Title

ARE Update Volume 12, Number 5

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Publication Date

2009-06-01

Agricultural and Resource Economics
UPDATE
GIANNINI FOUNDATION OF AGRICULTURAL ECONOMICS • UNIVERSITY OF CALIFORNIA
V. 12 no. 5 • May/June 2009

Reducing Volatile Organic Compound Emissions from Pre-plant Soil Fumigation: Lessons from the 2008 Ventura County Emission Allowance System

Henry An, Rachael E. Goodhue, Peter Howard, and Richard E. Howitt

In 2008, the California Department of Pesticide Regulation implemented a volatile organic compounds emission allowance system for emissions from the use of fumigants. We evaluate lessons from this program for the design and implementation of any future emission allowance systems.

Also in this issue

Volatile organic compounds (VOCs) contribute to the formation of ground-level ozone, a pollutant regulated under the Clean Air Act due to its harmful effects on human health and the environment. Several regions in California are "non-attainment areas," meaning that their ozone concentrations exceed the regulatory standard for too many days during the peak ozone season of May through October, when weather conditions most favor ozone formation. The use of some pesticide products results in the emission of VOCs. In cooperation with the California Air Resources Board (CARB), the California Department of Pesticide Regulation (CDPR) is responsible for reducing pesticidal VOC emissions in order to help bring California's non-attainment areas into compliance with federal standards.

As part of its plan for meeting its commitment to reduce VOC emissions from pesticide use, CDPR issued regulations regarding VOC emissions from field fumigation in January 2008. Low-emission application methods were required for fumigation conducted during the peak ozone season. In addition, CDPR specified that it could impose limits on the amount of fumigation by individual growers if its projections estimated that the use of low-emission application methods would not be sufficient to achieve its targeted reduction. While CDPR proposed a four-year phase-in period that had been approved by CARB, the phase-in was rejected by the federal district court in December 2007. Consequently, CDPR had to implement restrictions on the amount of fumigants used by individual growers in Ventura County. CDPR issued emission allowances to growers for the 2008 peak ozone season—May 1 to October 31. The emission allowances were discontinued September 3, 2008, in the wake of a federal appellate court ruling in favor of CDPR's appeal of the original 2006 federal court order regarding CDPR's efforts to reduce VOC emissions from pesticide use. Although the allowance system was not even in effect for an entire season, some lessons can be drawn from the experience that may prove useful if another system for limiting fumigant use by individual growers must be implemented in the future, whether in Ventura County or elsewhere.

In early 2008, growers submitted requests specifying product, acreage, and field location to the Ventura County Agricultural Commissioner. That office checked to ensure that the application method was allowed under the regulations, and to ensure that the grower controlled the field in question. The requests were then forwarded to CDPR, which calculated the percentage of requests that would be issued to growers as emission allowances. If the requested fumigation treatments were identical to

Table 1. Gross Crop Revenues Per Pound of Emission Allowance by Crop: Requested Pre-Plant Soil Fumigation Products, Application Methods, and Application Rates, 2008

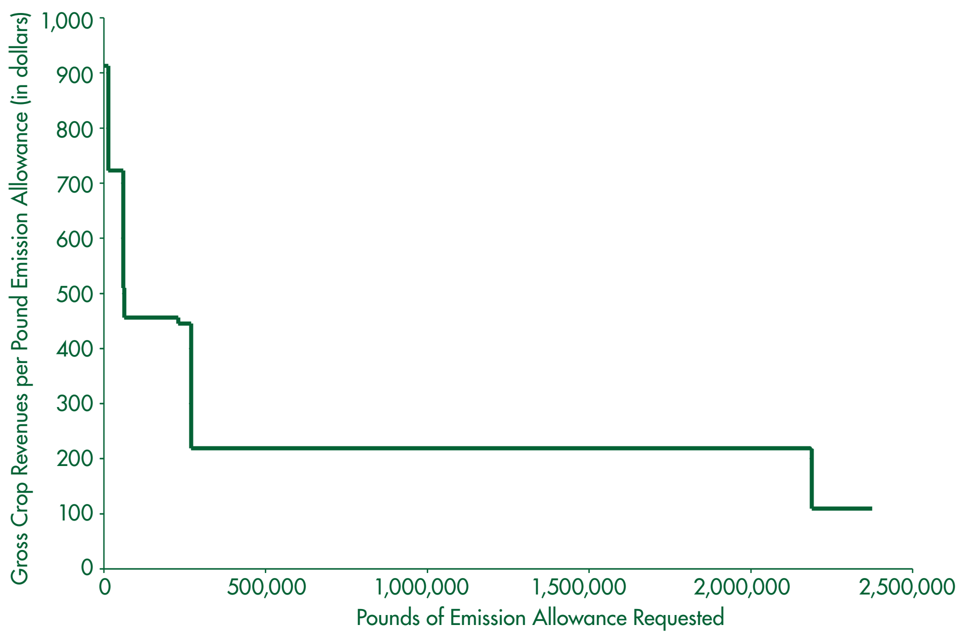
Crop	Revenue/ lb. Emission Allowance	Crop's Total Requested Allowance	Cumulative Requested Allowance
Lemons	$913	13,677	13,677
Raspberries	$713	46,620	60,297
Avocados	$510	2,820	63,117
Tomatoes	$456	166,281	229,398
Flowers	$445	39,936	269,334
Strawberries	$219	1,915,340	2,184,674
Turf/Sod	$218	3,278	2,187,952
Peppers	$110	187,600	2,375,552

Source: CDPR (2008b) and VCOC (2007).

the implemented fumigation treatments, then this approach would have resulted in an identical percentage reduction in fumigated acreage across growers.

