Netherlands (Reus and Pak, 1993; Verhoeven et al., 1994). Trivelato and Wesseling (1992) note that, according to the toxicity classification of the World Health Organization (WHO, 1992), 23% of the total quantity of pesticides imported into Costa Rica between 1985 and 1989 is classified as 1a or 1b (i.e., highly dangerous; this percentage decreased to 18 in 1993 (Agne, 1996)), while 30% is included in the United Nations Environmental Program's list of banned, cancelled, severely restricted, or never registered pesticides. Even though, by 1993, the first percentage had declined to 18, Costa Rica's pesticide imports increased by nearly 50% in value terms between 1990 and 1994 (Agne, 1996), following a similar increase between 1985 and 1990 (Seitz, 1994). In volume terms between 1989 and 1993, pesticide imports increased from 8.9 to 12.5×10^6 units (kg + 1 a.i.), valued at some US dollar ($) 78×10^6 (Bernal et al., 1995; Castillo et al., 1997). Over 40% of these imports consists of fungicides (Castillo et al., 1997).

Despite large variation across regions, between crops, and among individual farmers, between 70% and 100% of farmers in Costa Rica rely exclusively on pesticides to control weeds, pests and diseases (Castillo et al., 1989). In the 1980 decade, about 35% of total pesticide imports (in value terms) in Costa Rica was used in banana cultivation where pesticide use amounts to some 45 kg a.i. ha^{-1} yr^{-1} (von Düszeln, 1988; Castillo et al., 1997)[2]. By 1991, this percentage had increased to 50 (García, 1993), rising further to 57 by 1993 (Bernal et al., 1995), largely as a result of an increase in banana area, from $21x10^3$ ha in 1987 (Sanchez and Barrientos, 1992) to $49x10^3$ ha in 1993 (Barrientos and Páez, 1994) and increasing quantities used. Besides banana, vegetables and non-traditional crops (especially ornamental plants and flowers) are also heavy users of pesticides (Agne, 1996). Banana plantation laborers and other agricultural laborers are often considered high-risk groups in terms of the probability of suffering health damage. Compared to Costa Rica as a whole, the yearly incidence of occupational pesticide poisoning among agricultural laborers is significantly higher in the Atlantic Zone (Wesseling et al., 1993) which region is responsible for 95% of Costa Rican banana production (CORBANA, 1994). The province of Limón (which constitutes the larger part of the Atlantic Zone) was responsible for nearly 50% of all pesticide intoxication cases in 1995 (Anonymous, 1996).

This paper concentrates on the quantitative measurement of the economic costs of pesticide-related health damage suffered by wage laborers and independent smallholder farmers in the Atlantic Zone of Costa Rica during 1993. The economic costs considered in this study include foregone earnings resulting from temporary disability after intoxication, as well as the costs associated with medical treatment.

2. Pesticide use and health damage

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[2] From data in Castillo et al. (1997) one can calculate that banana is responsible for some 20% of total pesticide use in Costa Rica in volume terms (a.i.).

The type of health damage suffered by an intoxicated laborer depends, among others, on the pesticide involved and the specific circumstances under which the exposure took place. In banana, for example, symptoms contracted in the packing plant after applying fungicides (needed to conserve the bananas during transport) consist mainly of contact and allergic dermatitis at the hands and feet, often complicated with mould infections. Aerial spraying of pesticides (mainly fungicides to combat the fungus Mycosphaerella fijiensis, also known as Black Sigatoka) may cause contact and allergic dermatitis and eye problems to plantation laborers on the ground. The herbicide paraquat is often implicated with eye problems and chemical burns at the hands, feet, back and genital area (van Wendel de Joode et al., 1996). Exposure to nematocides may result in systemic poisoning of varying degree of severity. Equipment of insufficient quality as well as inadequate safety and control measures might increase the risk of adverse health effects from pesticides. For example, leaking backpack sprayers are often associated with chemical burns by paraquat. Even though legislation in the areas of occupational use of pesticides and protection of laborers does exist in Costa Rica, its implementation leaves to be desired (Trupp, 1988; Wesseling, 1994; Agne, 1996). In smallholder agriculture, even though some education regarding the safe use of pesticides has been provided by the government, since the beginning of the program in 1986 through 1993, less than 10% of the agricultural work force has been reached (Agne, 1996).

3. Registration

Occupational accidents and diseases of wage laborers have to be reported by the employer to the National Insurance Institute (INS) which is responsible for coverage of medical treatment costs

(costs of medicines and doctor fees) as well as payment of 75% of the laborers' regular wage during the time of disability. Occupational health damage increases production costs since employers are obliged to pay for accident insurance to the INS. Thus, in addition to the input price of the chemicals used, equipment costs, and labor costs for application, the costs of pesticide use include insurance premiums to the INS. Even though such insurance covers the costs associated with any kind of occupational illness (including, e.g., traumas which usually result in considerably longer disability and correspondingly higher costs compared to accidental pesticide poisonings), it can be reasonably assumed that the part of the premiums paid to the INS to cover pesticide intoxication risk is, on the average and in the aggregate, roughly equal to medical treatment costs and disability payments associated with such intoxication.

