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Greenhouse Gas Mitigation Opportunities in California Agriculture

Outlook for California Agriculture to 2030

Daniel Sumner

University of California-Davis

February 2014

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Greenhouse Gas Mitigation Opportunities in California Agriculture: Review of the Economics
NI GGMOCA R 7

ABSTRACT

California agriculture is diverse and complex, producing several dozen major crop and livestock commodities using the state's great spatial variation of natural and climate resources and well-developed infrastructure of input delivery systems, processing systems, and marketing services. What, where, and how these commodities are produced reflect biophysical, economic, and policy drivers, all of which have and will continue to change. This report examines the statewide greenhouse gas (GHG) emissions and emissions mitigation potential of alternative futures for California agriculture through 2030. It finds that the dairy industry in California has by far the largest GHG emissions of all the state's agricultural production systems but that the industry's growth trajectory is uncertain. Three potential growth scenarios suggest that baseline dairy emissions could decrease by as much as 20% or increase by as much as 40% (almost one-quarter of the entire agricultural sector's current emissions). This variation in baseline emissions projections may be as large as or larger than the industry's emissions mitigation potential.

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CONTENTS

INTRODUCTION

This study assesses likely developments over one and a half decades and considers alternative scenarios of demand growth reflected in market prices, subsidy and related policies, environmental regulatory pressures, irrigation water costs and availability, hired labor costs and availability, climate changes, and other factors. It focuses on major commodities and aggregates, especially those most relevant to greenhouse gas (GHG) emissions and emissions mitigation.

Approaches

Projections over different time horizons face different uncertainties. Shorter-term trends reflect current constraints and in the case of perennial crops account for acreage already planted to trees and vines. However, over a horizon of a few years, annual weather and pest shocks as well as demand fluctuations may dominate trends and underlying forces that assert themselves over a longer horizon. The U.S. Department of Agriculture (USDA) and other national and international organizations generate 10-year baselines of production, exports, and prices for major field crops and livestock commodities, including dairy. These baseline forecasts on a national basis do not cover many of the most important commodities produced in California. Nor do they cover longer-term forces affecting the economic, regulatory and resource landscape in California and globally. Yet expectations about these long-term forecasts already affect payoffs to agricultural investments, including investments in GHG mitigation.

For some commodities, this study uses standard time series trends to examine projected production quantities and planted areas assuming that current commodity patterns continue. For some commodities, the report uses single variable (univariate) statistical models that put additional weight on recent years. For the dairy and forage segment of California agriculture, it also uses a statistical approach that incorporates supply-and-demand relationships into the time series analysis—i.e., a vector autoregressive (VAR) model.

Statistical approaches provide a basis for comparison with more informal projections that reflect information on potential changes in relative costs, resource constraints, demand, regulations, and other factors. The analysis also informally incorporates supply-and-demand considerations. Rather than attempting to develop a complex formal mathematical simulation model that incorporates all the major forces affecting supply and demand, it relies on projections of future market conditions and broad assumptions about resource constraints.

One challenge of both formal and informal forecasting approaches is to reflect physical constraints such as land of various characteristics and irrigation water. Modelers must also recognize that some prices or rental rates to these (almost) fixed inputs are determined within the economic system. Some commodities—such as milk, beef, poultry, and eggs produced in concentrated livestock operations—use very little specialized land or irrigation water.

A second challenge is to reflect biological relationships such as typical crop rotations. Some crops that do not otherwise appear profitable independently continue to be grown as a part of a multi-year strategy. A third challenge is to reflect economic relationships, such as which commodities are complements and substitutes in production or demand. For example, the link between forage crops and dairy production is particularly important in California and for the state's GHG emissions and mitigation opportunities.

