Weed control practices on Costa Rican coffee farms: is herbicide use necessary for small-scale producers?

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Introduction

Coffee production has played a strong role in shaping the Costa Rican agricultural landscape and culture since its introduction in the early 1800s (Sick 1999). Beforehand, these producers primarily depended on traditional practices in farm management which were developed over centuries and relied heavily on manual labor. The farm was maintained as an agroforestry system consisting of a dense overstory of diverse tree species – with coffee planted in the understory – and other plants carpeting the ground.

However, since the 1980s, Green Revolution technologies, such as the use of improved seed varieties, chemical fertilizers, irrigation and pesticides, have become widely embedded in the culture of coffee farming in Latin America, Costa Rica included (Rice and Ward 1996; Rice 1999). This was the result of three coinciding factors: the widespread infestation of a fungal rust disease (*Hemileia vastatrix*); the introduction of neoliberal economic policies; and institutional links to bilateral aid agencies, such as the US Agency for International Development (USAID), which launched a regional Coffee Improvement Projectin 1978 to industrialize coffee production (Hernandez Navarro 1995; Rice 1999).

In only 20 to 30 years, traditional practices in farm management on coffee farms were replaced by modern techniques, which included rows of coffee plants fully exposed to sun without an overstory of trees and bare ground between rows of trees. The introduction of Green Revolution technologies, including pesticides, has provided many benefits to producers, such as increased crop yield and quality, reduced need for cultivation, and improved working conditions by reducing manual labor and increasing time for leisure activities and education (Flynn 1992; Tilman 2001; Monaco et al. 2002). In addition, it has been argued that the intensification of agricultural production has “saved” land for other uses such as forest preservation, and has averted the need to brin gmarginal lands into production (Waggoner 1997).

The use of pesticides and fertilizers often leads to a cycle of dependency on agrochemicals; heavier applications of fertilizers and pesticides become necessary over time in order to maintain productivity and control pests (Altieri 1995; Conroy et al. 1996). The application of fertilizers and pesticides also can be problematic because by entering natural ecosystems, the substances may kill wild plants and animals, and disrupt the functions of the former agro-ecosystem (Matson et al. 1997; Pimentel et al. 1992). About 85–90% of pesticides never reach the target pest, and instead move into the air, soil, water and other species other than the pest (Moses et al. 1993). There is also increasing documentation that shows that heavy use of pesticides negatively affects production by contaminating soils, creating resistant pest populations, and inducing illnesses in farm laborers.

Pesticide use and dependence on increasing amounts of pesticides pose problems not only for the health of the local environment, and farmers and their families, but also for the financial viability of the farm. At the same time that costs for chemical inputs have increased, the price offered to farmers for coffee has decreased, creating smaller profit margins, and forcing a number of small-scale farmers to give up coffee production. Small-scale landholders constitute the majority of coffee farmers in Costa Rica; 92% of the coffee farmers in Costa Rica in 2008 owned less than five hectares of coffee, comprising 44% of the total area in coffee production (Icafe 2009). As a result of the historical trend of coffee being grown on small-scale farms in Costa Rica, small-scale farmers have shared with large-scale farmers a relatively prosperous lifestyle with a high standard of living and high levels of human development, leading to a healthy rural economy (Sick 1999). However, the current changes in this dynamic have contributed to the increasing rate of urban migration that is problematic in Costa Rica. In order for coffee production to continue to serve as a source of income for small-scale farmers in Costa Rica, there has to be a change in current mainstream farming practices.

A number of articles have espoused the value of maintaining high numbers of small-scale farms in contrast to high numbers of large-scale, industrial or corporate farms. One of the environmental advantages of small-scale farms is their greater use of labor per hectare, used for example, in manually controlling weeds by chopping (Altieri and Liebman 1988; Labrada 1997; Rosset 1999). As a result of using more labor to manually control weeds, small-scale farmers rely on smaller quantities of pesticides, which function as a substitute for manual control practices (Boyce et al. 1994). Large-scale farmers use fewer laborers per hectare compared to small-scale farmers because they have access to fewer family members to work the farm, and thus rely heavily on hired laborers to work on the coffee farm. For example, a small farm may consist of two hectares, with four family members working on that area, creating a 2:1 worker to area ratio, whereas a large farm may consist of 24 hectares, with eight people hired to work that area, leading to a 1:3 worker to area ratio. A negative consequence of large-scale farmers' utilization of less labor per hectare is that they use larger quantities of chemical inputs as a substitute, because it takes less time to apply pesticides than to manually control pests (Boyce et al. 1994).