4. Methodology

4.1. Study area

The study area consists of the counties of Guácimo and Pococí located in the Atlantic Zone of Costa Rica (Fig. 1). The agricultural sector of the Atlantic Zone is dominated by the cultivation of banana (over 50,000 ha in 1994, or about 20% of the total agricultural area). Other important crops include palm heart, cassava, plantain, ornamental plants, and maize (Table 1). Banana and ornamental plants are mainly grown by agricultural enterprises that employ wage laborers. Maize, cassava and plantain are typical smallholder crops, while palm heart is cultivated both in plantations and by small and medium-scale farmers (Jansen et al., 1996).

Banana plantations are mostly owned by transnational corporations or large nationally-owned companies. These corporations and companies are responsible for about 95% of banana exports. Virtually the entire banana area in Costa Rica is found in the Atlantic Zone, with about 35% located in the counties Guácimo and Pococí (Stoorvogel and Eppink, 1995).

4.2. Data

The data used in this study to assess the degree and corresponding costs of health damage resulting from acute intoxication with pesticides originated in the INS and refer to the year 1993. The Pesticide Program of the Universidad Nacional (PPUNA) had used the INS data to construct a database containing information regarding the types of pesticides involved and the specific circumstances under which each intoxication took place for wage laborers in Guácimo and Pococí. This information was linked to data bases from the INS containing information on medical costs and disability payments to wage laborers. No data exist regarding pesticide intoxication in smallholder agriculture since independent small and medium-scale farmers are not normally insured.

Plantation owners in Costa Rica generally oblige with the legal requirement to report occupational accidents to the INS. Thus, even though no information is available regarding companies' medical services (which theoretically could cause underreporting), these are not widespread, and it can therefore be safely assumed that the PPUNA data on the number of acute intoxications with pesticides which affected wage laborers in Guácimo and Pococí in 1993 are rather accurate. On the other hand, severe or fatal cases of intoxication are directly transferred to medical institutions in the capital city of San José (Wesseling, 1994). Since such cases do not get reported to the INS in Guápiles, they are not included in this study.

4.3. Economic assessment of health damage

To obtain a picture of health externality costs associated with pesticide use by small and medium-scale farmers who are not wage earners, the results obtained for wage laborers were extrapolated by assuming that health damage and its associated costs asymptotically approach a maximum with increasing levels of pesticide use. It is assumed that each case of intoxication can be traced back to one chemical, i.e., no attention is paid to the notoriously difficult problem of separating the effects of individual chemicals under conditions of multiple-chemical use (Loewenson, 1995). Keeping the number of laborers engaged in the application of a pesticide constant, increasing levels of pesticide can be expected to harm an increasingly large number of laborers. Assuming that laborers are not at risk to die, health costs will tend to a maximum at some extreme level of pesticide application at which all laborers will become incapacitated. This relationship is depicted in Fig. 2 and can be mathematically described as follows:

$$C^T = C^{max}(1-e^{-\alpha X}) \qquad (1)$$

where

X refers to the total quantity of pesticide applied

C^T refers to the total health costs associated with X

C^{max} refers to the maximum health costs

To calculate α, which reflects the change in health costs following an increase in the quantity of pesticides applied, data would be needed on total health costs, maximum health costs, and the quantity of pesticides applied. However, the fact that maximum health costs are unknown precludes the calculation of a unique value for α. A solution is found by linking costs to percentages lost working hours as a result of pesticide intoxication through the conversion of equation (1) into the following format:

$$LH^{T} = LH^{max}(1-e^{-\alpha X}) \qquad (2)$$

where

LH^T represents the total lost working hours per ha as a percentage of total working hours per ha involved with the application of a specific pesticide

LH^{max} equals the maximum possible percentage lost working hours per ha (i.e., 100) and corresponds to the maximum costs

X represents the total quantity of pesticide applied

Given values for LH^T and X, α can be calculated as follows:

$$\alpha = -[\ln(1-\frac{LH^{T}}{100})]*X^{-1} \qquad (3)$$

Data on costs due to occupational intoxication and associated health costs in banana for the counties Guácimo and Pococí were used to calculate α from equation (3). Even though this procedure is based on only one year of observations and ignores the possible influence of safety practices which may vary according to the quantity of pesticides applied, it allows a clearcut quantification of the relationship between pesticide use and health damage.

Given α calculated from equation (3), and assuming that the health effects of pesticide use do not differ by crop, equation (3) may be applied to other crops as well provided that similar pesticides are applied. On the other hand, health effects may differ with different production- and pesticide application practices. Banana is cultivated in plantations that are mostly owned by large corporations, with safety practices relatively well developed in 1993 for extremely toxic cholinesterase inhibiting nematocides. Small and medium-scale farmers often lack education and information, not only regarding optimal input levels but also regarding safety practices regarding pesticide use. On the other hand, as of 1993 many banana companies had not implemented safety measures for paraquat and fungicides.

