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Challenges to World Agriculture in the 21st Century

by Alex F. McCalla

World agriculture in the 21st century will face three major challenges: how to feed a growing world population, how to contribute to reducing the still–high prevalence of rural poverty in the world, and how to respond to increased concerns about managing the natural resource base.

Challenge I: Global Food Security

The first and continuing challenge facing world agriculture is to produce enough food to feed the growing world population. World population could reach eight billion people by 2025. Nearly all of the increase of two billion people in the next 25 years will be in developing countries.

The urban population in developing countries will rise by a like number. The implications of urbanization are significant for the food system. It is estimated that people living in rural areas depend on their own production for more than 60 percent of their food supply (only 40 percent is purchased in the market). People living in urban areas, however, depend on the market for close to 90 percent of their food supply. So every time one person moves from a rural to an urban setting, needed market supplies must increase by a factor of two.

Where will this food come from? If trends of the last 50 years continue, expanded trade will not be the answer. Since 1960 world grain production has more than doubled, and world grain trade also doubled. Thus the share of world grain consumption that is traded remained constant at about ten percent. This says that on average, 90 percent of the world food production is consumed in the country where it is produced. If this trend continues, then it is clear that most of the increase in the food production must come from production systems in the countries where the additional people will live.

And where will they live? Most of the population growth between 2000 and 2030 will occur between the Tropic of Capricorn and the Tropic of Cancer, in countries that are still experiencing rapid population growth.

Putting these two "facts" together suggests that most of the food needed to meet increased needs in the next 25 years must be produced in tropical and subtropical farming systems. We know that these systems are complex, highly heterogeneous, fragile, generally low in productivity, and dominated by small-scale, poor farmers. And to make

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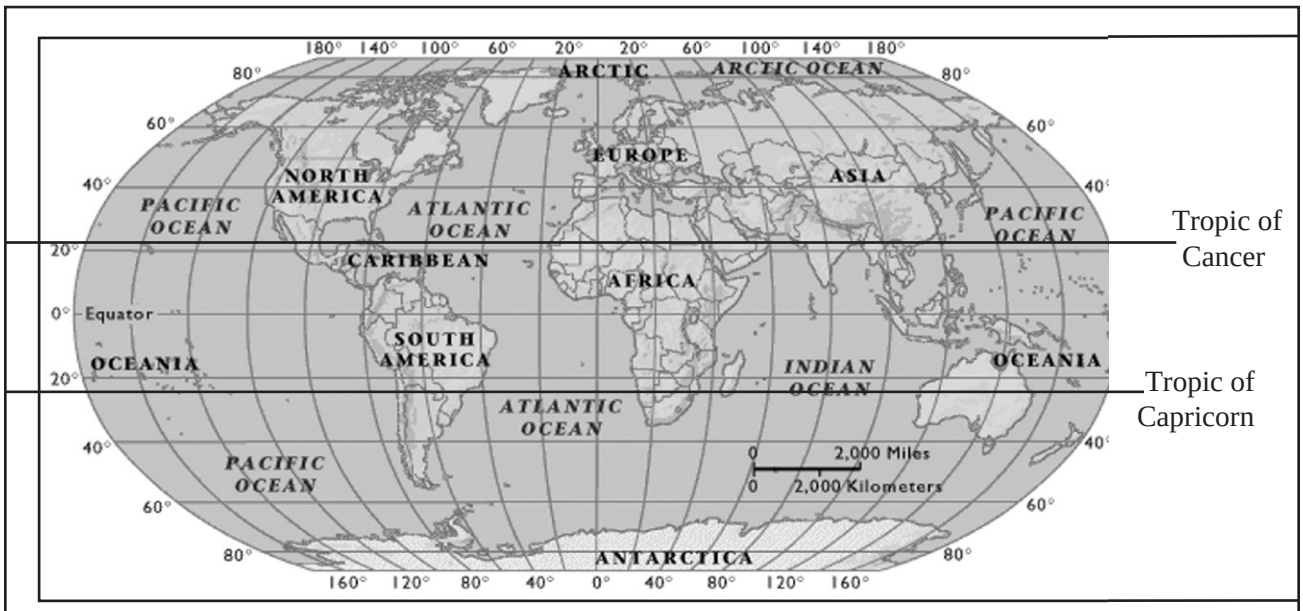

On average, 90 percent of the world food production is consumed in the country where it is produced. Most of the population growth between 2000 and 2030 will occur between the Tropic of Capricorn and the Tropic of Cancer. Map by MapQuest

things more complicated, we know much less about farming systems in these regions than we do about systems in temperate regions.

So the food production challenge ahead is not small or easy. It requires increasing the productivity of complex, low–yielding farming systems in ways that do not damage natural resources or the environment.

Challenge II: Poverty Reduction

Despite the rapid urbanization projected to occur in the coming decades, it will be 2015 before as many people live in urban areas as in rural areas. As of today, some 70 percent of the poor are still rural dwellers, the majority of whom draw some or all of their income from agricultural activities. Literally billions of small and generally poor farmers live in poverty or near the poverty line.