As the system was administered, growers were not required to use the product, application method, or application rate specified in their emission allowance requests. The first lesson of the 2008 VOC emission allowance system in Ventura County is that this administrative decision meant that the across-the-board cut in emission allowances had different effects on growers' actual capacity for fumigated acreage. The vast majority of requests were for methyl bromide-chloropicrin products, although the use of methyl bromide had declined in Ventura County in recent years. Unsurprisingly, growers did not actually always use the product listed in their requests. They utilized other active ingredients for a substantial share of applications. Growers with greater scope to move to fumigation choices that result in lower emissions per acre were able to fumigate a greater percentage of the acreage specified in their emission allowance requests. Although one might argue that this is a desirable outcome because it provides growers with an incentive to adopt lower-emission techniques, its scope for doing so is limited, and offset by the relatively weak constraint on growers' ability to overstate intended treated acreage in their allowance requests.

Figure 1. Gross Crop Revenues per Pound of VOC Emission Allowances: Requested Products, Application Methods, and Application Rates, 2008



Because the emission allowances are not tradable among growers, and because the allowances were allocated based on requests that did not include the economic value per unit of emissions, the marginal benefit per unit of VOC emission allowance varies across growers. The second lesson from the 2008 VOC emission allowance system implemented in Ventura County is that the decision to make allowances non-tradable led to inefficient outcomes. The value of a unit of emission allowance varied across crops, but growers with higher values were not able to purchase additional allowances from growers with low values.

We use the information supplied in the allowance requests to provide a crude measure of the differences in the value of a unit of emission allowance across crops. The ideal measure would be the risk-adjusted net returns per unit for each crop but since these numbers are not available, gross crop revenues per unit are used instead. To the extent that net returns per acre *as a percentage of revenues* per acre are the same across crops, using revenues rather than net returns will result in the same ordinal ranking by crop even though the absolute values will be different.

Crops can be grouped by their revenues per pound of emission allowance, as shown in Table 1. Lemons have a substantially higher willingness to pay than other crops. Raspberries, avocados, tomatoes, and cut flowers have a substantially higher willingness to pay than strawberries and turf/sod, which in turn have a substantially higher willingness to pay than peppers. Economic theory predicts that the price of a pound of emission allowance will be determined by its marginal revenue product, which will be determined by the net returns

Table 2. January–July Pre-Plant Soil Fumigated Acreage, 2004–2008

	Crop											
	Strawberries		Unspecified Crop		Peppers		Tomatoes		Lemons		Outdoor Flowers	
Year	Jan-Apr	May-Jul	Jan-Apr	May-Jul	Jan-Apr	May-Jul	Jan-Apr	May-Jul	Jan-Apr	May-Jul	Jan-Apr	May-Jul
2004	639	5,337	419	703	1,052	150	258	1,055	224	3	48	69
2005	--	4,203	180	833	443	389	344	332	11	31	24	29
2006	76	3,416	373	1,505	342	193	212	510	19	68	15	40
2007	20	2,680	235	1,409	551	64	--	100	72	--	19	--
2008	873	1,416	1,501	443	798	33	760	217	152	24	7	41

Source: PUR data, various years, CDPR. 2008 data are preliminary.

per pound of emission allowance for strawberries and/or turf/sod, because these two crops would account for the lowest-valued unit of emission allowance given the total amount of emission allowances. Growers who have higher valuations for a unit of emission allowance would be willing to pay at least as much per unit. Growers who have lower valuations per unit of emission allowance will be willing to sell at this price. Because products' emission potentials vary, and application rates and methods vary, crops with the highest value of production per acre are not necessarily the crops with the highest gross crop revenue per pound of emission allowance. Flowers, which have the highest value of production per acre, have only the fifth highest gross crop revenue per pound of emission allowance. Again, we emphasize that this analysis assumes that the ordinal ranking of risk-adjusted net returns per unit of emission allowance is represented adequately by the ordinal ranking of gross returns per unit of emission allowance. If a crop's net returns as a percentage of gross returns are substantially higher or lower than those for other crops, or if crops vary greatly in the riskiness of their net returns, then ordinal rankings are more likely to differ.

Figure 1 plots emission requests by crop in decreasing order of **gross** crop revenues per pound of VOC emission allowance. It shows that if growers had used their requested treatments, a market for emission allowances would have resulted in a substantially different allocation across crops than the across-the-board percentage cut used in the 2008 process did. Based on preliminary data, growers' actual fumigation choices were very different from those in their emission allowance requests. To the extent that growers of crops with relatively low gross revenues per pound of emission allowance adopt lower emission approaches than growers of the crops with the highest gross revenues per pound of emission allowance do, then the difference in their willingness to pay for a unit of VOC allowance will decrease. Conceivably, their ordinal ranking may even change. Another consideration is that, in practice, a variety of products with various active ingredients are used on a given crop, implying that some growers of a given crop will have a higher willingness to pay than others will.

Implementing a market for emission allowances would equalize the value of a pound of emission allowance across uses. Growers would be allowed to sell allowances or to use them for pre-plant soil fumigation once the allowances were assigned. Initially, the state could sell emission allowances, or allowances could be allocated across growers based on historical use or other criteria. In the former case, the revenues from the sale of emission allowances could be used to cover program administration costs and fund research into means of reducing VOC emissions from fumigants, including research regarding alternatives to fumigation. Either being required to purchase emission allowances or having the opportunity to sell unneeded emission allowances to other growers will provide an incentive for growers to adopt lower emission production methods.