On the other hand, it has been demonstrated in other parts of the world and in different types of farming systems that small-scale farmers mis-use and overuse pesticides (Matteson et al. 1993; Palis 1998; Matteson 2000; Bernard and David 2001; Fan 2001; Pontius et al. 2002; Pretty 2005). This literature identifies the following reasons: risk-adversity; ignorance of how to use pesticides appropriately and effectively; and malfunctioning equipment.

Small-scale farmers are also vulnerable to marketing pressures of agro-chemical companies as the result of relatively weak extension-type services from alternative sources such as government agencies and producer associations. Agrochemical companies hire extension workers to maintain regular contact with individual farmers; these employees are motivated by bonuses and other financial incentives as part of a goal of increasing product sales (Schwartz 1994; Davidson et al. 2001), and represent a reliable (if biased) source of specialized information upon which farmers have come to depend (Abeysekera 1988; Ward 1995). This source of biased information represents another cause for farmers' overuse of pesticides.

The current study examined whether small-scale farmers used less herbicides per hectare than large-scale farmers. It was hypothesized that if small-scale farmers used more manual labor per hectare than large-scale farmers to control weed densities, then they would also use less herbicide per hectare overall compared to large-scale farmers. This research focused on weed control for several reasons. In the case of weed control there are well-known and widely used labor-intensive practices that substitute for herbicide application (IFAD 2003). Additionally, small-scale farmers in developing countries spend up to 50% of their time managing weeds – a significant farm management activity (Labrada 1997). Moreover, herbicides compose almost 50% of the pesticide market and are applied to more acreage than any other category of pesticide (NRC 1989).

Because the literature states that in some instances small-scale farmers may be stewards of countryside agriculture, but in other cases may be causing unnecessary adverse impacts through over- and mis-application of pesticides, it was important to examine small-scale Costa Rican coffee farmers' management practices with regards to herbicides to establish if they are overusing herbicides. If small-scale farmers are overusing herbicides, then there would be an opportunity to help them to improve their profit margins and also reduce negative impacts on their health and the surrounding environment by working to reduce or eliminate herbicides. This change could have large impacts because small-scale farmers represent 44% of the land in coffee production. If it is found that small-scale farmers overuse herbicides, then in order to motivate small-scale farmers to change their current practices, it would be important to also identify factors influencing their current rates and patterns of usage. A principle component of the research was to identify how small, large, organic (e.g., those who do not use herbicides or other pesticides, but are not necessarily certified), semi-conventional (e.g., farmers who do not use herbicides, but use other chemicals) and conventional farms compare with respect to herbicide use, type of labor,, amount of labor, and allocation of time to specific weed management activities. It is important to examine differences not only between small- and large-scale conventional producers, but also between small-scale conventional and organic producers. By examining the use of labor, herbicide use, and resulting yields, we could learn whether small-scale conventional producers gain any additional benefits from the use of herbicides compared to their organic counterpart. Further field work investigated the factors influencing weed management on small-scale farms; and measured farmers' experiences with, and opinion of, information services they received from agricultural extension workers.

The paper gives some background on coffee farmers' management practices and reviews different ways of controlling weeds. Sampling areas and interview methods are then presented, followed by the principal findings of the study. The paper addresses theories for why small-scale farmers may mis-use herbicides. .

Production practices

Weeds compete with crops for water, nutrients and direct sunlight (De Graaff 1986). The more this competition can be reduced by minimizing or eliminating weeds, the less yield loss the farmer will experience. However, not all weeds compete directly with coffee plants; it is important that farmers differentiate benign from harmful weeds (Altieri 1995). Different ways of controlling weeds in coffee farms are: (a) reducing the amount of direct sunlight by using shade trees, cover crops, intercropping and mulching; (b) utilizing manual practices such as chopping weeds or turning the soil over by shoveling; and (c) applying herbicides. Farmers may use only one of these methods or they may utilize some or all of the methods, and may also combine by implementing practices at different times of the year. Organic and semi-conventional farmers abstain from using any herbicides and instead use combinations of shade trees, mulching, turning the soil by shoveling, and manually chopping weeds. Again, semi-conventional farms differ from organic farms in that semi-conventional farms use other pesticides. Some conventional farmers may also utilize these practices in different combinations, while others do not, but they all apply herbicides regularly to their farms.