4.4. Validity

Total health costs as calculated in this study reflect a lower bound of the "true" (but unknown) total pesticide-related health costs, for at least six reasons. First, only occupational intoxications (resulting directly from pesticide application) are considered. That is, non-occupational (i.e., accidental, suicidal and homicidal) cases as well as the possibility of intoxication outside the production process (e.g., in consumption; see Kramer, 1990) are discarded. Second, no data were available regarding chronic intoxications (possibly causing such long-term effects as cancer and sterilization; Thrupp, 1991b; Wesseling et al., 1996) as these cannot be traced back to particular events. Thus, possible reductions in future productivity of the victims were not taken into account. Data limitations (particularly the lack of longitudal data regarding production levels and input use) also preclude a full-scale analysis of health and productivity trade-offs involved with the use of pesticides, as in Antle and Pingali (1994). Third, costs that are impossible to value economically, such as human suffering of the intoxicated laborer and dependents, are disregarded as well. Fourth, no data were available regarding financial losses due to inability of carrying out secondary economic activities. Sixth, there may have occurred cases of occupational pesticide intoxication that, for whatever reason, never got reported and consequently did not receive medical treatment. Finally, negative production effects as a result of wage laborers being temporarily disabled are assumed absent; the structure of the labor market in the Atlantic Zone of Costa Rica is such that no significant costs are to be made to replace temporarily disabled laborers.

5. Results

5.1. Incidence of occupational intoxication with pesticides

In 1993, a total of 602 cases of intoxications of agricultural laborers involving pesticides was reported for the two counties (Table 2). Of these, 86% took place at banana plantations, while the remaining cases (14%) took place at farm enterprises that employ wage laborers in the cultivation of palm heart, ornamental plants, or other crops (mainly pineapple). These trends were still present in 1995 (Anonymous, 1996) even though, on the basis of 1996 data presented in van Wendel de Joode and Wesseling (1997), one may expect that the absolute number of cases had decreased. According to unpublished data of the National Banana Corporation (CORBANA), in 1993 some 11.5×10^3 laborers were engaged in the cultivation of banana in the counties Guácimo and Pococí. Hence, the incidence of pesticide intoxication in banana plantations in 1993 was just under 5%.

In banana plantations, herbicides (particularly the widely used paraquat) were implicated in over 30% of all cases of intoxication. Fungicides and insecticides-nematocides (mostly nematocides) were associated with respectively 30 and 16% of all cases of intoxication. In 9% of all cases, data regarding the specific type of pesticide involved was lacking.

5.2. Compensation costs for temporary disability

In case an intoxicated laborer is temporarily disabled, the daily amount paid out by the INS in 1993 varied between $6 and $8, depending on the type of work the victim was engaged in. Table 3 shows that, in case of an ocupational intoxication, both duration and cost of temporary disability depended on the type of pesticide involved and on the circumstances under which the intoxication took place. For example, intoxication with insecticides or nematocides caused a temporary disability of, on the average, 5.5 days. However, intoxication with paraquat caused a much longer disability period of 9.5 days on the average. None of the cases of intoxication included in the data base used in this study led to permanent disability.

5.3. Medical treatment costs

Medical treatment costs consist of doctor's fees and costs of medical products needed for treatment (Table 4). While intoxications with thiabendazole (causing allergic or contact dermatitis with mould infections at the hands) or paraquat (resulting in burns and problems with nails and eyes) required relatively expensive medication and usually more than one doctor visit, treatment costs of poisonings caused by insecticides-nematocides were lower since the poisonings included in this series were relatively mild and symptoms usually did not last long. Moreover, the medical products involved are rather basic and therefore relatively cheap.

5.4. Total health costs of occupational pesticide exposure

On a per case basis, total health costs of occupational pesticide exposure, defined as the sum of disability payments and medical treatment costs, were highest for paraquat, followed by the costs of intoxications which took place during aerial application of fungicides or which involved thiabendazole (Table 5). Health costs of the intoxications with other fungicides or with insecticides-nematocides seemed much lower.

Paraquat was the most frequently reported chemical in these occupational pesticide accidents. Combined with its high total health costs on a per case basis (Table 5), this resulted in paraquat accounting for over 40% of total pesticide-related health damage costs in banana cultivation. The relatively frequent intoxications with insecticides-nematocides caused these products to be responsible for a significant share (13%) of total health costs in banana cultivation, despite their relatively low cost on a per case basis. The much lower intoxication frequency during aerial application of fungicides made that the latter accounted for a rather small part (7%) of total health costs in banana cultivation, despite relatively high costs per intoxication case.

While the average costs per case of intoxication for ornamental plants were relatively low compared to other crops (Table 5), total costs per ha were nearly double those for banana (Table 6), largely reflecting a higher number of pesticide intoxications per ha in ornamental plants compared to banana (Table 2). This is mainly due to the much higher number of workers per ha in ornamental plants compared to banana. Nevertheless, compared to total input costs and crop value, health externalities (as measured in this study) resulting from pesticide use in plantation agriculture in the Atlantic Zone of Costa Rica in 1993, at a maximum of just over \$5 ha^{-1} yr^{-1}, can be considered as low.

5.5. Relationships between quantity of pesticide applied and health costs in banana cultivation

In order to quantify the relationship between quantities of pesticides applied and health damage as expressed through lost working hours, α was calculated from equation (3) with data for banana. This was done for fungicides (applied by air), nematocides, and paraquat, since only for these types of pesticides a complete set of information was available. Data on working hours per ha involved with the application of each of the three types of pesticides are given in Table 7. To calculate the values for LH^T in Table 8, total lost working hours per ha for each type of pesticide (defined as the number of cases of intoxication times the average number of days of disability times eight hours) were derived from the data in Table 3, and combined with the data in Table 7.