Therefore the second challenge facing global agriculture is to develop technologies, policies and institutions that contribute to unleashing agriculture's full potential as an engine of growth. Meeting this challenge will require farmers to have access to both domestic and international markets.

Challenge III: Sustainable Natural Resource Management

The third challenge to agriculture in this new century is to create a set of technologies, incentives and policies that encourage small–scale farmers to want to pay attention to the long-run stewardship of the natural resources they manage. This is critical because farmers use most of the world's arable land and are involved in managing much of the world's forest and range land. Agriculture uses more than 70 percent of the world's fresh water, and much biodiversity is contained in agricultural systems. Agricultural activities influence the boundaries of forests and deserts. Therefore, the question of improving the management of our natural resources is intimately tied to improving the productivity and profitability of small-scale farmers in the developing world.

How Did World Agriculture Meet Past Challenges?

The performance of agriculture over the last 200 years has been phenomenal. World population has increased six-fold, and global agricultural production has more than kept pace. Falling real grain prices for most of the 20th century are evidence of that success. The sources of increased food production, however, have changed. For example, for most of the 19th century, increased output came from expanding the land area in production, and that expanded area was primarily located in "newly settled areas"—the Americas, Southern Africa and Australia. Science–based agriculture is really a product of the 20th century. The new technology—mechanical, biological, and chemical—came in different forms and was adopted in different sequences in different parts of the world. It led to phenomenal increases in yields in some parts of the world.

Land area expansion as a contributor to increased

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California Agriculture Faces a Rough Financial Year

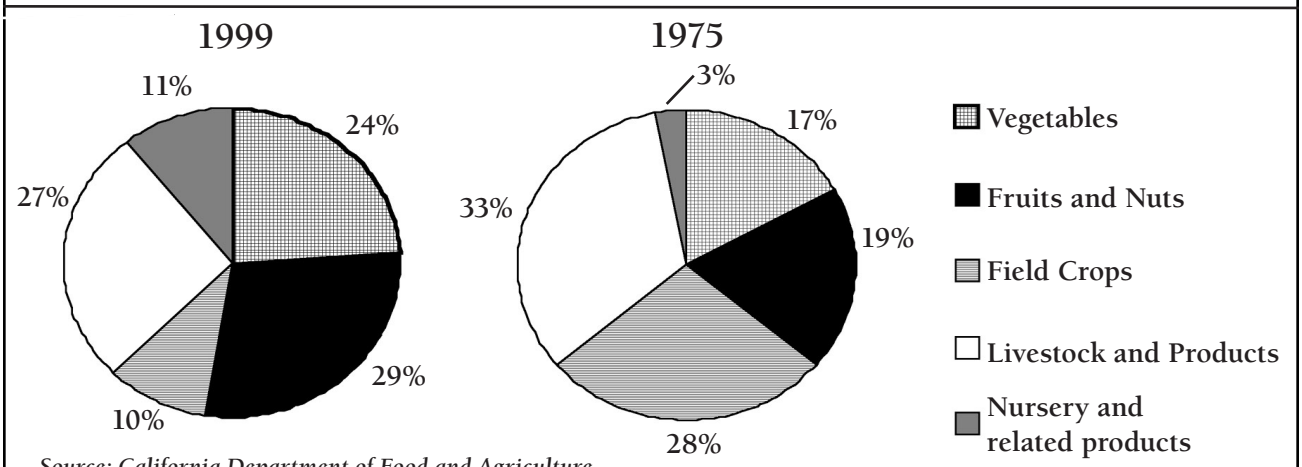
by
Warren E. Johnston and Daniel A. Sumner

California agriculture continues to struggle with low output prices, higher energy prices, uncertain supplies, and higher prices for other inputs as well. In part, California farm prices are in the same cyclical downturn that has gripped much of the rest of U.S. agriculture. Commodity prices tend to be linked by both supply and demand factors, and some of the same forces that drove down field crop prices (good global harvests and the Asian financial crisis) also caused problems in California. But, there are also some special factors in California and some commodity-specific events that continue to affect returns and risk in California agriculture. Full returns and cost data for year 2000, when final figures become available, are likely to be at least as dismal as the data for 1999 —and year 2001 results are expected to be no better.