The final lesson of the 2008 emission allowance system is that growers do have the flexibility to move at least some pre-plant soil fumigation treatments outside of the peak ozone season. Table 2 reports fumigated acreage by crop and year for the January–April and May–July time for the years 2004–2008 due to the effect of the emission quotas, using preliminary 2008 Pesticide Use Report (PUR) data from CDPR. As CDPR's appeal progressed, growers and others began to anticipate that CDPR's phase-in of emission allowances would be reinstated. By August the reinstatement appeared quite likely. Because growers' expectations likely influenced their decisions, we focus on the January-July period when the outcome was less certain.

The table includes acreage treated with pre-plant soil fumigation for an unspecified crop. Field-level analysis of pesticide use reporting data suggests that a significant share of the acreage in this category is planted with strawberries, although certainly not all of it. In 2008, the California Strawberry Commission reports there were 3,157 acres of summer-planted strawberries in Ventura County—substantially more than the 2,299 reported pre-plant soil fumigated acres for strawberries during the first seven months of 2008. Consistent with this difference in 2008, in 2005, 63% of the acreage treated with pre-plant soil fumigation for an unspecified crop also had reported pesticide applications for strawberries,

Table 3. Monthly Share (percent) of January–July Pre-Plant Soil Fumigated Acreage, 2004–2008: Strawberries

Year	Jan	Feb	Mar	Apr	May	Jun	Jul
2004	1	0	0	10	8	48	33
2005	0	0	0	0	7	58	35
2006	0	0	1	1	2	50	45
2007	0	0	0	1	13	74	13
2008	0	0	0	38	3	50	9

Source: PUR data, various years, CDPR. 2008 data are preliminary.

and an additional 11% had reported pesticide applications to strawberries and at least one other crop.

Table 3 reports the share of acreage fumigated monthly for the January–July period for the years 2004–2008 for strawberries. Comparing 2008 to previous years, a substantial share of pre-plant soil fumigation treatments were performed prior to the peak ozone season on land intended for strawberries. Applications were shifted into April, while the percentage in May and June declined. For the other crops, the annual pattern of applications was much less consistent for the 2004–2007 period, so it is difficult to draw any conclusions regarding a change in the monthly shares of fumigated acreage in 2008.

The emission allowance system is not in effect for 2009. CDPR projections indicate that its field fumigant use regulations will achieve the reduction in VOC emissions from pesticide use that is required to comply with the larger cap specified under the phase-in. Under the phase-in of emission quotas, more emission allowances are available to growers over the next few years. The immediate effect is to reduce the direct impact of emission quotas on growers. The longer-term effects pose a challenge. If the phase-in period is simply treated as a means to continue current pre-plant soil fumigation practices, then the only effect of the phase-in will be to reduce short-term regulatory impacts. If the phase-in period is used to identify and implement economically feasible lower-emission alternatives to current fumigation practices, then the phase-in period will also mitigate the longer-term effects of post-2012 regulations. In the event that CDPR must again implement emission allowances in Ventura County or elsewhere, the 2008 experience provides some guidance for the design of future systems.

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For More Information, the Authors Recommend:

Goodhue, Rachael, Richard Howitt, Peter Howard and Henry An. "Effects of the January 2008 CDPR Field Fumigation Regulations: Ventura County Case Study." Final report submitted to California Department of Food and Agriculture. April 2009. www.cdfa.ca.gov/files/pdf/GoodhueHowitt042309.pdf.

California Department of Pesticide Regulation. "Volatile Organic Compound (VOC) Emissions from Pesticides." 2009. www.cdpr.ca.gov/docs/emon/vocs/vocproj/vocmenu.htm.

As part of its plan for meeting its commitment to reduce VOC emissions from pesticide use, CDPR issued regulations regarding VOC emissions from field fumigation in January 2008. Comparing 2008 to previous years, a substantial share of pre-plant soil fumigation treatments were performed prior to the peak ozone season on land intended for strawberries.

Update on rbST Use in the California Dairy Industry

Henry An and Leslie J. Butler

The share of California dairy producers who use rbST reached its peak in 2001 and has slowly declined since then. Many producers have disadopted rbST and survey results suggest that rbST use in California will continue to decrease in the near future.

RbST has been in use for nearly 15 years, but many producers believe the future of dairy production in California will not include rbST.

Just over ten years ago, we reported on the use of recombinant bovine somatotropin (rbST), a genetically engineered growth hormone used to increase milk production in cows, in the California dairy industry (see *ARE Update*, Vol. 1, No. 2, Winter, 1998). Our conclusions at that time were as follows:

About 25% of California dairy producers were using, or had used, rbST, and another 20% had expressed interest in using it in the future.

California producers were using rbST on an average of about 25% of their herds, from which it was inferred that about 10% of the total California herd was being treated with rbST. Since average reported response rates were about 11%, we concluded that rbST's impact was less than a 1% increase in milk production.

We also concluded that there was some uncertainty about rbST use among its current and prospective users. While concerns about public opinion, and the effect on milk sales, had diminished dramatically since its commercial introduction in 1994, current and prospective users still had concerns about the effect of rbST on the health of their herds, adverse prices as a result of increased milk production, and the cost effectiveness and efficacy of the new technology.

Much has changed in the California dairy industry in the last ten years. In this brief update, we report some preliminary findings and take stock of what has happened since those surveys were conducted in 1994 and 1996.

