SUSTAINABLE AGRICULTURE FARMING SYSTEMS PROJECT
University of California, Davis
Summer 2007 VOL.7/NO.3

Putting a value on environmental services, quality

By Craig A. Bond, Karen Klonsky and Y. Hossein Farzin

Ecosystem services and environmental quality are not bought and sold in traditional markets. A simple price variable, for example, representing the costs of reducing runoff does not exist. Instead, economists have developed the notion of "shadow prices" that can be estimated from production and environmental data that give either the value of a non-marketable "good," such as a unit of indigenous nitrogen in the soil, or the abatement costs of reducing a "bad," such as nitrates in water. Such shadow prices can be used to develop alternative production systems, help producers meet environmental goals at the lowest costs, and help policy makers cultivate incentive systems to reduce agricultural pollution.

This article quantifies the costs associated with two potentially polluting activities: mechanized trips across a field, which may generate air pollution; and total quantity of pesticides used in production, which has the potential to contaminate ground and surface water. In addition, we report the results of estimates that help to illustrate the productive and joint productive/environmental efficiency of alternative production systems.

photo by Jeff Mitchell

The SAFS project has been comparing the efficiency of three production systems managed under either conservation tillage or standard tillage (above.)

Data

The data for this article is taken from the Sustainable Agriculture Farming Systems (SAFS) project. Three alternative production systems (conventional, low-input, and organic) in a two-year rotation of processing tomatoes followed by field corn using furrowed irrigation are considered. In addition, each production system was managed using standard and reduced tillage, for a total of six distinct production systems for each crop with three replications of each. Three years of data were available.

To allow for comparability between crops, an index was constructed for desirable outputs (i.e., corn and tomato yields) that incorporates as weights any price premium for organic produce. Inputs were measured as total expenditures on 11 cost categories. Undesirable outputs would ideally be direct measures of quantities of pollutants; however, due to measurement difficulties in the field, none were available. Instead, we choose to use proxy variables that are likely correlated with these "bads"--namely, total number of trips across a field and total quantity of pesticides (herbicides and fungicides) applied. While these are certainly not ideal variables, they do provide the opportunity to value changes in management that are associated with polluting activities.

Technical efficiency *excluding* environmental considerations

We first examine the estimated values of a total factor productivity (TFP) index, which compares the technical efficiency of each production system/tillage treatment by year, arbitrarily using standard tillage corn for 2003 as the baseline. The TFP index is defined as the ratio between the output and input quantities for each observation, with the baseline equal to one. Those observations with a TFP index

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greater than one are more efficient than standard tillage corn 2003. A TFP index less than one means the system is less efficient than standard tillage corn 2003. This index only uses marketable inputs and outputs without considering environmental variables.

Table 1 summarizes the results. Aggregating over both crops, the "Total" column shows that, on average, conventional systems (CONV) are most efficient, with organic systems (ORG) slightly less efficient than winter-legume cover cropped systems (WLCC). This is generally true for corn and tomatoes separately as well, though the loss in efficiency in moving to an alternative production system is greater for corn than tomatoes. There is little difference between standard tillage (ST) and reduced, or conservation, tillage (CT) overall. However, conservation tillage is most efficient for corn, but standard tillage is most efficient for tomatoes. Thus, technical efficiency across crops and technologies are system-specific, and generalizations must be made with caution.

Table 1: Economic Total Factor Productivity (TFP) relative to Conventional Standard Tillage Corn, 2003, by Production System (Baseline=1)

	Total	Corn	Tom
All	0.776	0.674	0.878
Standard Tillage (ST)	0.756	0.567	0.994
Conservation Tillage (CT)	0.797	0.781	0.813
Conventional Tillage (CONV)	1.138	1.248	1.027
Organic (ORG)	0.550	0.316	0.783
Winter Legume Cover Crop (WLCC)	0.641	0.457	0.826

Table 2: Distance function Estimates relative to Most Efficient Observation, by Production System (Most efficient=0)