The depth, breadth, and length of the current down–cycle has surprised and frustrated producers, processors, investors, financiers and analysts alike, following a run of growth in production and net returns earlier in the past decade. The value of California agricultural production grew significantly for most of the 1990s, starting at about $20 billion in the first half of the decade and growing to $27.2 billion by 1997, before slipping back to about $26.8 billion in 1998 and $26.7 billion in 1999 (in nominal terms). In 1998, the El Niño chopped output; in 1999 and 2000, crops rebounded but prices dropped. California net farm income has bounced up and down throughout the last decade. According to USDA figures, net farm income reached a peak of $6.2 billion in 1997, but fell to $5.8 billion in 1998 and then to just below $5.0 billion in 1999 (all in nominal terms). Lower net farm income in recent years has been driven by increases in major variable cost outlays for manufactured inputs (fertilizers, chemicals, petroleum fuel and oils, electricity), and for cost categories reflecting the increased intensification of California agriculture—for feed purchases, for machine hire and custom-work, for marketing, storage and transportation expense, irrigation water and for contract and hired labor.

Increased gross value of production has been a long-term trend reflecting, in part, continued intensification in the use of land. Over the last several decades, growers have shifted from land extensive crops to vegetables, perennial tree and

Figure 1. California Agricultural Production, 1999 vs. 1975



Source: California Department of Food and Agriculture

vine crops, floricultural products and intensive livestock production. Figure 1 illustrates this shift. For example, as late as 1975 field crops accounted for 28 percent of the value of California agricultural production. That has fallen to about 10 percent now. The only field crop to make it into the top 10 list of important commodities in California is cotton, and even cotton production dropped off the list in 1998. The gain has been spread among fruit, nut and vine crops, vegetables and, especially nursery and related production. Among the livestock crops, intensive dairy production has continued to expand while the sheep industry has shrunk and the beef industry has maintained its importance, especially as a pasture-based industry in the more remote regions of the state.

The shift towards perennial crops and intensive livestock production requires higher levels of investment and development costs, lags in the receipt of income due to nonbearing periods for trees and vines, and less ability to adjust to changing product prices. This increased investment per dollar of output means interest rates have become an important concern in California. Debt to assets ratios for California's farms and ranches is considerably higher than U.S. averages, in part due to more costly investments in land and improvements; hence, interest costs have risen while financial ratios have deteriorated over the past several years.

USDA indicators for 1998 and 1999 show moderately increased financial stress in response to lower farm commodity prices that began generally with the 1996-97 crop year. While financial stress indicators are rising, they are, however, at levels less than those of the farm recession and cost squeeze phase of the 1980s, due to restructuring and more conservative approaches toward credit. Still, year 2000 had the prospect to further elevate financial stress indicators for major portions of California agriculture experiencing weaker markets or higher costs of production, and we expect 2001 outcomes to be similarly affected.

Decisions for the 2001 production year have been difficult. In addition to generally weak price expectations, producers have been influenced by real uncertainties about both water and energy availability, the loss of processing capacity for important crops such as tomatoes, sugar beets, peaches and pears, competitive pressures in export markets, and concerns about pests and disease outbreaks here and abroad. Producers have been scrambling to find financially attractive alternatives and are moving ahead with planting decisions in a very risky environment.

Certain supply side issues are always a concern in California agriculture. These issues include concerns about over-plantings in perennial tree and vine crops, continued tensions about future water allocations, loss of processing or marketing outlets, access to adequate seasonal farm labor, the spread of exotic pests and diseases, higher interest rates and ever tighter environmental regulation. On the demand side, concerns center on the continued strength of U.S. economic growth, competition from foreign suppliers, and access to export markets.

Table 1. California's Top 20 Crop and Livestock Commodities 1975 and 1999

Rank	1975	1999
1	Cattle/Calves	Milk/Cream
2	Milk and Cream	Grapes
3	Cotton Lint	Nursery
4	Grapes	Cattle/Calves
5	Hay	Tomatoes, all
6	Tomatoes, proc.	Lettuce, all
7	Eggs, chicken	Strawberries
8	Nursery	Flowers/Foliage
9	Rice	Hay
10	Lettuce, head	Almonds
11	Sugar beets	Cotton Lint
12	Wheat	Carrots
13	Oranges	Chickens
14	Flowers/Foliage	Oranges
15	Barley	Broccoli
16	Peaches	Avocados
17	Potatoes	Chicken, Eggs
18	Almonds	Peaches
19	Strawberries	Rice
20	Tomatoes, fresh	Cantaloupe

Source: California Department of Food and Agriculture (CDFA)

Current Issues Affecting California Agriculture

California agriculture will be affected by how several public policy issues play out over the next

Table 2. Gross Agricultural Value and Net Income, 1990–1999 (in Billions $)

Year	Value of Agr. Production	Net Farm Income
1990	20.0	5.7
1991	18.6	4.2
1992	20.0	5.2
1993	21.5	6.0
1994	22.4	6.0
1995	23.3	4.9
1996	25.2	6.0
1997	27.2	6.2
1998	26.8	5.8
1999	26.7	5.0

Source: CDFA

few years. These include hired farm labor and immigration, North American economic growth, exchange rates, World Trade Organization (WTO) negotiations, crop insurance subsidies, direct payments for field crop farmers, water issues, environmental regulations and food safety regulations.