RbST Use in California through the Years

Many economic studies attempted to predict potential rbST adoption rates in the late 1980s and early 1990s, prior to rbST's commercial release in 1994. These ex-ante studies predicted national aggregate adoption rates of between 33% and 92%. In California, we conducted several ex-ante surveys and found that the percentage of respondents who claimed to be prospective users declined from 42% to 30% between 1987 and 1993, while the percentage of producers who said that they would never use rbST increased from 29% in 1987 to 62% in 1993. This latter group of producers had concerns that rbST would have negative health effects on their cows; that milk from rbST-treated cows would not be safe for human consumption; and that the use of rbST would not be profitable and—through overproduction—would sharply reduce the price of milk in the United States, leading to severe industry disruption.

A survey conducted about six months after the commercial release of rbST in 1994 showed that about 18% of producers were using rbST, and about another 5% had had previous experience through field trials run by the companies who were producing the new biotechnology. Another 18% said they would consider using rbST in the future while 59% declared themselves committed non-users. At this stage, it looked as if the maximum adoption rates for rbST would be around 40% of producers. Table 1 (see page 6) presents summary statistics of the adoption and use of rbST in 1994, 1997/98, and 2002.

Between 1994, when the survey was administered about six to nine months after the commercial release of rbST, and 1997/98, adoption rates climbed from about 23% (current and past users) to almost 46%. However, it is clear that many producers had tried

Table 1. Adoption and Use of rbST (%) in 1994, 1997/98, and 2002

	1994	1997/98	2002
Current Users	18	28	27
Past Users	5	18	18
Prospective Future Users	18	17	9
Non-Users	59	38	46

Source: Butler, 2003

rbST and decided to discontinue its use. The 1997/98 survey yielded over 50 different reasons why producers who had previously used rbST then stopped using it. For many, rbST was simply not producing positive results. Many felt that it was not cost effective, and many also had problems like mastitis, lameness, loss of condition, and lowered immune system functions which they attributed to rbST use. At the same time, the number of committed non-users dropped from a high of 60% in 1994 to around 37% in 1997/98.

However, during the period 1998–2002 many producers apparently changed their mind about rbST. While the percentage of current and past users remained about the same, the number of producers who became committed non-users rose to around 46%, and only 9% said they might use it in the future.

Since its release in 1994, the share of dairy operations that use rbST in California reached a peak of just over 30% in 2001, making California one of the larger adopters of rbST in the United States (see Figure 1). However, in the past decade, the percentage of dairy producers using rbST has decreased substantially, suggesting that many producers may be in the process of disadopting rbST. There are several reasons that producers may have stopped using rbST. First, many producers still question the efficacy of the technology and are uncertain that it leads to higher profits. While there is little doubt that some cows treated with rbST do produce more milk, the wide variability of increased milk production between cows, and the fact that they also consume more feed, leads to some uncertainty about the effectiveness of rbST. Second, milk prices and feed prices have fluctuated wildly over the last 15 years. When milk prices are comparatively low and feed prices are comparatively high, net profits may be negative. We showed that, between 1994 and 2002, the use of rbST was likely only profitable about half the time.

Other reasons for not using, or disadopting, rbST include concerns about its use and public perception, other ways to increase milk production and/or profitability, and increased demand for rbST-free milk.

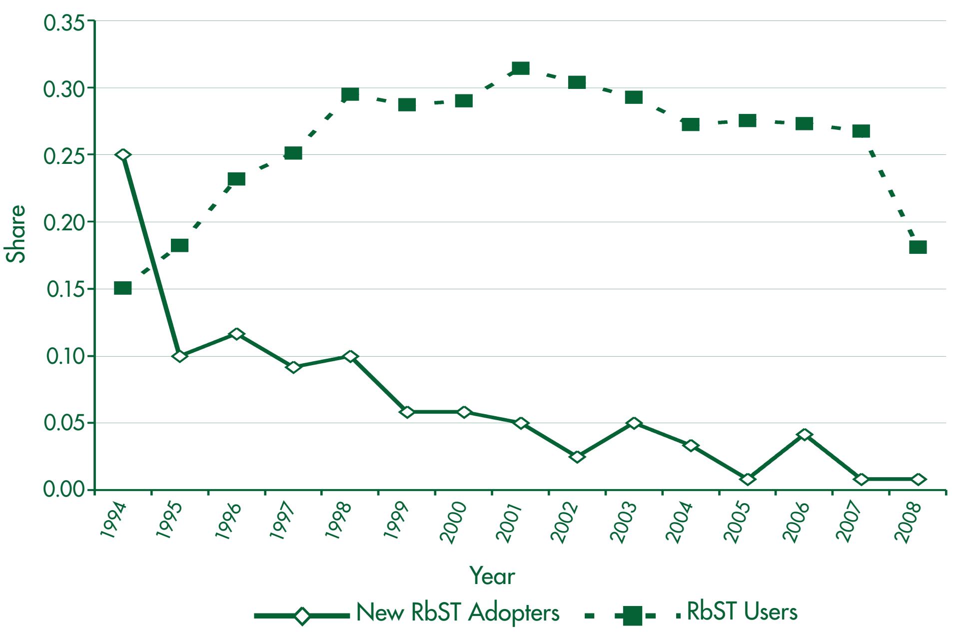
The 2008 Survey and Preliminary Results

We conducted a survey of California dairy producers in the spring of 2008 to determine the extent of rbST use and the impact of supply and demand shocks on the use and adoption of rbST. We sent surveys to approximately 1,400 dairy producers in California and received 256 responses. Producers currently running a dairy operation completed 243 of these surveys, for a response rate of approximately 18%.