	Total	Corn	Tom
All	0.790	0.841	0.738
Standard Tillage (ST)	0.823	0.897	0.749
Conservation Tillage (CT)	0.757	0.786	0.727
Conventional Tillage (CONV)	0.572	0.566	0.579
Organic (ORG)	0.692	0.803	0.582
Winter Legume Cover Crop (WLCC)	1.104	1.155	1.053

Technical efficiency *including* environmental considerations

In order to quantify our augmented efficiency and abatement cost measures, we use the concept of a "production possibilities frontier," or PPF. A PPF shows the maximum level of outputs that can be obtained from a fixed set of inputs. In this case, we are concerned with production of both desirable outputs (crops) and undesirable outputs (environmental outputs as represented by our proxies). Any data point that lies on the frontier is considered "efficient," in that one cannot increase desirable outputs without also increasing undesirable outputs. A data point lying inside the frontier is inefficient, in that either desirable outputs can be increased without increasing pollution, or pollution can be decreased without sacrificing crop output. The distance from such a point to the frontier is a natural measure of technical efficiency in the presence of jointly-produced outputs, including environmental "bads." We call this index the Environmental Efficiency Index (EEI).

To obtain abatement costs, we use the frontier to describe the tradeoff between, say, reducing an environmental pollution proxy and the resultant decrease in desirable crop output. Assuming that one of the outputs has a true value given by its market price, then, the dollar value of the undesirable output can be easily recovered.

Table 2 shows the EEI that includes the environmental proxies discussed above (number of trips across the field and total amount of pesticides used) along with the yields and cost factors. Unlike the TFP index, a lower value indicates greater efficiency, with a value of zero suggesting production along the technology frontier (i.e., most efficient). Conventional production is still most efficient across both crops and tillage regimes, but the lack of pesticide application in the organic system is taken into account, thus moving it ahead of cover-cropped systems in the efficiency rankings. This pattern is again maintained for both corn and tomatoes, although the very small differences between conventional and organic production measures for tomatoes is worth noting as reductions in pesticide use do not appear to significantly affect the combined economic/environmental efficiency measure. Credit for reducing trips across the field with this combined measure results in conservation tillage systems ranked more efficient than standard tillage regimes in aggregate and for each crop individually.

Incorporation of environmental considerations into the efficiency analysis thus effects both the qualitative and quantitative classifications of each of the production systems by crediting the "production" of environmental quality rather than simply crop yields. In the case of corn, there is little compelling evidence to suggest that non-conventional production systems should be promoted (say, through policy instruments) on environmental grounds, at least on the basis on this information. For tomatoes, however, it appears that organic production systems have the potential to increase environmental quality while simultaneously increasing output. Cover cropping fares the worst in terms of technical efficiency. However, we have not included a proxy for pollution resulting from fertilizer, which could change the results. Of course, profitability concerns of individual growers (including the costs of potentially switching to a new system) are likely to dominate production choice decisions.

Shadow prices

We estimated the shadow prices of avoiding the use of pesticides and reducing the number of trips across the field as a way of valuing the cost of adopting sustainable farming practices. The average shadow price estimates overall are $37 per pint of herbicide and $8 per trip across the field, although they have quite a large range (Table 3). In other words, the opportunity cost of abating one pint of herbicides is just under $40, while the opportunity cost of foregoing one trip across the field is just under $10. Alternatively, a producer operating at a zero herbicide level could increase output value by approximately $37 if an additional pint of herbicide was applied. Prices for each proxy are generally higher for corn ($59 and $10) than for tomatoes ($16 and $7) meaning that adoption of sustainable farming practices is more likely for tomatoes than corn. The organic system tends to admit shadow prices higher than the overall average. On average, standard tillage system shadow prices for herbicides are lower than conservation tillage systems, but higher than conservation tillage systems for number of trips across a field. These results imply that standard tillage systems are more reliant (in terms of output tradeoffs) on tillage operations than conservation tillage systems, which makes sense given the objectives of the conservation tillage regime. The results also imply that conservation tillage systems are more reliant on herbicides than standard tillage systems, which is also intuitive.