Demand for hired farm labor will continue to grow as the shift to more labor-intensive crops continues and mechanization proceeds only gradually. Hired farm wages crept up very slowly until recently, but significantly higher labor costs seem on the horizon. This is both a matter of border policy and economic conditions in Mexico. A guest worker program will allow more security, but is unlikely to lower labor costs.

On the demand side, continued economic growth in the U.S. underlies whatever strength there is in markets for produce, meats and other foods and ornamentals. The recent downturn in the U.S. macroeconomic picture is also troubling, especially for winegrapes and other income–sensitive products. For the future, improved income growth in poor countries and expanded access in other markets are crucial. The value of the U.S. dollar has been strong relative to the Euro, but on a California farm–trade weighted basis (which emphasizes the yen, Canadian dollar, peso and won) it was not stronger in 2000 than in 1999.

The importance of market access for exports is illustrated dramatically by the success of the California rice industry. For two years, the industry resisted the price collapse facing long–grain rice grown in other states in large part because of an assured WTO–created market in Japan. Potential import competition will also continue to be an issue for many commodities, including garlic, canning peaches and dairy products.

Government subsidy programs are less important in California than in most of the U.S., but that does not make them irrelevant. The doubling of direct "contract" payments and the generous use of the marketing loan programs have shifted several hundred million dollars to field crop producers in California. Recent legislation has also increased the subsidy for crop insurance or other risk management tools, and the Congress has targeted new programs for crops that have not had such subsidies in the past. Unfortunately, crop insurance subsidies have the potential to create industry disruption if not applied carefully, and many California industries have expressed reluctance to accept the proposed programs even if they include large insurance premium subsidies. This is an issue to watch carefully, as growers may find it profitable to farm the insurance subsidies by planting outside the most suitable regions or adopting other risky cultural practices.

Once again, California agriculture faces water supply uncertainties in 2001. Critical legal and political problems always affect water for California agriculture. Reduced water availability, rising uncertainties and increased costs could reduce economic returns and the capitalized value of assets in areas dependant on surface water.

Environmental and food safety regulations are expanding steadily and concerns about their effect on profitability continue. The dairy and beef feedlot industries face animal waste regulations that continue to raise production costs and affect location of facilities. Stronger federal regulation may, however, help the relative position of California producers. The range-based livestock industries face non-point source pollution issues related to small streams and watersheds. For the produce industry and other food crops, the implementation of the Food

Over the last several decades, growers have shifted from land extensive crops to vegetables, perennial tree and vine crops, floricultural products and intensive livestock production.The shift towards perennial crops requires higher levels of investment and development costs, lags in the receipt of income due to nonbearing periods for trees and vines, and less ability to adjust to changing product prices.

Quality Protection Act continues to be the central focus of concern. If current pesticides are pulled off the market, many major California industries will find it hard to find substitute materials because the costs of acquiring regulatory approval for chemical manufacturers is just too high relative to potential revenues.

Asset Values

Asset values are affected by changes in commodity prices and production costs. If recent plantings of trees and vines result in production in excess of market demands, commodity prices will fall, decapitalization will affect the less productive orchards and vineyards, and marginal plantings will be removed. Despite the recent price drops and cost increases, according to available data, the average value of land has not decreased in most production areas. However, the "spread" between low and high prices for a given class of land in a given region may widen as changing expectations influence buyers and sellers. Recent reductions in interest rates provide some support for asset values and land rents as lower interest rates mean reduced operating costs and higher capitalization rates. With lower commodity prices, land rent reductions were an active topic in lease renewal negotiations for the 2001 crop year. Share rents are reduced and cash rents less available from financially stressed producers.

Conclusions

The current 2001 crop year is a challenge for producers, and others involved in California agriculture. California producers have worked through down cycles in the past. We can expect well–managed firms to maintain or regain profitability on the upturn. Agriculture is cyclical, but there is nothing very regular about the cycles. Farm returns will turn up again, we just do not know when. Outcomes of public policy issues can influence the timing and the strength of the rebound when it does occur.

Pointers to watch for are continued economy–wide income growth in North America, a bad harvest or supply problems elsewhere in the world, less-than-perfect weather here in California, renewed economic growth in Japan, and robust growth in the rest of Asia. Better access to markets in China will also help. Things may get worse before they get better if a slow down in North American economic growth sharply affects domestic demands, if Japanese growth slows even further, or if very large California crops overwhelm demand growth.

Warren Johnson is an Emeritus Professor in the ARE department at UC Davis. He can be reached by e-mail at: warren@primal.ucdavis.edu or by telephone at (530)752-1535. Daniel Sumner is the Frank H. Buck, Jr. Professor of Agricultural Economics at UC Davis. He is also the director of the Agricultural Issues Center. Dr. Sumner can be reached by e-mail at: dan@primal.ucdavis.edu or by telephone at (530)752-5002.