Besides time spent on preparation of the aircraft and actual flying time, the yearly labor input required for the application of fungicides by air involves mainly flagging and was calculated at about 3 hours ha^{-1} yr^{-1} (Table 7). At 0.13 hours ha^{-1} yr^{-1}, lost hours constituted only a small part (4.3%) of total labor used in fungicide application, with correspondingly low health costs (Table 8). With a yearly fungicide use of some 24 kg a.i. ha^{-1}, α assumed a value of $1.8x10^{-3}$, implying that, e.g., a doubling in the quantity of fungicide applied (to 48 kg a.i. ha^{-1} yr^{-1}) would result in a LH^T value of 8.3%, corresponding to a still low health damage cost of \$0.50 ha^{-1} yr^{-1}.

For nematocides, based on a total of 7.5 hours ha^{-1} yr^{-1} needed for their application and an average yearly application of 16 kg a.i. ha^{-1}, an α of $2x10^{-3}$ was obtained. Average lost labor, even though double that for fungicides, was still low at 0.25 hours ha^{-1} yr^{-1}. Health costs were limited to \$0.42 ha^{-1} yr^{-1} (Table 8).

In 1993 in banana plantations, paraquat was applied at a rate of about 3 l ha^{-1} yr^{-1}, requiring about 20 hours of labor input (Table 8). Based on these data, a α of $13x10^{-3}$ was calculated. Nearly one hour of labor ha^{-1} yr^{-1} was lost in the application of paraquat, costing \$1.11. Compared with input costs of \$12 ha^{-1} yr^{-1} for paraquat, these health costs were considerable.

5.6. Health costs associated with the use of pesticides in other crops

The estimated α for fungicides calculated for banana could not be extrapolated to plantain, cassava, maize and palm heart, since in these crops fungicides are not applied by air. Regarding nematocides, even though different types (with different amounts of active ingredients) are used in banana and in other crops, no distinction was made between the different types of nematocides. This is justified since different types of nematocides mainly belong to the same toxicity class as identified by WHO and consequently can be expected to cause similar health effects. Paraquat is commonly used in different crops and the application of this herbicide is similar among different crops. Moreover, relatively few other herbicides were used.

Consequently, for paraquat and nematocides, values for α calculated for banana were combined with data regarding prevailing pesticide practices of small- and medium-scale farmers (Table 7), to obtain an indication of the health costs of these pesticides when used in smallholder agriculture. Whereas estimated health costs associated with the use of pesticides in maize, cassava and plantain were lower than those in banana plantations, potential health damage due to occupational pesticide intoxication in the cultivation of palm heart were substantial (Table 9). Health costs associated with pesticide use in plantain were probably underestimated due to the fact that the negative health effects of fungicides were not calculated. Total potential health damage associated with the use of paraquat in palm heart was valued at over \$11 ha^{-1} yr^{-1}, accounting for 35 and 7% of pesticide costs and total production costs, respectively.

6. Discussion and conclusions

For an enlightened discussion regarding the pros and cons of pesticides, adequate quantification of the various costs and benefits associated with their use is needed. This study has attempted to contribute information to the pesticide debate by quantifying part of the human health costs that result from occupational hazards in the application of pesticides in the Atlantic Zone of Costa Rica. The use of pesticides in the Atlantic Zone is widespread, and externalities are widely believed to prevail in terms of negative effects on human health. In farm enterprises that employ wage laborers, these external costs are (partially) internalized through insurance premiums to the INS which provides health insurance and coverage of the risk of laborers losing income due to occupational accidents. However, independent smallholder farmers, who are usually not insured by the INS, do not include health damage costs in their private production cost calculations. As a result, such costs are not taken into account in their decisions regarding levels of production and corresponding inputs. Given the lack of knowledge among smallholders regarding safe use of pesticides, and the general absence of measures that effectively avert exposure, the "true" marginal costs of pesticide use in the smallholder sector are nearly certainly underestimated, and actual pesticide use levels likely exceed socially optimal levels.

Even though benefits of pesticide use are difficult to measure in economic terms (Agne et al., 1995), quantities applied as found in most farm-level studies are such that the marginal productivity of pesticides exceeds their marginal costs (Crissman et al., 1994). In banana cultivation, the productivity increasing effect of pesticides can be considered as large; indeed, in the case of fungicides, despite their documented declining marginal productivity over time due to increasing resistance (Agne, 1996), their application can even be considered a sine qua non since in the absence of fungicides the Black Sigatoka fungus would virtually eliminate all export production. In view of the considerable amount of research on banana cultivation that is continuously being carried out, both by individual companies and by the government-owned CORBANA, prevailing input practices (in terms of pesticide use), even if perhaps not sustainable in the long run (Castillo, 1995), can be expected to assure that the production of banana takes place close to the technical efficiency frontier. Compared to the immediate benefits, health costs (as measured in this study) associated with occupational pesticide intoxication in banana plantations in the Atlantic Zone are low for the producer and do not act as an incentive to change current input strategies. As a percentage of total production costs, occupational health damage costs in banana cultivation seem negligible, while as a percentage of the input cost of the pesticide only health costs associated with the use of paraquat are significant.