Pruning shade trees entails cutting the lower branches of the tree with a handsaw. The branches are cut into smaller pieces which are then either left on the ground as a form of ground cover or carried away to be burned; in either case, the leaves from the shade tree are left on the ground and block sunlight from reaching weeds. In addition to the stress from competition with coffee plants, reduced light intensity caused by shade trees is a major factor in limiting weed growth (Anderson 1996). Manually chopping weeds involves using a machete to cut the weeds, or a hand hoe or shovel to turn the soil and uproot the weed. In most cases the former is preferred, which leaves the soil intact and reduces erosion.

The two dominant herbicides used in coffee production in Costa Rica are paraquat and glyphosate. A water-soluble, non-selective and post-emergent herbicide, paraquat kills plants on contact via chemical reactions (Taiz and Zeiger 2002; Syngenta 2005). The U.S. banned paraquat for general use (paraquat may now only be used by licensed applicators) because of its high toxicity, high epidermal absorption, and longer persistence in the environment (US EPA 1997), but because paraquat is less expensive than glyphosate and readily available in Costa Rica, it is therefore commonly used by small-scale farmers (Chaverri pers. com. 1999). Although glyphosate is more expensive than paraquat, farmers use it because it completely kills the weed (Chaverri pers. com. 1999; Viquez pers. com. 1999).

Study sites and methodological approach

The two principal methodological approaches used over the span of this research were structured and semi-structured interviews, observations of farmer training sessions, and shadowing extension workers during daily activities. The interview was chosen as the main means for data collection because it appeared to be the most reliable means of collecting farm-level detailed information about management activities in this context. Most of the interviews were retrospective, and collected information based on a recall of farm activities in which farmers engaged in 1999. While the validity of recall studies have been questioned, previous studies on farmer recall of management activities have shown a high level of accuracy (Blair and Zahm 1993; Duell et al. 2001; Hoppin et al. 2002). All of the interviews conducted with coffee producers took place in either the Central Valley, in small towns called Atenas and Naranjo (these locations from now on will be referred to as the Central Valley), just prior to the harvest period of autumn 1999, or in the southern region of Coto Brus, principally in the small communities surrounding the town San Vito (from now on referred to as Coto Brus) during autumn 2000. These two areas were chosen as representative of two main coffee-producing regions in Costa Rica (see Figure 1). The farms and farming conditions sampled in the survey formed an eclectic mix, fairly representative of the coffee communities within these two regions. The altitude of the farms range from 750 to 1600 meters in the Central Valley and 800-1200 meters in Coto Brus. Farms in both regions have slopes ranging from 0–50%. According to the Fabio Baudrit Experimental Station in Alajuela, the average diurnal temperature for Alajuela Province is 29.42±1.6ºC. Average annual rainfall in this region ranges between 1639 and 2239 mm per year. Average rainfall in San Vito is 4200 mm, with an average temperature of 21.5ºC and 88% relative humidity (Icafe 1998).

Figure 1 about here.

All interviews were conducted face-to-face and were collected using one of three methods: (1) door-to-door, which consisted of identifying areas of coffee production and then visiting each farm in the area; (2) from farmers at the local coffee collection center where they regularly visited to deliver harvested coffee cherries; and (3) from farmers at the local coffee processing mill, where farmers visited once a week to collect their payment for the coffee cherries delivered during the week to the collection centers. In the latter two cases, farmers were interviewed after they arrived at the location and were waiting in line to be served. . This sampling strategy was used in order to reach the greatest number of farmers in a short period of time in line with both time and travel constraints. Additionally, due to the relatively small number of organic coffee farmers, farmers who were members of the organic coffee processing mill were targeted and interviewed. All interviews were tape recorded and later transcribed. Each interview was conducted in Spanish and lasted approximately 15 to 20 minutes.

The first interview consisted of a set of questions divided into seven sections: (1) descriptive data about farm production; (2) amount and division of labor for manually chopping weeds, pruning shade trees, and applying herbicides; (3) amount of herbicide used; (4) sources of information and assistance; (5) credit services; (6) future of the farm; and (7) sentiments on organic production. Overall, 215 farmers were interviewed during this phase of the research: 116 farmers in the Central Valley and 99 farmers in Coto Brus; 100% of the farmers interviewed were male, ranging in age from early 20s to late 60s. Almost 25% (n=52) of the farmers interviewed were large-scale producers with 20 hectares or more in coffee. With regards to small-scale farmers, 85 small-scale conventional producers (two were removed as outliers), 9 small-scale, semi-conventional producers, and 14 small-scale organic producers were interviewed.