Key Economic Issues in Commodity Tree-Pull Programs

by Matt A. Andersen and Richard J. Sexton

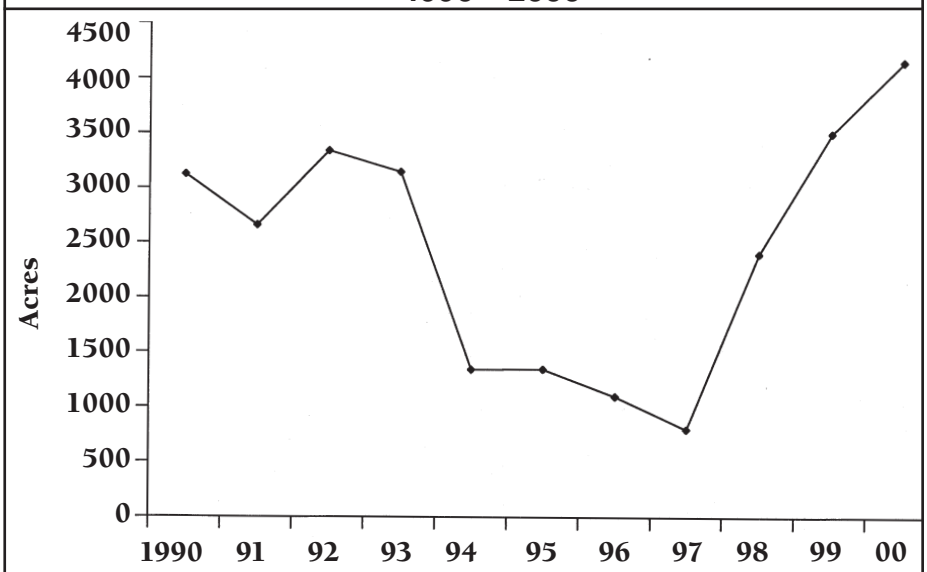
An important trend in California agriculture during the 1990s was the shift of agricultural land from annual crops, such as grains and cotton, into perennial tree fruit and nut and vine crops. This trend was caused by superior profitability of these crops relative to most annuals during this time period. See the lead article in this issue of *ARE Update* for further discussion of this and other key trends in California agriculture.

A not surprising outcome of the increased plantings in perennials is that supply has now increased relative to demand for most of these commodities, causing low prices and profitability. Oversupply problems are especially troublesome for perennials because the up-front costs of establishing the orchard represent a large percentage of the total production costs. These costs are "sunk" in the sense that they are not recoverable even if production of the crop is halted. As a result, supply of perennial crops tends to be very unresponsive or inelastic to price changes, meaning that oversupply problems are not readily corrected by price signals emanating from the market.

Tree/vine removal programs are being considered presently by several California perennial crop industries as a way to address the oversupply problem, and increase prices and profitability. The California pear and canning peach industries established tree-pull programs during the 2000 crop year. These industries have been buffeted by slow growth in the canned fruit sector and the bankruptcy of Tri-Valley Growers, one of the major pear and peach processors in the state. The California dried plum (prune) industry is planning to operate a tree-pull program to be effective for the 2001 crop year. Several other commodities, including apples, raisins, and apricots, are also in various stages of discussion regarding programs. This article examines the key economic issues pertaining to tree/vine-removal programs.

Figures 1 and 2 focus on the cling peach industry to illustrate some typical trends for California perennial crops. Figure 1 shows that a sharp upturn in plantings of peach acreage occurred at the end of the 1990s, while Figure 2 depicts price trends over the past decade for cling peaches. For the most part, prices have been stagnant in nominal terms over the past decade, meaning that real prices and profitability have been declining. However, as the large 1998–2000 plantings begin to bear, significant price decreases are likely in the offing, unless the industry takes action.

Figure 1. California Cling Peaches Acres Planted 1990—2000

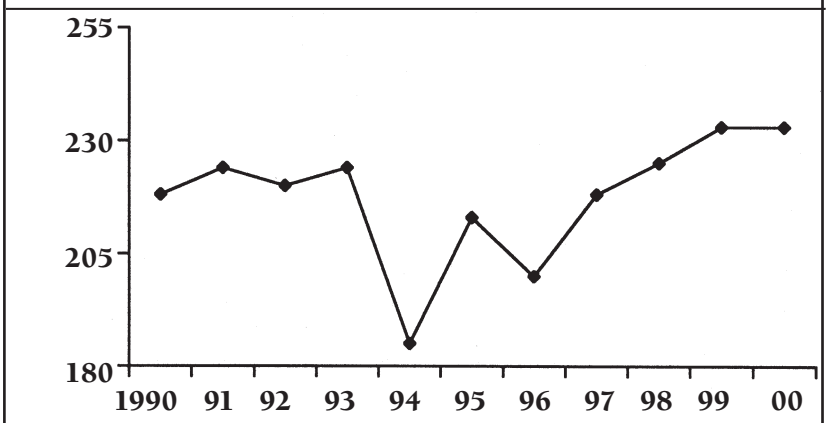


Source: California Canning Peach Association

Supply and Price Impacts

A first issue in designing and evaluating a tree/vine-pull program is the supply impact that will result from a program. The impact on supply will almost always be proportionally less than the amount of acreage removed because growers will elect to remove less productive acreage. Thus, a 10