Resource Issues

Cropland and irrigation water are both under intense supply pressure. Land use for crops has declined in California even during the recent period of high prices for many farm commodities (USDA-NASS 2013). Urbanization and environmental concerns have reduced the availability of Central Valley farmland. Irrigation water has simply not been available for all the potentially planted acres south of the

Sacramento/San Joaquin Delta, and no technological fix appears likely to keep sufficient water in agricultural use (UC AIC 2009). Climate change is likely to increase the water challenges if less precipitation falls as snow, warmer winters cause the snowpack to be less secure, and warmer springs make runoffs come earlier. In that case, storage of large irrigation water supplies into the late summer is even more problematic. Moreover, groundwater resources have gradually become scarcer as farmers have replaced limits on surface water deliveries with more groundwater pumping (CDWR 2009). Ongoing responses include additional attention to water-saving technologies, crops that produce more value per unit of water and less production of thirsty crops for which the opportunity costs of local irrigation water mean they cannot compete at globally set market prices (UC AIC 2009).

Regulatory Concerns

Specific regulatory issues face many industries in many locations. According to farmers and investors, the broad regulatory situation and outlook in California has generally raised costs and discouraged investment in farms and agricultural processing and marketing. Much controversy surrounds the magnitude, but not the direction, of the impacts of these regulatory issues. The California ecosystem is fragile, and threatened species complicate farming in many regions of the state. Ground water quality in several regions has long been of concern, limiting livestock numbers and use of nitrogen fertilizers (Harter and Lund 2012). Regulatory concerns cause growers to change their input use and commodities.

Important regulations and policies include federal farm subsidies and price regulations, state price regulations for dairy, hired farm labor regulations, and environmental regulations—particularly state and regional rules related to air quality and water quality. For summaries of regulatory issues related to groundwater, air quality, farm labor, land use zoning, energy, food safety, animal welfare, and climate, see UC AIC (2009). Compared with other states, California farming faces tighter regulations on air and water quality and farm labor because of its large labor-intensive farms and its natural resource base (Harter and Lund 2012; Kuminoff 2007). Regulations that affect the costs of agricultural processing affect demand for farm commodities, and in some cases they are more important than regulations on farming itself. GHG mitigation policies are a part of this mix (Sumner and Rosen-Molina 2010).

Effects on Farm Output Prices, Quantities, and Farmland Prices

Industries' response to increases in production costs relative to those costs for other commodities or regions depends on market conditions. Where California production comprises a small share of the relevant market output, prices do not respond to rising California costs, leading to changes in use of resources that can be shifted among farm commodities. For example, if costs of wheat production in California were to rise relative to wheat costs in other regions of the United States, national wheat prices would be unaffected, and wheat production in California would decline as land use shifted to other crops. However, California is the dominant producer of almonds in the world market, and the crop now covers much of the land best suited to almonds in California. Higher costs in California would be partly reflected in higher almond prices and partly in lower prices of land most suited for almonds. The reduction in almond acreage would be moderated by both of these impacts. If costs rise for crops broadly in California, land prices and land rents would decline, but farmland would generally remain in productive use. Because land rents are in the range of $360 per acre for irrigated cropland, they would not fall to zero even if production costs increased, Consequently, all but the least productive land would remain in production.

Following this reasoning, most California fruit, tree nut, and vegetable commodity production as well as cow-calf grazing would remain in place even if relative costs rise. However, major California livestock industries use little land and are flexible enough to shift out of state if local costs rise. Dairy, eggs, poultry, and feedlot beef industries are not tied to particular land resources and are more affected by operating costs of feed, labor, energy, and waste management. For these industries, California output may fall substantially in response to a rise in California variable costs relative to costs in competitive regions.

Further Considerations

No formal statistical or structural economic models are available to provide projections of the likely path of California agriculture over the next two decades. Therefore, this report develops and uses time series statistical model forecasts to reflect past trends. It discusses some of the basic economic forces and constraints mentioned above and incorporates ad hoc commodity- and location-specific considerations where appropriate. Crops and livestock industries sometimes are complementary and sometimes compete for the same resources, and so industries must be considered together to recognize resource limits and local supply-and-demand relationships. California agriculture is also connected to the broader economy. Macroeconomic considerations are particularly important for the path of real interest rates and exchange rates. But, for a few commodities with income-sensitive demands (such as expensive wines made from coastal grapes), broader economic growth matters as well. To reflect these considerations, the report draws on the same macroeconomic forecasts used by USDA (USDA Office of the Chief Economist 2013b).