Additional field work conducted during the spring of 2001 further investigated the factors influencing weed management on small-scale farms. A second interview consisted of structured but open-ended questions about the impacts of sources of information on coffee production Interviews were conducted and collected in the same way as the first interviews; 18 interviews were conducted. Findings based on the early interviews, with regards to small-scale farmers weed management, were shared with the farmers interviewed and their opinion with regards to the initial survey results was solicited. The second interview also was designed to measure farmers' experiences with, and opinion of, the information services they received from agricultural extension workers. The purpose of these interviews was to see if a pattern might emerge.

Data analyses consisted of single regressions, ANOVA, and descriptive statistics. The data were divided in order to test the hypothesis using these criteria: (1) small farms (≤5 hectares), medium farms (5–20 hectares) and large farms (≥20 hectares); and (2) small conventional farms, small semi-conventional farms and small organic farms. It was important to compare small-scale conventional farms with semi-conventional and organic farms to see if the farmers who abstain from any herbicide utilize a different amount of labor in other weed control activities compared to conventional farmers. Answers to qualitative questions were coded after transcription, and analyzed for content (Bryman 2004). Similarly coded responses were grouped by theme, and data were then analyzed by code headings to uncover patterns in the farmers' responses in the thematic area. Prices for data regarding wages and the costs of herbicides collected in 1999 were adjusted for inflation to 2000 prices using the producer price index for Costa Rica. Measurements of variables (see table 1) were calculated per hectare per year, unless otherwise stated; and the length of a work day was standardized.

Results

The amount of time spent on different weed management practices, related to farm size, was analyzed to test the hypothesis that small-scale farmers use more labor and less herbicides than large-scale farmers. The results of the regression analysis showed that small-scale farmers use more labor on weed management activities than large-scale farmers. The ANOVA revealed a significant difference between the amount of labor used on small versus large farms. The mean value, at a 1% level of significance, for the total amount of labor spent on weed management activities, was 76.7 days for small farms and 37.1 days for large farms (Table 1).

The results showed that both the amount of time spent chopping weeds and the amount of time spent pruning the shade trees correlated negatively with farm size (Table 2). Thus, small-scale farmers spent more time manually chopping weeds and pruning the shade trees than did large-scale farmers. The ANOVA showed a significant difference between small and large farms in regards to the total amount of time spent chopping weeds. The mean value for the amount of time spent chopping weeds by small-scale farmers was 55.0 days, while large-scale farmers spent 18.6 days chopping weeds. There was no statistically significant difference between the groups regarding the amount of time spent pruning the shade trees. Despite greater use of labor in manual weed control, small-scale farmers did not use less herbicide than large-scale farmers. The ANOVA showed that there was no statistical difference between the amount of herbicide used by small and large farms, with the mean for herbicide use at 6.34 liters for small farms and 5.21 liters for large farms. In addition, the relationships between farm size and a number of farm characteristics, specifically, density of coffee plants, percentage of the farm shaded and production level were examined, yet none of these analyses yielded any significant differences (see Table 1).

Insert Table 1 and Table 2 here

While small-scale farmers used more labor, they continued to use as much herbicide per hectare as large-scale farmers, even though herbicide use is purportedly a labor substitute. Herbicide use was correlated by farm size with other variables with which the literature had indicated a relationship could be expected, such as amount of family labor used and total number of people working on the farm (see Table 2). When total herbicide use per hectare was regressed against the total number of labor days manually chopping weeds per hectare, the result gave insignificant R-values. In contrast, as farms increased in the amount of family labor used, the analysis revealed an increased amount of time spent on each weed management activity, including herbicide application. The two regions were tested for statistical difference in each of the variables measured (see Table 1) using ANOVA; the use of labor was the only variable that had a significant P-value. Farmers in the Central Valley used more hired labor, and farmers in Coto Brus used more family labor. A series of ANOVAs were then conducted in order to establish whether there was a statistical difference between the weed management activities of small-scale conventional, semi-conventional, and organic farmers. The total amount of labor spent on all activities on each type of farm was compared, and the results showed that there was no statistical difference in the amount of time spent chopping weeds and fixing the shade for the three types of farms. Although not measured, if other farm management factors are held constant, the only significant difference between small-scale conventional and semi-conventional farmers was their use of herbicides. Even organic producers, who use no form of pesticides, used the same amount of labor to manually control weeds as their conventional counterpart. Given the analysis, it appears that small-scale conventional farmers could reduce their herbicide use without experiencing declines in coffee productivity.

Farm characteristics were also analyzed to see if the different farm types chose different strategies for managing the physical characteristics of their farms. There were no statistical differences between the three farm types groups for any of the characteristics measured (see Table 3).