For other crops (i.e., cassava, plantain, maize, and palm heart) that are widely grown under smallholder conditions in the Atlantic Zone, health costs were estimated through the application of estimated relationships between pesticide use and health costs based on data for banana. The vast area dedicated to banana in the Atlantic Zone, combined with the large quantities of fungicides used, make that the total amount of pesticides used in banana cultivation far exceeds the quantities used for any other crop in the region. On the other hand, on a per ha basis, the use of pesticides other than fungicides in banana is not always higher than in smallholders' fields of, e.g., plantain or palm heart. Indeed, the contrary seems to be the case for paraquat; as a result of shading in banana plantations, the absolute quantity of paraquat used on a unit area basis is lower than in palm heart, resulting in lower per ha absolute health costs. Because of larger quantities of active ingredients applied, health damage costs of pesticide use might be quite substantial in the cultivation of particularly palm heart. Moreover, in the case of plantain, since most small- and medium-scale farmers lack safety gear and adequate knowledge regarding the application of nematocides, it can be reasonably assumed that, at a given application level, they are more likely to get intoxicated than laborers in banana plantations. To assess the effect of the virtual absence of safety measures in the smallholder sector, a new set of values for LH^T was calculated for small- and medium-scale farmers (Table 10). In the case of nematocides, new calculations were performed on the basis of twice the actual nematocide input levels listed in Table 7. The situation with paraquat differs significantly from that regarding nematocides; as of 1993, safety measures had been implemented on only relatively few banana plantations. Consequently, new values for LH^T for small- and medium-scale farmers in the case of paraquat were calculated on the basis of 1.5 times the actual paraquat input levels listed in Table 7. The results indicated that, once the effect of a lack of safety measures in the smallholder sector is taken into account, health costs associated with the use of paraquat and nematocides in plantain were still relatively low at close to 4% of pesticide costs (Table 10). In palm heart, however, health damage associated with the use of paraquat alone raised the cost of pesticide use by 50%. Moreover, if the findings of Andreonni (1986), pointing to off-site costs of occupational accidents and diseases that are about four times as high the costs of medical treatment costs and lost labor time, apply to pesticide intoxications as well, the total social costs of paraquat (i.e., costs associated with occupational intoxication as well as off-site costs) in palm heart may be as large as 2.5 times the costs of the herbicide itself.

The finding that health externalities (as measured in this study) associated with the use of pesticides in banana cultivation the Atlantic Zone of Costa Rica were small does not mean that health damage is unimportant. Even though, from an economic point of view, pesticide use in banana plantations may be less excessive than is often claimed, i.e., quantities applied may be such that marginal benefits in the production process are relatively close to the sum of the pesticide price plus the marginal health cost (Antle and Capalbo, 1994), the latter were certainly underestimated in this study since neither long-term negative health effects nor other social costs could not be taken into account. That is, the "true" marginal costs of pesticides in banana cultivation nearly certainly exceed the sum of the pesticide price and occupational health damage costs, even if it is unknown by how much. Thus, in this sense there may exist a case for lowering pesticide use in banana cultivation, despite its potential implications for income, employment and foreign exchange earnings. Furthermore, even though it cannot be valued economically, personal suffering reduces the quality of life and is not socially desirable. Moreover, a clean environment and a healthy population is of importance for society as a whole and should therefore be protected. If there are no private incentives to do so, there is a task for the government. However, current legislation and government budgets only allow for limited control on the application of pesticides. In extreme cases, certain highly toxic pesticides may be banned completely. An alternative policy suggestion resulting from the negligible occupational health cost but large production effect of pesticides in banana cultivation may consist of a pesticide tax, revenues of which could be used for the further development of safety practices, new legislation, and enforcement of existing legislation, as well as for research on alternative pest and disease control practices. In addition, information campaigns aimed at improvements in knowledge of workers may effect positive changes in health (Loewenson, 1995). It has been shown elsewhere (Jansen et al., 1997) that a pesticide tax would be most efficient if its level would directly depend on the degree of toxicity of the pesticides involved. In this way the herbicide paraquat, responsible for the largest part of intoxications still in 1995 (Anonymous, 1996), would be taxed considerably, presumably resulting in its substitution for either another, less toxic though currently more expensive herbicide such as glyphosate, or manual weed control. Given evidence from other countries suggesting that particularly large farmers may be heavily opposed to taxing pesticides (Smith and Martin, 1992), an alternative may consist of raising insurance premiums above the level needed to pay for expected health damage that results from occupational intoxication. The immediate problem with both policy measures is that the optimal level of intervention will remain unknown until reliable estimates regarding the costs of long-term health damage of pesticide use become available. For the case of a pesticide tax there exists some research evidence that, unless the tax levied is very high, its effect on technology choice in general, and quantities of pesticides used in particular, may be quite limited in the Atlantic Zone of Costa Rica (Jansen et al., 1997).

On the basis of the results generated by this study regarding the relative magnitudes of health costs associated with occupational pesticide intoxication in banana cultivation and smallholder agriculture, it can be concluded that government action, financed by revenues from a pesticide tax or excess insurance premiums, should also focus on the smallholder sector where pesticide use can be intensive and indiscriminate, resulting in considerable health damage. Such action may consist of training in pesticide use (only about one-third of Costa Rican farmers has received such training; Castillo et al., 1997), provision of technical services to farmers, and improving the control of legal regulations. These measures become even more relevant given the increasing attention that the various structural adjustment measures give to non-traditional export crops which are typically high users of pesticides (Jansen et al., 1996). On the other hand, management in banana cultivation is undergoing changes. Besides a significant reduction (up to 60%) in the quantity of nematocides applied (Corrales and Salas, 1997), improved safety measures such as closed fumigation chambers have been introduced in several plantations. Similarly, in several banana plantations, the number of herbicide applications decreased with concurrent increases in the use of manual labor for weeding and the use of cover crops. In addition, at least one large banana company no longer uses paraquat and dropped nematocide applications significantly as a result of refining site specific management and sampling methods. As a result, the incidence of pesticide-related occupational injuries in banana plantations in the Atlantic Zoner of Costa Rica showed a significant decrease between 1993 and 1996 (van Wendel de Joode and Wesseling, 1997). Finally, a frequently mentioned argument against the use of the proceeds of a pesticide tax to cover the costs of some sort of pesticide-monitoring institutional body has to do with the potential danger that the functioning of such a body may become too dependent on its source of finance (i.e., the tax). At the same time, however, an obvious alternative to such a tax seems absent as yet.