Figure 2. California Cling Peach Prices 1990—2000



Source: California Canning Peach Association

percent reduction in acreage will result in less than a 10 percent reduction in supplies. In some cases, growers may be compensated under a removal plan for marginal acreage that was targeted for removal in any event. Imposing a minimum yield threshold for eligibility helps address this problem. A second supply–side issue concerns replanting of the affected acreage. If growers are allowed to replant pulled acreage, the programs can have the perverse effect of actually increasing supply over the long–run because newly planted acreage is inevitably more productive than old acreage. A common feature among programs under discussion now is a five-year moratorium on replanting. This provides the industry some protection against replanting, but also means that a monitoring and enforcement mechanism must remain in effect well past the actual period of implementation of the program.

The price impact from the reduction generated by a tree/vine-pull program depends upon the price responsiveness, or elasticity, of demand for the commodity. The more inelastic the demand, the greater the impact on price for a given percentage reduction in supply. Figure 3 depicts two alternative farm-level demand curves. D_1 is more inelastic relative to D_2. H^+ is the commodity harvest in the absence of a tree-pull program, and H^- is the harvest if a program is implemented. P_0 is the grower price in the absence of a program under either demand, but price rises to P_1 with a tree-pull program under the inelastic demand, D_1, but the same supply reduction only raises price to P_2 under the more elastic demand, D_2. Quite simply, tree pulls are more effective for commodities that face relatively inelastic demands.

UC Davis agricultural economists have studied the elasticity of demand for a number of the commodities. A recent estimate of the elasticity of demand for dried plums is –0.6. This means that a 10 percent crop reduction for dried plums might be expected to increase price by about 16.7 percent. Conversely, the demand for canned pears is considerably more elastic, perhaps as high as –2.0. The demand for pears for fresh consumption is likely to be less elastic than the processing demand, but the likelihood is that a tree-pull program for pears will have less of a price impact than an equivalent program for dried plums.

The immediate price impacts from a tree/vine–removal program also depends upon the amount of commodity in inventory. Most fruits are readily storable in processed or semi-processed form. Rising stocks of inventories are a sign that a commodity is in oversupply relative to demand. The first impact from a reduction in harvests will be a reduction in inventories towards the desired levels. Little price impact at the grower level will be experienced, regardless of the underlying elasticity of demand, until inventories reach the desired levels.

Organizing and Paying for a Program

The structure of a tree/vine-removal program is a crucial dimension in its ultimate success or failure. Most of the industries contemplating removal programs operate under the auspices of federal or state marketing orders. These orders allow the industry to self–regulate in various areas such as promotion, research, grading and volume regulation, if they can agree to do so. Volume regulation is the most controversial function allowed under marketing orders, and it is the least utilized. The raisin industry is presently the only industry authorized to conduct a removal program under its marketing order. Other industries could seek approval from the California Department of Food and Agriculture (for a state order) or from the U.S. Department of Agriculture (for a federal order) to add a removal feature to their order. However, approval is not certain (the state in particular has been very reluctant to approve volume controls) and is a time-consuming process, likely requiring

at least two years from the time of initial request to ultimate approval. An advantage of conducting a removal program through a marketing order is that participation in the program is mandatory if the industry agrees on a program and the relevant state or federal authorities approve it. Mandatory participation need not mean that everyone must remove trees or vines. Rather, it means that everyone must contribute to funding the program.

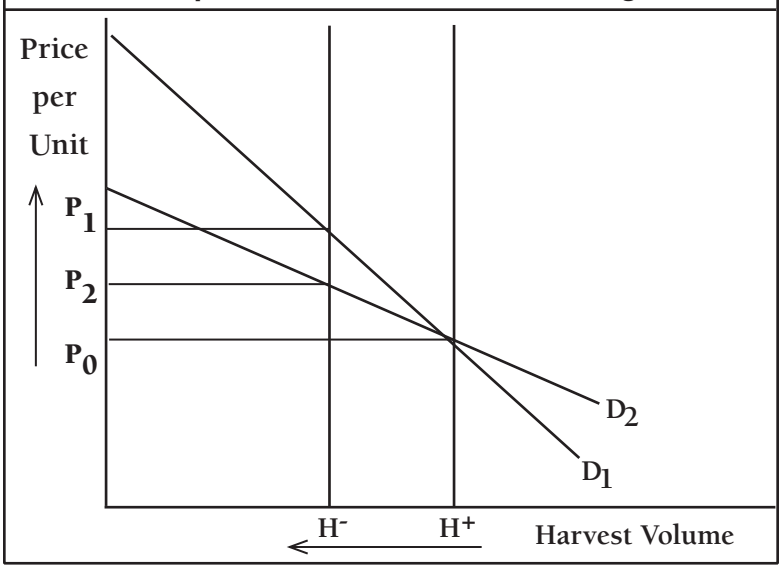
One alternative route to the market-order process is a voluntary program operated under the auspices of a cooperative association. Involvement of a cooperative in a voluntary program is critical because the Capper-Volstead Act grants producers who act jointly in a cooperative limited protection from prosecution under federal or state antitrust laws. Without this protection, agreement to remove trees or vines could be construed as illegal collusion under the antitrust laws. A cooperative bargaining association is in place in most of the industries involved in removal plans.