Insert Table 3 here

Discussion

The findings of the study show that while small-scale farmers do use more labor per hectare than large-scale farmers for weed control activities, they continued to use as much herbicide per hectare as large-scale farmers, even though herbicide use has long been regarded as a labor substitute. Thus, small-scale farmers appear to fail to capitalize on an opportunity to use less herbicide. Organic producers use similar amounts of labor as small-scale conventional producers, but they avoiding herbicides. A review of the literature indicates a number of possible reasons for the unanticipated behavior of small-scale producers with respect to herbicide use. One topic addressed is that small-scale farmers are risk-adverse; small-scale farmers have fewer resources available to them as a safety net during years when profits are lower than expected. With this in mind, small-scale farmers' decisions are influenced by their desire to reduce variability in annual income. The use of herbicide — although it lowers overall income — may operate as insurance against income variability. When farmers act to avoid risks, uncertainty about how weed densities affect crop loss increases the probability that weeds will be treated at lower densities even though the cost of doing so will not reliably increase their profit. Farmers end up spending more money on herbicide than they would have lost in profits resulting from weed-induced lower yields (Olson and Eidman 1992; Auld and Menz 1997). As a result, risk-adverse behavior may play a role in decisions regarding the use of herbicides among Costa Rican coffee farmers (see also Bentley and Thiele 1999).

Small-scale farmers thus appear to have an opportunity to save money by using less herbicide (Olson and Eidman 1992; Mora and Soto 1996; Auld and Menz 1997). This is an important factor for Costa Rica and its coffee producers to consider as the current price squeeze caused by increasing production costs and decreasing coffee prices cause small-scale farmers to quit coffee production.

Overuse of herbicides sometimes stems from the uninformed expectation that any weed problem can be controlled most effectively by herbicides (Radosevich et al. 1997). Studies show that not all weeds have a negative effect on crop yield levels (Lotz et al. 1990; Altieri 1995). In fact, the lack of knowledge about appropriate situations for herbicide application can lead to crop damage and yield losses (Labrada and Parker 1994). Emphasis needs to be on the appropriate handling of certain weed species in order to avoid yield losses. Gerowitt's (1997) final economic evaluation of a number of studies indicated that in cases where farmers used herbicides, 20–50% of the time, spraying was not necessary. The use of herbicides in conjunction with the presence of shade trees reduces variability in yield as a result of reduced weed–crop competition. However, a study conducted in Costa Rica on the use of herbicides among farmers with and without shade trees found that although farmers recognize the benefit of shade trees with regard to weed reduction, farmers with shade trees still used more herbicides per hectare than farmers that did not use shade trees (Mora and Soto 1996). As with chopping weeds, farmers in the study did not use shade trees as an opportunity to reduce herbicide use.

These results illustrate small-scale farmers' need for more information regarding the costs of herbicide use. In addition, more information about alternative management options and research in partnership with farmers with regards to this topic would allow farmers to make better-informed decisions regarding production management. More information about weed–herbicide dynamics would also serve to reduce uncertainty about the effects of weed management on coffee production, thereby reducing or allaying small-scale farmers' risk-adverse thinking and behavior. Small-scale farmers' unexpectedly high level of herbicide use may also be the result of an underlying pressure among farmers to demonstrate a competitive image. Of the farmers interviewed, there were many farmers who proudly displayed their rows of coffee with bare soil between rows. One organic farmer commented that "the other farmers don't think of me as a farmer." When asked why, he explained, "because my farm is messy- there are lots of weeds and other plants growing around the coffee." In this case, neighboring farmers do not consider him a legitimate farmer because he does not keep his farm “clean” by using herbicides to clear the topsoil of all plants other than the coffee tree. This kind of social pressure can be an additional contributing factor to a high level of herbicide use.

One of the aims of both the first and second interviews was to record farmers’ sources of support and information, and to probe farmers’ attitude towards these sources. Although the questions of the second interview were open-ended, many of the farmers shared similar experiences. They told how the extension workers from the chemical companies visited them on the farm once or twice a year and made recommendations as to which chemicals to buy to treat existing problems. The following are some of the responses received from farmers when asked about their opinion of the impact of the chemical company services:

- “They have a positive effect because they help with fertilizer and they give technical assistance. They have a negative impact because they encourage farmers to use more chemicals.”
- “It is positive — they recommend very good products to use and they visit the farm one to two times a year.”
- “They tell me to use much chemicals and much caution. They visit once a year.”
- “They visit the farm and tell the farmers to use more chemicals.”
- “More or less. They want to sell more chemicals so they tell farmers to use more when it is not necessary.”