The main focus of the survey was to determine the state of technology use on California dairy operations, with an emphasis on rbST. We asked questions related to the timing of rbST adoption and diffusion; the reasons for adopting and/or disadopting rbST, if applicable; the effect of the rbST shortage in 2004; and cooperatives' embargo on rbST use. Our main result is that rbST use in California is on the decline. The confluence of low profitability, increasing consumer backlash, and a shifting of demand toward more natural milk has led many dairy producers to conclude that rbST is not an effective technology.

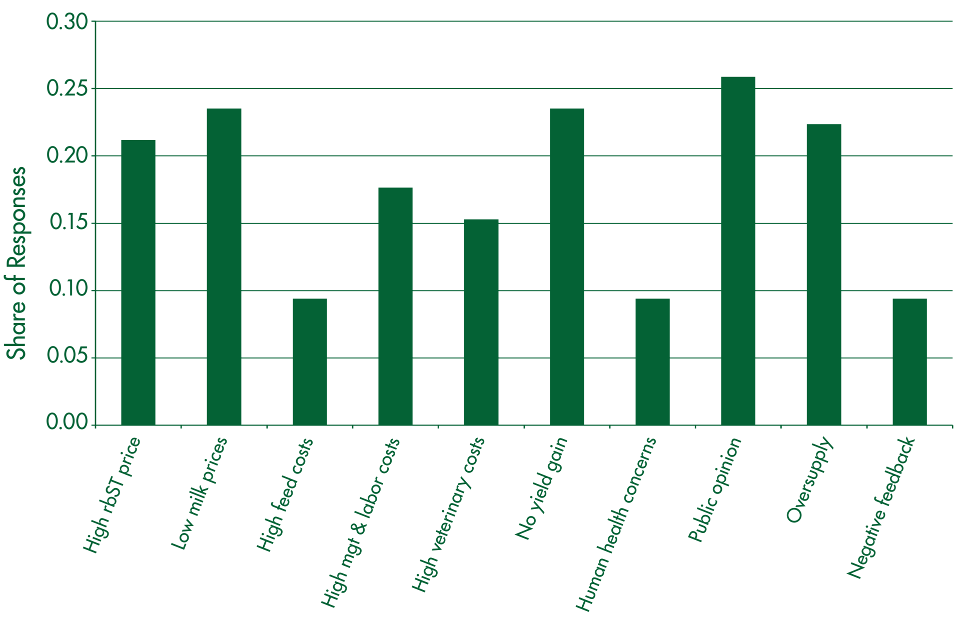
Our results show that 42% of all respondents have used rbST at one point in time. Figure 2 shows the share of new adopters by the year of rbST adoption as well as the share of producers who are using rbST. In 1994, 25% of the producers who had ever used rbST adopted it the first year it was available.

Figure 1. RbST Adoption and Diffusion



Source: Authors' calculations

Figure 2. Reasons for Disadopting RbST



Source: Authors' calculations
Note: Respondents were allowed to select more than one reason as being "very important" in their decision to disadopt rbST

After 1994, the number of new adopters decreased but was steady until 1999. Thereafter, the number of new adopters was small and decreasing. More than 75% of all adopters did so by the year 2000. Regarding rbST diffusion, in 1994, 15% of dairy producers were using rbST. Peak rbST use occurred in 2001, when just over 31% of producers were using rbST. The share of producers using rbST has declined since 2001 and was 18% as of 2008.

Slightly over 17% of respondents were still using rbST at the time of our survey. On average, these producers treated 47% of their herd with rbST, which is higher than the figures obtained in earlier surveys. Another figure that has increased is the share of disadopters: 35% of producers in our survey had disadopted rbST. The reasons for disadopting are varied, and Figure 2 shows ten possible factors and the share of respondents who claimed that particular reason was a "very important" determinant in their decision to disadopt rbST. Our results suggest that the most important factors leading to disadoption are: high price of rbST (21%), low milk prices (24%), no yield gains (24%), fears about negative public opinion (26%), and an oversupply of milk (22%).

The effect of the 2004 shortage on rbST was severe: over 80% of our respondents said that the shortage had a negative effect on their rbST usage. These negative effects included delaying the onset of rbST use, treating fewer cows with rbST, and injecting rbST every 28 days instead of the prescribed 14-day cycle. Moreover, just over 9% disadopted rbST as a direct result of the shortage.

Many of the milk producers surveyed were asked by their buyers to stop using rbST, whether or not they were actually using it at the time. Of the current users, fewer than 10% were asked to stop using rbST. However, over 45% said that their buyer offered a premium for rbST-free milk, ranging from $0.05–0.35 per hundredweight of milk.

Due to the small sample size, the robustness of our results and representativeness of California's dairy producers cannot be assured. However, our results on rbST adoption and diffusion are consistent with those collected at the national level.

Conclusions

The major trends that emerge from our survey data are: first, rbST use has declined both in terms of the number of users and the intensity of use; second, demand pressure from retailers and processors has played a significant role in the producer's technology choice decision; and third, many producers believe the future of dairy production in California will not include rbST.

RbST has been in use for nearly 15 years now, but it appears that its future as part of the management system on California dairies is in jeopardy. Results from our latest survey show that rbST is being used on the smallest share of dairy operations since its commercial introduction in 1994. Future work on this data set will consist of estimating the determinants of rbST adoption and disadoption; the effects of the 2004 rbST shortage; and the factors that affect the diffusion of rbST at the individual and state level.