Under a voluntary program, such as the one being contemplated by the dried plum industry through the Prune Bargaining Association, funds are collected through contributions by members of the cooperative and, possibly, processor and handlers, and utilized to induce members to remove trees/vines. Free riding is a key limitation on this type of program. Everyone in the industry will benefit from the higher prices and reduced inventories caused by a removal program, but only those who belong to the cooperative association can be assessed to fund the program. Thus, growers who don't participate in the effort by remaining outside the cooperative benefit proportionally more than those who do participate. Although these growers cannot obtain payment to remove trees/vines, they incur no costs from the program, are able to harvest their entire acreage, and benefit from any higher prices generated through the program.

A second alternative is to secure U.S. Department of Agriculture (USDA) funds to operate a program. USDA has funding under a program called Section 32 to make commodity purchases to support industries experiencing severe problems due to oversupply and low prices. The conventional use of these funds is to purchase product from inventories and dispose of it through uses that do not compete with normal market channels such as prisons, school lunches, and food closets. Discussions center on whether such funds might be used to support tree/vine removal. From the perspective of the affected industries, this route is preferable because it leads to semi-permanent removal of supplies, as opposed to a one-time removal when product is purchased from inventories. If the USDA is willing to get involved in this manner, it surmounts the free-rider problem from a voluntary program because the costs of operating the program are effectively transferred to taxpayers.

In conclusion, high inventories and low prices are an unfortunate fact for many California perennial crops. Tree/vine removal programs are one way to attack the problem, but several issues need to be addressed. Will the acreage reduction be only temporary and lead to replanting with higher-yielding varieties? How will the program be funded? Voluntary programs are vulnerable to free-rider concerns, but provisions for mandatory programs don't exist in most industries. How much will price be affected? This answer hinges on the percentage of the potential harvest that is removed, the elasticity of demand for the product, and the movement of product from inventories.

Figure 3. How Elasticity of Demand Determines the Price Impact from a Tree-Removal Program



Matt A. Andersen is a graduate student in the ARE department at UC Davis. He can be reached by e-mail at: andersen@primal.ucdavis.edu or by telephone at (530)752-6768. Richard J. Sexton is a professor in ARE who can be reached by e-mail at: sexton@primal.ucdavis.edu or by telephone at (530)752-4428.

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output declined in importance throughout most of the 20th century. Developments to increase the intensity of land use through, for example, greatly expanded areas of irrigated agriculture, played a significant role in increasing agricultural output over much of that period. But in general, over the last 200 years, science and technology have played an increasingly important role in meeting world food needs.

The results of these technological developments have been really quite substantial. The 1960s was a period in which there were dire predictions of famine, yet the world did remarkably well in providing adequate global supplies of cereals. From 1960 to 1990, global cereal production doubled, per capita food availability increased 37 percent, per capita calories available per day increased 35 percent and real food prices declined 50 percent.

Even with these good indicators of overall global performance, significant regional differences remained. For instance, in sub-Saharan Africa, per capita food availability decreased between 1960 and 1990.

The global gains over the 1960–90 period came from the Green Revolution and from rapidly expanding production in developed countries based on conventional genetic crop improvement and intensified monocultures using high levels of fertilizers and pesticides. The policy environment in most countries was protective and inward looking. Farmers in rich countries were subsidized, receiving high guaranteed prices that further encouraged intensification. Farmers in poor countries, on the other hand, were taxed. The international trading system under GATT allowed agriculture to remain highly protected.

But despite all these gains, more than 840 million people remain undernourished, mostly in Africa and South Asia. Worldwide, 1.3 billion people live on less than U.S. $1 per day, and the majority of them are in agriculture. Rates of natural resource degradation are judged to be increasing.

Can Agriculture Meet the Three Challenges?

Meeting the Supply Challenge There are widely differing views on the difficulties of meeting food needs in the 21st century. Those using economic projection or simulation models, based significantly on history, tend to project sufficient global supplies until at least 2010. The International Food Policy Research Institute (IFPRI) reaches similar projections to 2020. Those projecting on the basis of resource availability and environmental constraints (perhaps these should be called ecological modelers) are generally much more pessimistic. The most extreme view combines resource constraints with biological yield.