Table 3: Estimated Shadow Prices of Undesirable Outputs by Crop, 2005$

	Total		Corn		Tomato	
	Herbicide	Trip	Herbicide	Trip	Herbicide	Trip
All	37.28	8.40	58.74	10.13	15.83	6.67
Standard Tillage (ST)	32.84	10.80	51.95	13.34	13.74	8.27
Conservation Tillage (CT)	41.72	6.00	65.53	6.93	17.92	5.07
Conventional Tillage (CONV)	31.52	4.00	48.30	5.85	14.73	2.15
Organic (ORG)	50.41	15.75	79.70	18.18	21.11	13.31
Winter Legume Cover Crop (WLCC)	29.92	5.46	48.21	6.37	11.64	4.55

Results summarized from a forthcoming August 2007 Journal of Agricultural and Resource Economics *article entitled "Estimating Agricultural Pollution Abatement Costs at the Plot Level Using Experimental Data: A Maximum Entropy Approach," by C.A. Bond and Y.H. Farzin.*

Overall shadow prices for abatement of herbicides are generally higher than the comparable input cost (between $3 and $20 per pint), while shadow prices for tillage are slightly lower than the approximate $20 per acre. One interpretation is that the increase in revenue from using herbicides is greater than the cost of herbicides. In contrast, the value of an additional tillage operation is less than the cost of the tillage operation. It follows that many farmers operating under conventional production systems would be more likely to reduce the number of tillage operations but less likely to reduce the amount of herbicide used based on current market conditions.

Effects of alternative agricultural practices on pesticide detection, concentration in runoff water

by Ana Lucía Córdova-Kreylos, Jozsef Lango and Kate M. Scow

Introduction

The National Water Quality inventory has identified agricultural nonpoint source (NPS) pollution as the main impact to natural water sources (e.g. rivers and lakes), as well as an important source of pollution to groundwater reserves. Agriculture pesticide use is a potential source of NPS pesticides to aquatic environments.

Agricultural impacts on surface water and ground water can be minimized by properly managing activities that cause NPS pollution through adopting practices that buffer or reduce the amount of runoff from agricultural fields. These include planting winter cover crops, reducing tillage or conservation tillage, and building sediment traps to collect winter rain and summer irrigation runoff. Cover crops protect soil from water erosion, and increase infiltration (*SAFS Newsletter* Winter/Spring 2006, Vol. 6, No.2). Sediment traps allow sediment to settle out of runoff water and thus reduce pesticide transport form fields.

To evaluate the effects of management practices on NPS in California row crop systems, samples of runoff water were analyzed for pesticides from nine plots at SAFS. Management treatments included conservation tillage (CT) and standard tillage (ST) across organic, low-input and conventional cropping systems in two-year tomato-corn rotation. Organic plots are managed according to the California Certified Organic Farmer guidelines and their nitrogen inputs from manure application and winter legume cover crops (WLCC). The low input system gets occasional application of pesticides with reduced conventional nitrogen inputs compared to the conventional cropping system and supplemental nitrogen from WLCC. The conventional system is strictly agrochemical based and reflects the Central Valley's typical farming practices. Four pesticides were selected for monitoring based on pesticide application history from fall 2003 to summer 2005. These included: tillam (pebulate), trifluralin, metolachlor, and lambda (L)-cyhalothrin. Glyphosate was applied in all the fields used for this study, but was not analyzed due to lack of standard extraction and analysis method for this compound.

Sampling and analysis

One-liter event-based samples of winter runoff water were collected between January and April 2006 with an ISCO autosampler (Teledyne ISCO, Inc., NE) and processed within 24 hours. Centrifuged samples were spiked with a surrogate standard (terbutylazyne) to evaluate recovery. The pesticides were extracted from the runoff water, deuterated naphthalene and pyrene internal standards added and then analyzed using an HP 5973 Gas Chromatograph/Mass Spectrometer.

Results

A total of 41 runoff water samples from SAFS plots were collected during the 2006 winter storm season. During 2003 to 2005, conventional plots received tillam, trifluralin, metolachlor and L-cyhalothrin; low input (WLCC) plots received L-cyhalothrin and no conventional pesticides were applied to organic plots. Trifluralin and L-cyhalothrin were not detected in any runoff samples. Tillam was detected in two samples and metolachlor in 11 samples.