There are six chemical companies in Coto Brus, and each one employs an extension worker to work full time, visit farmers, and to market the products sold by their company. At the end of each visit, they write a list of chemicals that the farmer should buy in order to control the different pests that affect the crop, and they recommend quantities and rates of application of agro-chemicals to apply.

In Coto Brus there are seven cooperatively- and privately-owned processing mills and one regional National Coffee Institute (Icafe) office, all of which also employ extension workers, whose responsibilities are to conduct experiments within the region, test farm management techniques, advise farmers on how to manage their farm, and to disseminate information on new national developments in coffee production. These responsibilities leave little time for the extension workers to visit farmers on their farms. Instead, extension workers from Icafe and the processing mills present information to the community primarily in the form of group presentations, courses, flyers, and farmer field days. The farmers said that they rarely receive a visit from the extension workers from Icafe or the processing mills and that they – the farmers – do not have time to travel to the offices. The following statements reflect well the opinion that farmers had of extension employees of Icafe and the processing mills: “Positive — they are professionals in *agronomia*; but I think that they should help the producers more,” and “Very little impact — they should revise their work in order to be more effective. They need to visit the farmers more on the farm because the farmers do not know that much about Icafe to know or to have an interest in coming into the main office. In order to educate the producer, they should go to the farms.”

Many farmers try to follow the recommendations made by the extension workers from the chemical companies, because the extension workers are also typically trained agronomists. What is more valuable is that the industry-employees extension worker spends one to two hours examining the farm, so the extension worker has a better understanding of the farmer’s particular pest management problems. The information and support that small-scale farmers receive from the chemical companies fill the vacuum that results from little personal contact with extension workers from Icafe or the processing mills. This paucity of information is not a phenomenon specific only to the small-scale coffee farmers sampled here; small-scale farmers in the developing world often lack access, or face high transaction costs, to secure access to accurate and balanced information sources. As agriculture has become increasingly technical, farmers have become passive agents, acting on the advice of commercial extension workers, whose specialized knowledge have given them power over farm management (Ward 1995). Free advice from such “trustworthy” extension workers, with whom farmers have had consistent contact over time, is most likely to be followed (Ward 1995). Small-scale farmers’ insufficient knowledge make them more likely to use pesticides over alternative practices which are knowledge-intensive (Fleischer 1999), and it makes them prone to the risk of misusing herbicides (Mortimer 1997).

In addition to recommended chemicals, farmers may also be encouraged to use agro-chemicals by extension workers who work for the processing mills and Icafe. Sources of information such as the current *Icafe Manual* (1998) show a strong bias towards Green

Revolution practices. It was difficult to assess, however, how much government extension workers relied on the manual, because they were also conducting ongoing experiments to reduce chemical use and some claimed not to follow the recommendations in the manual. An Icafe extension worker interviewed said, “I recommend that they (small-scale farmers) chop the weeds because I know that they don’t have the money to pay for herbicides.” The general manager of one of the cooperatives explained that his organization encourages pollution-free production and that it offers courses on organic production methods to members. When this manager was asked how he thought the situation could be improved, he said, “We need more specialists working together with the farmers, but we don’t have the money for that.” According to a survey of the status of weed management in developing countries, Akobundu (1997) cites the lack of well-trained weed scientists and limited funding for research and extension as major constraints to improving weed management. . The effect of weeds on crops is less clear through visual observation alone than the effect of insects and fungus; thus, support for improvements in weed control receives far less attention than other categories of pest control (Auld and Menz 1997). In several developing countries, weed control, research, and extension receive altogether too little support (Auld and Menz 1997).The government can promote improvements by increasing funding to research institutions for this type of farm management research. The infrastructure for distribution of funding is already in place. It only requires financial stimulation, with far greater rates of returns coming in the form of an improved economic situation for small-scale farmers (Conway 1997) and improved human and environmental health. If allocations cannot be made, then it may still be possible for Icafe to play a stronger role in helping farmers to overcome the high transaction costs of obtaining more information by helping to organize some form alternative agriculture community where participants share knowledge and experiences and support each other in trying new practices that use less chemical inputs, and which has been done successfully in some countries and in some types of farming such as organic farming and conservation tillage. In this way, small-scale producers could become empowered and break their dependency on commercial chemical organizations (Hassanein 1999).

Conclusions

Based on the amount of labor that small-scale farmers use to manually chop weeds, their use of herbicides appears to be excessive and unnecessary. Since small-scale farms represent 44% of the productive coffee area in Costa Rica, this finding reveals a considerable potential to make substantial improvements in lowering levels of environmental pollution. The results of this study, if extended to coffee farmers throughout Latin America, suggest a very large-scale problem of herbicide overuse. Helping small-scale farmers to reduce their herbicide use is an opportunity not only to improve the health of the environment and of small-scale farmers who use herbicides, but also to increase farmers' profit margins; thereby helping small-scale farmers to succeed profitably even during years of low coffee prices.