How can these economic optimists on the one hand and the ecological pessimists on the other hand reach such different conclusions in projecting food supply potential? Their differences come from how they deal with four critical projection variables.

1) *Assumptions about the rate of increase in biological yields.* Economic modelers are projecting production growth of 1.5-1.7 percent per year, less than in earlier periods, but it still results in adequate supplies, as population growth rates are projected to fall even more rapidly. Ecological modelers point to yield increases in the 1990s of less than 1 percent, yield stagnation in intensive irrigated systems – e.g., triple–cropped rice in the Philippines and a decline in yields in rice–wheat systems in South Asia. These modelers are very skeptical about biotechnology being a savior.

2) *Assumptions about how much land will be added to or lost from agricultural production over the next 30 years.* Economic modelers continue to assume some increase in land area under agricultural production but less than in the previous period. Ecologists

Most of the food needed to meet increased needs in the next 25 years must be produced in tropical and subtropical farming systems. We know that these systems are complex, highly heterogeneous, fragile, generally low in productivity, and dominated by small-scale, poor farmers. Photo by The World Bank

argue that land lost to urban and industrial use, plus degradation of existing land, means that *less* land will be available in the future.

3) *Assumptions about how much land can be subjected to increased intensification through irrigation and/or changed cropping patterns.* Intensification had a big impact over the past 40 years as irrigated area in developing countries doubled and cropping intensity increased. Economic modelers project that this trend will continue, though at lower levels. Ecologists argue that there will be no more new irrigation but rather increased competition for water and significant land degradation.

4) *Assumptions about the impact of environmental degradation on food production capacity.* Economic modelers tend to ignore natural resource constraints. Ecologists see them as big issues. Land erosion and water pollution will reduce yields. Rangelands are overgrazed and fisheries depleted.

In my judgment, the optimists are too optimistic and the pessimists are too pessimistic. Reality suggests that feeding two billion more people will be an enormous challenge. The bottom line is that virtually all of the increase in production globally will have to come from knowledge–based agricultural intensification, using modern science and biological technology, accompanied by improved capacity to deal with biotic and abiotic stresses. Land expansion and intensification through capital intensive irrigation simply will not make significant contributions to output. In fact, we may have to raise output with *less* land and *less* water and do it in a resource–friendly way.

Can these challenges be met? On the production side, there are four "big ifs" or uncertainties:

1) ***If** we can develop sustainable production systems capable of doubling output. This is an unprecedented challenge for agriculture and biological science.*

2) ***If** we have in place domestic and international policies and institutions that do not discriminate against agriculture and that provide appropriate incentives to hundreds of millions of farmers around the world.*

3) ***If** we continue to invest in public agricultural research—for example, through the Consultative Group on International Agricultural Research (CGIAR)—and build stronger partnerships with the private sector to tap the enormous potential of molecular biology.*

4) ***If** we stay the course with removing distortions to freer agricultural trade.*

These will all help to meet the food supply challenge.

Meeting the Poverty and Natural Resource Challenge

In the developing world, poverty remains a predominantly rural challenge. To meet these challenges, we must improve the productivity and profitability of millions upon millions of small farmers and promote employment–intensive rural growth.

For this to occur, farmers will need new, appropriate technology. Here the role of biotechnology should be critical if it can be applied to the crops of complex farming systems in the tropics and subtropics.

Profitability will come from increased market orientation as farmers produce food and fiber for domestic and international markets. Here the critical issues are appropriate policies and incentives.

If we can help improve farmers' wellbeing, we will also have the additional benefit of encouraging farmers to be more effective stewards of the world's natural resources. Therefore the issue of improving the welfare of rural communities, by improving the profitability of agriculture, is a **triple-win situation**. *It contributes to poverty reduction, it contributes to food security and it contributes to improved natural resource management.*

Implications for California and U.S. Agriculture

The consequences for the United States and California of meeting these challenges are substantial and positive. International trade is accounting for a steadily increasing share of U.S. and California agricultural sales. Markets grow when countries grow and incomes rise. Thus, reducing rural poverty in developing countries ultimately benefits us. Forty years ago Taiwan and South Korea were concessional markets for food give–aways. Today they are important markets. Likewise India, China and other developing countries will become better markets when their economies perform better. Even better news for California is that as incomes rise further, the composition of imports shifts from basic grains and bulk products toward fruits, vegetables, processed foods, specialty products and other higher value imports.

Alex McCalla is an Emeritus Professor in the ARE department at UC Davis and the former director of the Agriculture and Natural Resources Department of the World Bank. He can be reached by e-mail at: alex@primal.ucdavis.edu or by telephone at (530)752-1529

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To subscribe to ARE Update, contact:
Julie McNamara, Outreach Coordinator
Department of Agricultural and Resource Economics
University of California
One Shields Avenue, Davis, CA 95616
E-mail: julie@primal.ucdavis.edu
phone: 530-752-5346

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One Shields Avenue
Davis, CA 95616