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The Emerging Global Biofuel Industry: The Biofuel Situation and Policies in Developing Countries

Carl E. Pray and David Zilberman

This article summarizes a consensus of views emerging from the conference—The Biofuel Situation and Policies in Developing Countries—sponsored by the Giannini Foundation of Agricultural Economics and the Energy Biosciences Institute (EBI), which convened in Berkeley, California, on May 7–8, 2009.

Agriculture in the 21st century faces two huge challenges. The first is the "traditional" challenge of feeding people. The world population is growing and more importantly, as the populations in developing countries get richer, they demand more meat. The feed required for these animals multiplies the demand for grain. The second "new" challenge to agriculture is to satisfy the demand for biofuels. The demand for liquid fuels for vehicles is growing even more rapidly than demand for food, and the size of the fuel market is enormous. The extraction of oil is increasingly difficult and expensive. The uncertainties about oil supply and prices, the growing, stricter constraints on fossil fuel emissions, and the success of Brazil in producing biofuels from sugarcane have created a demand for clean liquid fuels.

In the recent past agriculture has been able to meet the challenge of the increased demand for food, fiber, and beverages. In the early part of the 20th century, that challenge was met through expanding the area under agricultural production. In the latter part of that century, production increased primarily due to increased yield per acre. These yield increases can be attributed to the application of science to develop new fertilizer and water-responsive varieties of crops, new management practices, along with the application of industrial inputs such as farm machinery, irrigation equipment, fertilizers, and chemicals. However, since 2006, the increased production of biofuels was correlated with a rapid increase in food prices, which raised concerns that agricultural supply cannot keep up with these increased demands.

The Potential

The good news is that there is potential to dramatically increase agricultural supply. The productivity of existing animals, such as swine and cattle, and crops, such as rice, wheat, corn, oil palm, and sugarcane, is likely to increase because of new knowledge about the biology of plants, animals, disease, plant pests, and soils. There is evidence of substantial progress in productivity growth of sugarcane in Brazil and oil palm in Malaysia. Also, major investments are being made in genomics, molecular breeding, and tissue culture to ensure that these productivity increases continue.

In addition, studies have identified vast genetic potential for productivity increases in production of biofuels with crops that have not yet been exploited such as miscanthus, jatropha, and algae. Farmers and scientists in China already have considerable experience with miscanthus and have found extensive biodiversity that can be exploited. Likewise, researchers on jatropha in India discovered an enormous amount of genetic variation, and both the public and private sectors are carrying out major efforts to develop the best cultivars and management practices for efficient cultivation of the crop. Recent advances in biotechnology enable improving the productivity of these new crops at a faster rate than was feasible in the past.

The other good news is that there is land available for expanding production of food and biofuels, some of which had been cultivated in the past but abandoned for political or economic reasons. From an environmental perspective, this land is attractive for biofuel (and food) investments because its carbon debt has already been paid. Other lands are being cultivated in very extensive types of agriculture and could be more intensively cultivated with the addition of irrigation, fertilizer, and/or better management. In addition, major areas of Africa, Latin America, the former Soviet Union, and Southeast Asia have not been cultivated for a variety of reasons, including low population densities, wars and political instability, lack of infrastructure, soil problems (aluminum toxicity in the savannas of Brazil and Africa, salinity in some Asia soils), and disease and pest problems. Improved political situations and new methods will allow expansion of farming to some of these uncultivated lands. However, in some areas, it may be necessary to use rangeland or even forests to meet our agricultural needs.

To be economically viable and overcome regulatory constraints, new biofuels need to utilize low-cost feedstock and biomass, relying on economical conversion technology requiring relatively low quantities of energy (below 30% of the energy content of the fuel produced). Companies (Amyris), public/private research partnerships (EBI), and public institutions

(Chinese Academy of Sciences) are currently developing conversion technology using various approaches, and they report promising results.

Necessary Investments and Institutional Changes by the Private Sector

Taking advantage of the opportunities for expansion of food and biofuel production through increasing agricultural productivity, land cultivation, and increasing biofuel conversion will require private firms, governments, and civil society to make a number of difficult decisions.

The demand for more food and biofuels, coupled with new and more productive crops and available lands for agricultural production, presents important opportunities for small and large firms alike to increase their incomes. Recent studies show evidence that sugar mills, sugarcane farmers, and laborers in Brazil have all benefitted from the expansion of biofuels production. Simulation studies of the impacts of increased biofuel production in China and Mozambique predict that small farmers could obtain substantial benefits from biofuel production in those countries. However, the extent of the benefits depends on the type of crops and the structure of landholdings.

The development of new biofuel products requires investments in research and technology development in various components of the supply chain. Private firms need to make major investments in feedstock and biofuel production, biofuel transport and storage facilities, and biofuel distribution capacities. Indeed, BP is making investments in biofuel production in the United States, Brazil, and the UK, partnering with universities and specialized firms. The oil palm industry in Southeast Asia has established an organization for sustainable oil palm production, which will conduct research to develop sustainable practices and will work to certify plantations as sustainable.

The introduction of biofuels is leading to the development of new industrial structures, which integrate different types of industries. These new structures are evolving, in search of efficient ways of linking a range of operations, from farms to filling stations. As part of this restructuring, oil companies are buying into agricultural production firms, and BP is forming a joint venture with Brazilian sugar mill companies to build two ethanol production facilities in Brazil.