This study represents a first step in the direction of valuing health damage due to pesticide exposure in Costa Rica. Further research may focus on quantifying production effects of pesticides, analyzing indirect exposure of humans to pesticides (through food contamination or environmental pollution), and economic valuation of such externalities using appropriate techniques. This may result in improved measurement of the social costs associated with pesticide use in Costa Rica.

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Table 1
Area under different crops in the Atlantic Zone and the counties of Pococí and Guácimo

Crop	Pococí	Guácimo	Atlantic Zone
	Area (ha)		
Banana[1)]	13201	5362	52737
Cassava[2)]	552	386	n.a.[3)]
Plantain[1)]	295	55	3234
Palm heart[1)]	1146	599	2189
Maize[2)]	411	501	960
Ornamental plants[1)]	n.a.[3)]	n.a.[3)]	500

[1)] 1994 data.
[2)] 1992 data.
[3)] n.a.=no data available.
Sources: CORBANA (1994); Jansen *et al.* (1996); Murillo and Mora (1996); unpublished data from CNP (National Production Council).

Table 2
Frequency of pesticide-related injuries suffered by wage laborers in the counties Guácimo and Pococí, 1993

Crop	Type of pesticide	Product	Exposure circumstances	Number of cases: Total	Number of cases: Per 100 ha
banana	fungicides	thiabendazole	packing plant	128	0.69
		other fungicides (mancozeb, chlorothalonil, propiconazole)	packing plant	16	0.09
		other fungicides (benomil, mancozeb, chlorothalonil, tridemorph)	aerial spraying	36	0.19
	sub-total			*180*	*0.97*
	insecticides-nematocides	insecticides (mainly chlorpyriphos)	field	14	0.08
		nematocides (terbufos, fenamiphos, carbofuron)	field	81	0.44
	sub-total			*95*	*0.51*
	herbicides	paraquat	field	180[1]	0.97
		other (esp. glyphosate)	field	7	0.04
	sub-total			*187*	*1.01*
	not-further-specified pesticides	unknown	canals	11	0.06
		unknown	unidentified	46	0.25
	sub-total			*57*	*0.31*
total				519	2.80
palm heart	herbicides			11	n.a.[2]
	unidentified pesticides			6	n.a.[2]
total				17	n.a.[2]
ornamental plants	unidentified pesticides			22	4.40
	herbicides			7	1.40
	fungicide	mancozeb		6	1.20
total				35	7.00
other crops	herbicides and fungicides	paraquat, other herbicides, fungicides		31	n.a.[2]
grand total				602	n.a.[2]

[1] The involvement of paraquat was confirmed in 100 cases and considered highly probable in 80 cases
[2] No data available
Source: unpublished data of of the PPUNA and the Research Program on Sustainability in Agriculture (REPOSA - CATIE/WAU/MAG); Table 1; and Wesseling *et al.* (1993).

Table 3
Average duration of disability and disability compensation ($) per intoxication case, by type of pesticide, 1993

Crop	Type of pesticide (no. of cases)	Average duration of disability (days)	Average disability compensation ($)
banana	thiabendazole (128)	7.0	49
	other fungicides in packing plant (16)	4.5	34
	aerial application of fungicides (36)	7.5	61
	insecticides-nematocides (95)	5.5	48
	paraquat (180)	9.5	67
	other herbicides (7)	3.5	23
	pesticides at canals (11)	8.5	69
	unidentified pesticides (46)	4.5	33
	total (519)	7.3	54
palm heart	total (17)	5.5	40
ornamental plants	total (35)	5.5	34
other crops	total (31)	7.5	49

Source: calculated from unpublished data of the INS.

Table 4
Average medical treatment costs per intoxication case in banana plantations

Type of pesticide	Average no. of doctor visits	Total cost of doctor visits ($)	Main symptoms	Estimated costs of medication ($)[1]	Average total cost per intoxication case ($)
thiabendazole	2	26	dermatitis (infected, contact, allergic)	33	59
other fungicides in packing plant	1	13	dermatitis, eye	27	40
aerial application of fungicides	2	26	contact dermatitis, allergy	27	53
insecticides-nematocides	1	13	systemic	14	27
paraquat	2	26	skin and eye burns, nail damage	34	60
other[2]	1	13	various	27	40

[1] Based on interviews with two medical doctors of the INS.
[2] Includes other herbicides, application of pesticides at canals, and cases where neither the type of pesticide nor the circumstances were known.
Source: calculated from unpublished data of the PPUNA and INS.