It is important to examine the support services offered to small-scale farmers to identify how they may be improved to better meet farmers' needs. In Costa Rica, the chemical companies play a dominant role in the information structure supporting coffee production. Their help and advice fills a gap in small-scale farmers' needs. This desire for support services would be better met by the national coffee institute (Icafe), whose role is to support farmers by making information about the most advanced and appropriate techniques for managing coffee production available in order to ensure an efficient and high quality production. However, it is not enough to only make the information available, as this research has shown. Extension workers from Icafe need to work with the producers one-on-one on their farms to help identify appropriate means of managing their crop. This would improve communications not just from extension worker to farmer, but also from farmer to extension worker, leading to an improved awareness of farmers' needs. In order to meet this need, more funding is required to increase Icafe's resources, primarily to fund the number of extension workers. Until this can be done, the chemical companies will continue to fill the niche as a prime source of support for small-scale farmers, farmers will lack balanced information due to the high costs of obtaining that information, and excessive herbicide use will continue.

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Table 1: Analysis of variation between small farms and large farms.

Variable	***Small farm mean (SD)*** *N= 109*	***Large farm mean (SD) N= 52***	***P-value***	***F-value***
Total # of labor days spent on all weed management activities/ha-year	76.7 (116.6)	37.1 (57.5)	0.013	3.272
Total # of days spent chopping weeds/ha-year	55.0 (110)	18.6 (41.3)	0.012	3.188
Total # of days spent fixing the shade/ha-year	13.3 (14.4)	8.9 (14.4)	0.087	1.557
Total amount of herbicides used/ha-year (L)	6.37 (8.87)	5.21 (6.15)	0.379	0.424
Total # of hours worked by hired labor/ha-year	50.8 (120.0)	134.9 (173.9)	0.001	7.276
Total # of hours worked by family labor/ha-year	405.9 (702.6)	43.9 (85.7)	0.000	9.386
Average plant density/ha	4844 (1252)	5414 (1404)	0.010	3.453
Production (kg)/ha	1844.6 (920)	2120.6 (607.2)	0.041	2.167
% of the farm shaded	79.2% (31.7%)	68.9 % (41.1%)	0.093	2.073

*P-values refer to Bonferroni p-values. Since the degrees of freedom in each analysis were over 200, using a 5% level of significance, an R-value of .138 or greater with a P-value less than .05 was used as the criterion to conclude a correlation between variables.

Table 2: Regression analysis of farm management characteristics.

Dependent Variable	Independent variable	DF	R-value	P-value
Total amount of labor spent on all weed management activities/ha-year	Farm size	210	-0.184	0.007
Total amount of labor spent chopping weeds/ha-year	Farm size	210	-0.163	0.017
Total amount of labor spent fixing the shade/ha-year	Farm size	210	-0.176	0.010
Total amount of herbicides used (L)/ha-year	Farm size	212	-0.062	0.370
Total amount of herbicides used (L)/ha-year	Total # of labor days chopping weeds/ha-year	211	0.042	0.542
Total amount of herbicides used (liters)/ha-year	Total number of people working on the farm /ha-day	213	0.015	0.830
Total amount of herbicides used (liters)/ha-year	Total number of hours worked by family labor/ha-year	211	0.148	0.037

Table 3: Analysis of variation between small conventional, semi-conventional and organic farmers

Variable	*Conventional farm mean (SD) N= 83*	*Semi-conventional farm mean (SD) N= 9*	*Organic farm mean (SD) N= 14*	*P-value*	*F-value*	*ANOVA P-value of difference between groups*	
Total # of days spent on all weed management activities/ha-year	63.6 (54.1)	25.9 (19.5)	42.4 (47.5)	0.060	2.884	Convent-Org Convent-S.Org Org-S.Org	0.157 0.039 0.454
Total # of days chopping weeds/ha-year	39.8 (44.2)	19.5 (16.5)	27.3 (32.2)	0.2580	1.375	Convent-Org Convent-S.Org Org-S.Org	0.297 0.165 0.660
Total # of days fixing shade/ha-year	13.3 (13.7)	6.4 (6.0)	15.2 (17.3)	0.301	1.216	Convent-Org Convent-S.Org Org-S.Org	0.634 0.159 0 .140
% of the farm shaded	80.4% (29.9)	61.1% (48.6)	86.4% (22.4)	0.144	1.972	Convent-Org Convent-S.Org Org-S.Org	0.500 0.079 0 .058
Production (kg)/ha	1864 (946.0)	1789 (863.2)	1426 (625.6)	0.250	1.406	Convent-Org Convent-S.Org Org-S.Org	0.097 0.812 0.351
Plant density/ha	4893 (1302.0)	4587 (429.8)	4473 (1016.0)	0.420	0.874	Convent-Org Convent-S.Org Org-S.Org	0.237 0.477 0.828