A particular challenge is the design of institutions for expanding feedstock production. Should feedstock be produced in plantations, which may be most efficient and most attractive to foreign investors, or should they be produced by contracting with smallholders? Contracting may sacrifice some efficiency, but will be more appealing to consumers and environmentalists in the developed countries and more attractive to politicians in the developing countries who would have to approve these investments. Maybe some sort of hybrid, such as a nucleus estate with smallholders surrounding it, would work best. A Mozambique study suggests that contracting with smallholders has a more direct impact on reducing poverty than a plantation, but that plantations also would benefit small farmers through various types of spillovers.

Important Government Investments and Policies

Governments have the unenviable role of balancing the goals of food security, energy security, social equity, and an improved environment. To meet the food and energy security goals, governments have to make decisions on investments in infrastructure, farm and biofuel subsidies, and research on agricultural productivity and biofuels. For example, weak rural infrastructure such as roads and communication are major constraints to food and biofuel production in Africa. Subsidies can induce major increases in food and biofuel production and farmer incomes, but they do so at the expense of taxpayers and other potential government programs. Investments in biofuel production research are necessary, as are investments in food crop research and programs to train scientists working on both food and biofuels so that new funds for biofuel research from the private sector do not overrun local scientific capacity.

Governments and the societies that they represent will have to deal with a range of contentious issues. Should they provide subsidies and tax breaks to encourage biofuel production? Many people applied for, and were approved to receive, biofuel subsidies and tax breaks in Malaysia, but only a few went into production (and most of these are currently idle due to low oil prices). Should governments implement biofuel mandates? Mandates are now on the books in many countries in Africa, Latin America, and Asia. However, with the exception of China, these policies have not been implemented, and even in China they have had limited impact because the government has permitted only five biofuel production facilities to start operating.

Should governments try to pick winning technologies and support them by handing out subsidies or grants to investors? In earlier fuel crises, the U.S. government supported numerous wind power companies—all of which are out of business now. Recently, U.S. corn ethanol producers such as VeraSun and Northeast Biofuels have filed for bankruptcy after years of government support. Brazil's choice to push a sugarcane-based ethanol industry is a rare example in which the government actually did pick a winner.

Should food crops even be used for biofuel production? The governments of China, India, and South Africa have announced that they will not support the use of food crops for biofuel production. Consumers in these societies generally support these policies, as do the consumers of biofuels in developing countries. Farmers, however, producing crops such as sugarcane, corn, and oil palm do not support such restrictions, and where they are politically strong, such as in Malaysia and Brazil, no such restrictions exist.

What types of land can be used for biofuels and who can use it? The central governments of China and India say that biofuel production should be restricted to wastelands. However, there is evidence in both countries that provincial governments are considerably less restrictive and welcome the use of forests, pastures, or agricultural land for biofuels. Malaysia has very strict regulations on the use of forests for oil palm plantations. Indonesia has similar regulations, but has a much more difficult job of enforcing these standards. Land-use conversion to biofuel production may cause a significant net increase in greenhouse gas (GHG) emissions. Should governments establish conversion criteria based on these emissions or other measures of societal net benefits?

Who should be allowed to invest in biofuel and food production and under what conditions? Should governments approve investments by oil companies (BP, Shell), foreign sugar companies, sovereign wealth funds, and major foreign concerns (the Daewoo Corporation, China National Cereals, Oils and Foodstuffs Corporation (COFCO))? Or should governments restrict investments to large government oil companies, local private companies, and large local plantations? Will these companies be allowed to buy land, buy local food companies, or become joint venture partners? The recent political turmoil in Madagascar following the decision to lease 3.2 billion acres to Daewoo for agricultural development shows how contentious this issue is.

The economics of biofuels and energy are affected by trade and agricultural policies. For instance, the U.S. import tax on ethanol has enhanced corn ethanol production in the Midwest and reduced imports from Brazil. The Brazilian biofuel sector is likely to thrive under a free trade regime, while protectionist policies in the United States and Europe may reduce overall biofuel production and, in the short run, lead to local expansion of biofuel crops, replacing food crops in these developed countries.

Biofuel policies are forcing countries to deal with a number of key environmental trade-offs. All policies, even the status quo, have environmental impacts. A business-as-usual scenario implies extensive GHG emissions from fossil fuels and from agriculture (particularly animal agriculture). We could stop consuming palm oil, which could save orangutans in Indonesia, but greatly increase soybean production in Brazil and reduce the Brazilian rainforest. Biofuels could lead to a reduction in GHGs by replacing part of the fossil fuels, but now studies have shown that biofuels can contribute to GHG accumulations if they are not produced in an efficient, low-impact manner. Furthermore, biofuels can directly and indirectly lead to the destruction of the rainforests of Borneo and the Amazon, and the biodiversity in those rainforests. So, the choice is not whether or not to have environmental impact, the choice is what environmental impact is society willing to tolerate in order to have food, fuel, and reduced GHGs.

Not all biofuels are alike; some may generate more GHG emissions than they save, so regulation of the environmental side effects of biofuels matters. Researchers compare three policy regimes. One is cap and trade in GHG emission permits that will price fuels and give cleaner fuels an edge. Another is a low-carbon fuel standard (like California's standard aiming to reduce emissions by 10%), which considers both the direct and indirect GHG effects of various fuels and discriminates in favor of sugarcane biofuels versus corn biofuels, and Arabian oil versus oil produced from tar sands. A third policy is developing biofuel standards and setting a mandate of a certain percentage of fuel use dedicated to biofuels. This policy does not discriminate between cleaner and dirtier biofuels or oils, and may, in the long run, increase the GHG emissions per unit of energy as the fraction of oils produced from tar sands and shale increases. The likely choices of environmental regulation influence research, crop management, and conversion technology selection as new biotechnologies are introduced in the United States, Brazil, and Malaysia.