Table 5
Average total health costs ($) per case of pesticide intoxication suffered by wage laborers, by crop

Crop	Type of pesticide	Disability payment	Medical treatment costs[1]	Total costs
banana	thiabendazole	49	59	108
	other fungicides in packing plant	34	40	74
	aerial application of fungicides	61	53	114
	insecticides-nematocides	48	27	75
	paraquat	67	60	127
	other[2]	38	40	78
palm heart	total	40	40	80
ornamental plants	total	34	40	74
other crops	total	50	40	90

[1] For palm heart, ornamental plants and other crops, the average of the medical costs as calculated for banana was used.

[2] Includes other herbicides, application of unknown pesticides at canals, and cases where neither the type of pesticide nor the circumstances were known.

Table 6
Total health costs associated with pesticide use by wage laborers in the counties Guácimo and Pococí, 1993

Crop	Pesticide	Total costs for Guácimo and Pococí ($10³)	Costs per ha[1] ($)
banana	thiabendazole	13.8	0.74
	other fungicides in packing plant	1.2	0.06
	aerial application of fungicides	4.1	0.22
	insecticides-nematocides	7.1	0.38
	paraquat	22.9	1.23
	other[2]	5.0	0.27
	total	54.1	3.00
palm heart	total	1.4	1.36
ornamental plants	total	2.6	5.18
other crops	total	2.8	n.a.[3]
	grand total	60.0	

[1] Calculated on the basis of area data in Table 1.
[2] Includes other herbicides, application of pesticides at canals, and cases where neither the type of pesticide nor circumstances were known.
[3] No data available.

Table 7
Pesticide application practices in banana plantations and in smallholder production of cassava, plantain, palm heart, and maize in the Atlantic Zone of Costa Rica

Crop	Type of pesticide	Time spent (hours ha^{-1} $application^{-1}$)	Number of applications yr^{-1}	Total time spent (hours ha^{-1} yr^{-1})	Quantity applied ha^{-1} yr^{-1} (active ingredients)
banana	fungicides (application by air)	0.1	32	3	24 kg
	nematocides	2.5	3	7.5	16 kg
	paraquat	1.5	13	20	3 l
cassava	paraquat	1.5	3	5	1.5 l
plantain[1)]	paraquat	5	3	15	4.5 l
	nematocides	3	2	6	11 kg
	fungicides	3	10	30	10 kg
palm heart	paraquat	5	8	40	16 l
maize	paraquat	3	2	6	3 l

[1)] Export quality.
Sources: de Haan and Waaijenberg (1988); Pluimers (1995); unpublished data from CORBANA, Coopepalacios (cooperative of plantain growers), and the Costa Rican Ministry of Agriculture and Livestock (MAG).

Table 8
Lost labor hours and corresponding health costs ($) due to intoxication with pesticides in banana

Type of pesticide	Total labor hours lost yr^{-1} [1)]	Labor hours lost $ha^{-1}\ yr^{-1}$ [2)]	LH^T, or lost hours $ha^{-1}\ yr^{-1}$/ total application hours $ha^{-1}\ yr^{-1}$	Health costs $hour^{-1}$ of lost labor[3)]	Health costs $ha^{-1}\ yr^{-1}$	Health costs as a % of pesticide costs[4)]	Health costs as a % of total production costs[5)]
fungicides (application by air)	2160	0.13	4.3%	1.90	0.25	< 0.1	< 0.1
nematocides	4180	0.25	3.3%	1.70	0.42	0.2	< 0.1
paraquat	13680	0.74	3.7%	1.50	1.11	9.2	< 0.1

[1)] Calculated on the basis of data in Table 3.
[2)] Calculations are based on a banana area of $1.85x10^4$ ha (Table 1).
[3)] Defined as total health costs (Table 6) divided by total lost labor hours.
[4)] Approximate per ha input costs for fungicides, nematocides and paraquat amount to respectively $\$1.2x10^3$, $\$0.2x10^3$ and $12 (source: unpublished data from CORBANA).
[5)] Total production costs for banana amount to about $\$4.5x10^3\ ha^{-1}yr^{-1}$ (source: unpublished data from CORBANA).

Table 10
Lost labor hours and associated health costs when taking account of lack of safety measures in smallholder agriculture