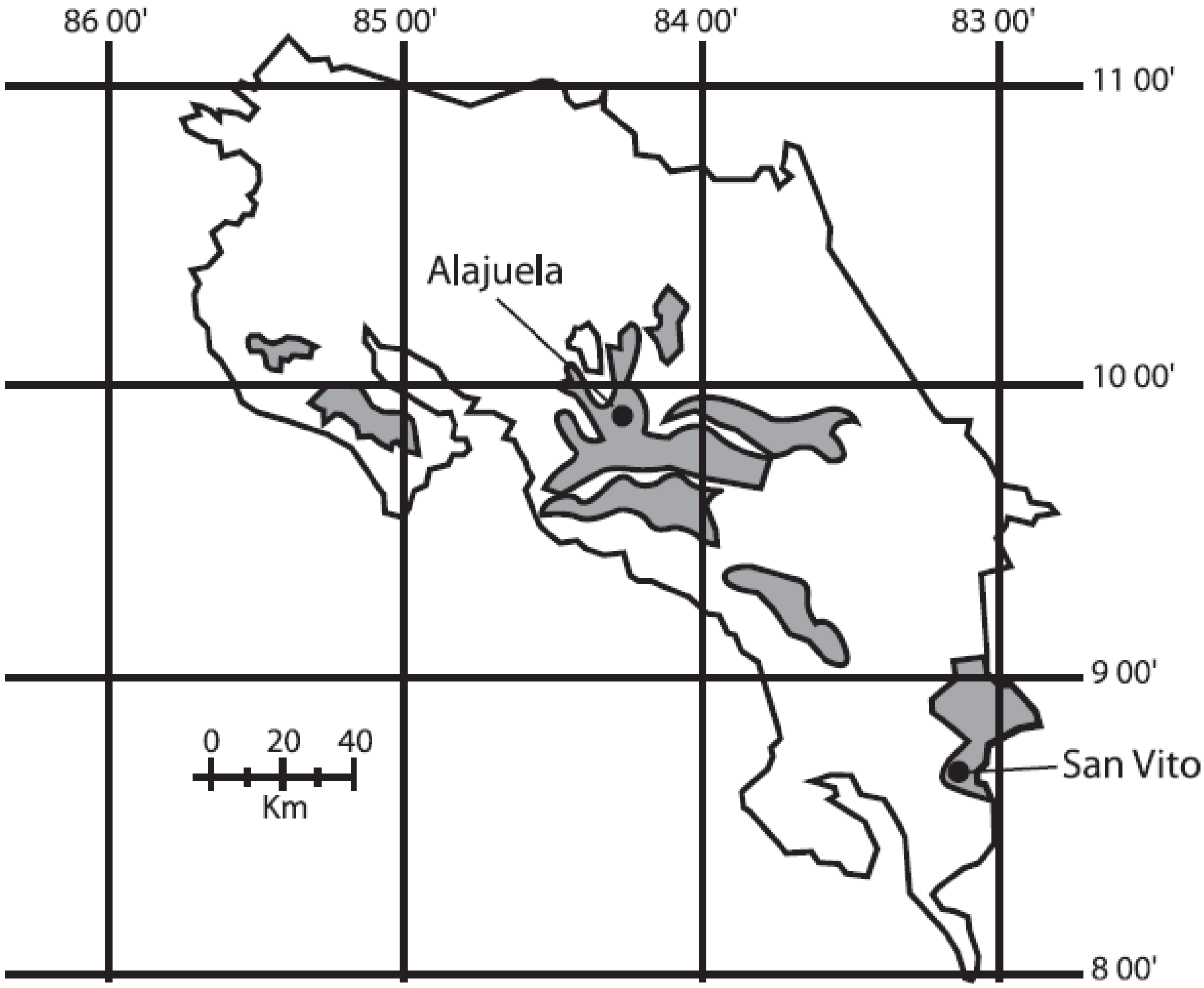

Figure 1. Map of Costa Rica with principle coffee-producing regions shaded. The two sampling areas, Alajuela and San Vito are indicated.

Source: Segura and Reynolds (1993)