What Does It Mean to California?

Biofuels expand the range of agricultural products, and will lead to integration of the agricultural and energy sectors, as well as the emergence of integrated sets of agricultural, environmental, and energy policies. Renewable fuel and carbon regulation in California are in the forefront of these policies, both in the United States and globally. California agriculture is not likely to be a major producer of biofuel crops, but California forest, and perhaps rangeland, may be utilized to produce biofuel products in the future, once cellulosic conversion technologies are fully established. However, the primary gain to California will stem from its relative advantage in the knowledge sector, which places it in the forefront of development of improved genetic material for biomass production and new conversion technologies for biofuels. Thus, development of biofuels and expansion of their use, as part of a strategy to reduce dependence on fossil fuels, are likely to be important elements of an emerging renewable energy sector in the state.

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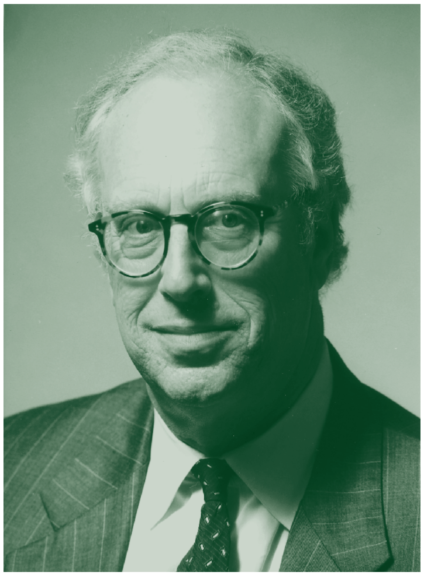
Faculty Profile: W. Michael Hanemann— Climate, Water, and Ties to the Value of a Good Dessert

by Max Auffhammer



W. Michael Hanemann
Professor
Agricultural and Resource Economics
UC Berkeley

If one counts citations to journal articles, W. Michael Hanemann is the single most successful environmental and resource economist of our time. He made seminal contributions in not just one, but three areas of environmental economics. He was the leading figure in developing methods to quantify the value of environmental amenities not traded in markets. If a court needs to determine how much a polluter should have to pay for accidentally destroying or damaging an ecosystem, methods developed by Michael, his colleagues, and many students allow one to put a dollar amount on these damages. His work and expertise were instrumental in assessing how much the public is willing to pay for the preservation of Mono Lake or how much Exxon should be forced to pay to make up for the environmental damages from the Exxon Valdez disaster.

Second, Michael has been a leading expert on water resources in California. For years he served as the economic adviser to the state water quality control board. His work on drainage in the 1980s was instrumental to the implementation of landmark conservation and land use regulations for the Central Valley. In the 1990s his work provided the intellectual basis for moving toward tiered urban water pricing. Michael was also a key figure in facilitating water transfers from the Imperial Irrigation District to San Diego.

Most recently, Michael has made seminal academic contributions to the study of climate change and helped shape the state's climate change policy in his role as the director of the California Center for Climate Change. In his research, Michael refuted several major studies, which argued that the impacts of climate change on agriculture are likely to be negligible. By paying close attention to the role of irrigation and the damaging effects of extreme heat days on crop yields, he and his coauthors showed that U.S. agriculture is likely to suffer significant losses from climate change. Due to his work, it has been shown that both the agricultural and water sectors of the California economy will suffer severe stress from climate change. These studies ultimately provided the basis for justifying California's stringent and cutting-edge climate regulation.

Michael was born in Manchester, England in 1944. He gained his bachelor's degree in philosophy, politics, and economics from Oxford University in 1965. Two years later, he obtained a master's of science degree in development economics from the London School of Economics (which Mick Jagger is rumored to have attended at the same time). He left England for Cambridge, Massachusetts, where he gained his doctorate in economics in 1978. As is typical for Michael, he did not shy away from taking on multiple challenges at the same time, and started his appointment as assistant professor at UC Berkeley's agricultural and resource economics department in 1976. He was awarded tenure in 1984. He currently is the Chancellor's Professor in ARE and the Goldman School of Public Policy.

W. Michael Hanemann
Age Four

On a personal note, Michael has been married to his lovely wife Mary, who is a private banker, for 39 years. Michael at a young age (pictured at age four above), started wearing a suit and tie at all times —on a Saturday at the office, while taking surveys and measuring sand dunes at Southern California beaches, and while hiking in Yosemite. Further, he has developed a great passion for dessert and chocolate. As Mary notes, "the best way to have Michael adore and admire you forever is to go to lunch with him, order a chocolate dessert, and then tell him you're too full to eat it! He will be your friend and dining companion for life!" Finally, Michael is an avid traveler, omnivorous reader, and a treasured colleague, mentor, teacher and friend.

Professor Hanemann can be reached by e-mail at hanemann@are.berkeley.edu.

Agricultural and Resource Economics
UPDATE
GIANNINI FOUNDATION OF AGRICULTURAL ECONOMICS • UNIVERSITY OF CALIFORNIA

Department of Agricultural and Resource Economics
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One Shields Avenue
Davis CA 95616
GPBS

Published by the Giannini Foundation of Agricultural Economics

http://giannini.ucop.edu

ARE Update is published six times per year by the Giannini Foundation of Agricultural Economics, University of California.

Domestic subscriptions are available free of charge to interested parties. To subscribe to **ARE Update** by mail contact:

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