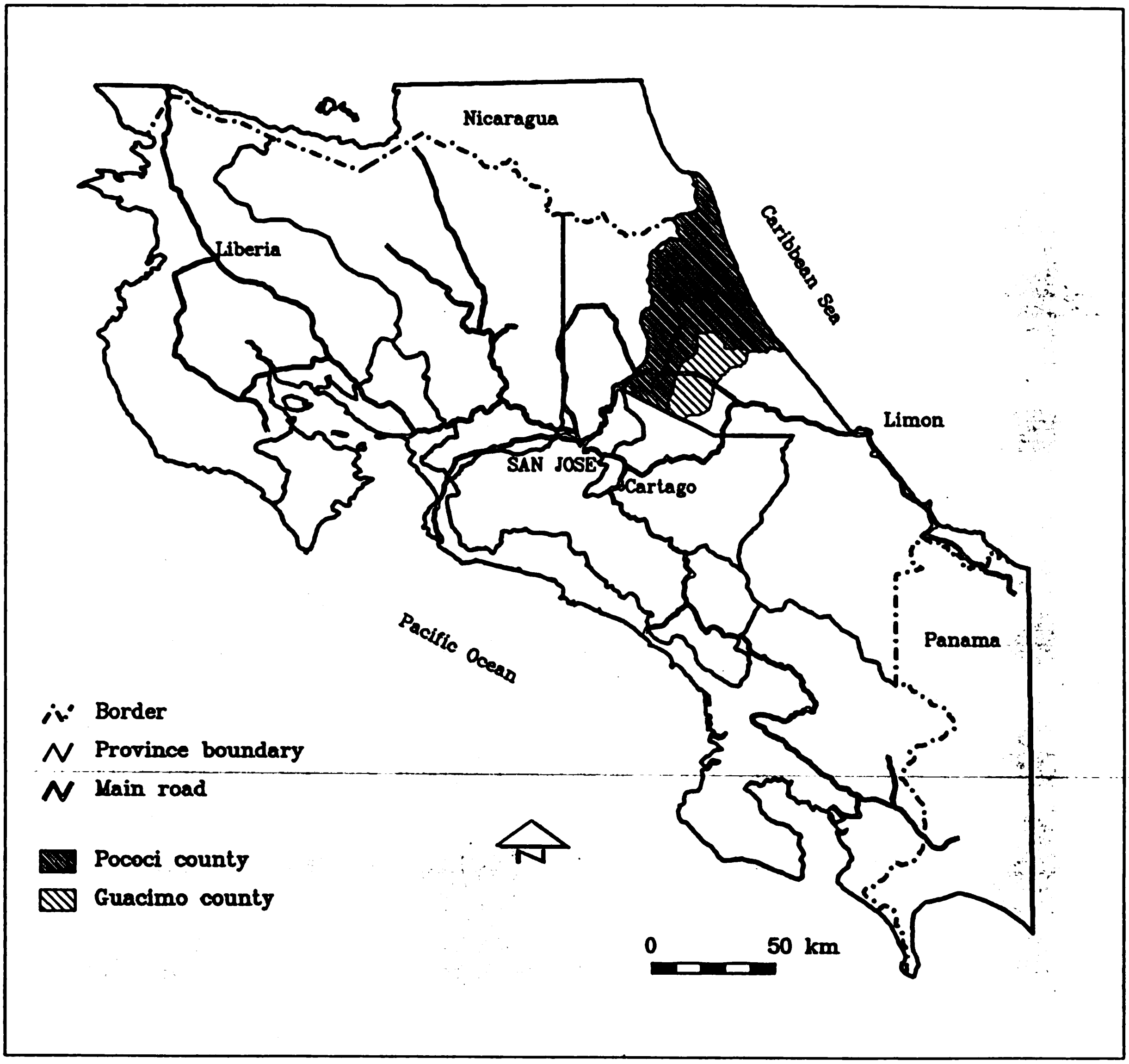
Crop	Pesticide	LH^T (%)[1]	Lost hours ha^{-1} yr^{-1}	Health costs ha^{-1} yr^{-1} ($)	Health costs as a % of pesticide costs	Health costs as a % of total production costs
Cassava	paraquat	2.9	0.15	0.2	1.7	1.3
Plantain	paraquat	8.4	1.3	1.9		
	nematocide	3.9	0.2	0.4		
	total		1.5	2.3	3.3	1.6
Palm heart	paraquat	26.8	10.7	16.1	50.2	10.1
Maize	paraquat	5.7	0.3	0.5	1.5	0.7

[1] Calculated on the basis of twice and 1.5 times the actual quantities of respectively nematocides and paraquat listed in Table 7.

Figure captions:

Fig. 1. Study areas

Fig. 2. Relationship between pesticide use and health costs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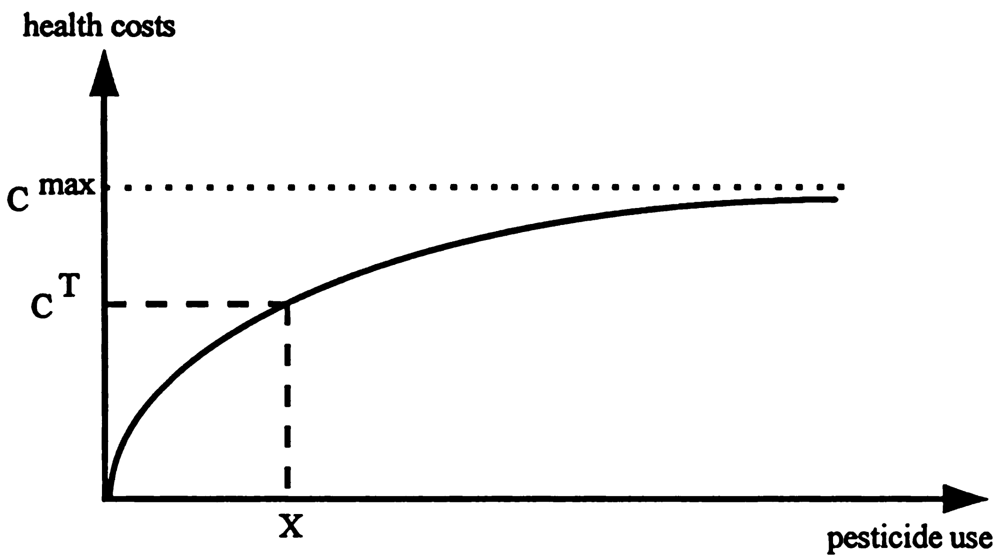
health costs
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pesticide use