No pesticides above their detection limits were found in runoff from the organic cropping system. In low-input and conventional systems, runoff water from ST plots had consistently higher pesticide concentrations (Figure 1). The highest concentrations were detected in the ST conventional cropping system plots. This result was expected, given that conventional ST plots had more pesticides applied than any other plots (trifluralin, metolachlor and L-cyhalothrin). Specifically, metolachlor was detected in 62.5% of ST samples, while it was only detected in 25% of CT samples.

In low-input plots, the differences between CT and ST were greatly diminished. This was perhaps due to the fact that all low-input plots are planted with winter cover crops that can reduce the amount of runoff and export of sediment. Metolachlor was the pesticide predominantly detected

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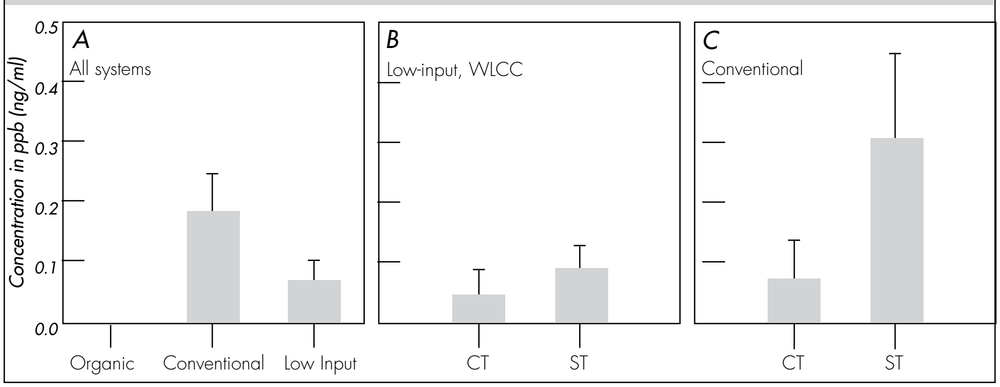
in the samples. Metolachlor is moderately persistent in the environment lasting up to one or two years. Metolachlor is the most water soluble of the four pesticides targeted in this study, which may explain why it was detected more frequently than the others.

Our results show that in conventional systems, some reduction of pesticide runoff was achieved by adopting CT. In organic and low input systems, pesticide usage was lower than in conventional systems and leading to pesticide runoff. Overall, the amount of pesticides measured in the conventional cropping system runoff was below detection limits with the exception of Metolachlor. The use of CT greatly reduced Metolachlor in runoff. The results indicate that management to reduce runoff is useful to reduce pesticide export.

We are currently analyzing data from four growers' fields to evaluate and compare the effects of sediment traps, reduced tillage, cover crops and fallow fields on pesticide runoff during the rain season and during irrigation events.

FIGURE 1. Average total pesticide concentration detected in samples from SAFS plots. Effects of standard tillage (ST) and conservation tillage (CT) on pesticide concentrations was determined in the low-input winter legume cover crop (WLCC) system, and conventional system plots.



Taking it to the farm: SAFS field day June 22, 2007

Join us for the annual SAFS field day on June 22 at **Muller and Sons** farm in Woodland, County Roads 95 and 19. We will present field results on runoff and soil carbon, weed management, county crop production, the soil food web, and the economics of alternative management practices. A grower panel will discuss water quality and reducing farm energy costs. The keynote speaker is **Tom Tomich,** head of the new UC Davis Agricultural Sustainability Institute, and the UC Sustainable Agriculture Research and Education Program. Sign-in at 8 a.m. and stay for lunch; events conclude at 1 p.m. The cost is $5; students and growers are free. Details at ***http://safs.ucdavis.edu/***, or call (530) 754-6497, or email sama@ucdavis.edu or Kabir@ucdavis.edu.—*Will Horwath, project leader*

More information on UC Davis sustainable agriculture farming systems projects is available online at **safs.ucdavis.edu**, including expanded newsletter articles, SAFS/LTRAS updates, and other resources.

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