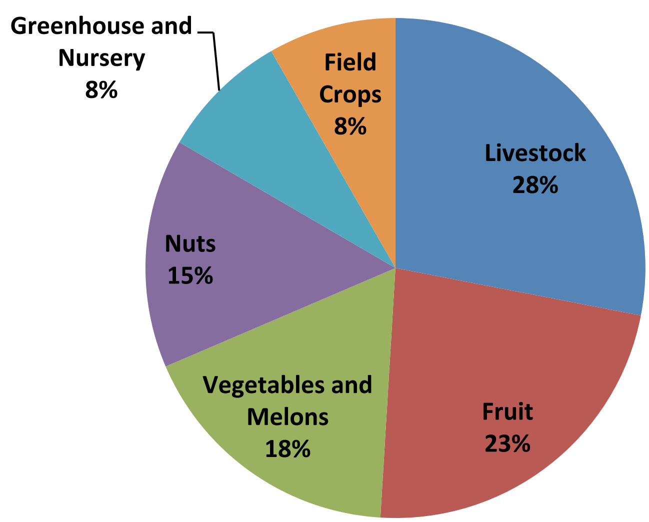
Because no single approach gives the same projections, and because ad hoc considerations for each commodity also leave room for a range of plausible outcomes, this report provides a range of estimates for every important outcome, including acreage allocations across crops and livestock numbers, which are vital to assessing GHG emissions and mitigation potential.

A SNAPSHOT OF CALIFORNIA AGRICULTURE EMPHASIZING GHG MITIGATION POTENTIAL

Revenue and Acreage

Figure 1 documents the breadth of California agricultural production. Livestock commodities contribute just over one quarter of the value of California agricultural output, which averaged about $41 billion annually from 2010 to 2012. All crop categories contribute significantly to total cash receipts. Field crops, which dominate in other major farm states, are the smallest category.

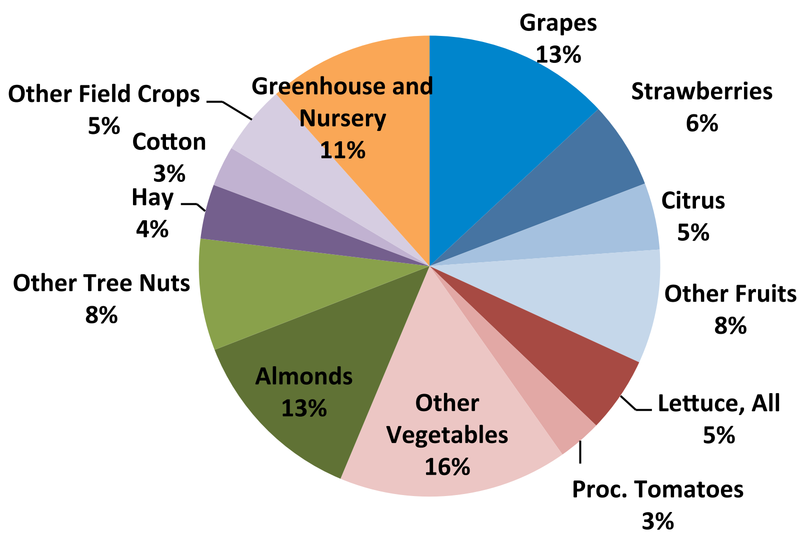
Figure 1. California Livestock and Agriculture Cash Receipts, 2010–2012



Source: USDA-ERS (2013a).
Note: Average total cash receipts = $40.8 billion.

Figure 2 presents crop revenue shares and documents the breadth of individual crops that contribute significantly. Grapes, almonds, and greenhouse and nursery crops are clearly important sources of revenue in California. But a host of other specific crops and the categories other vegetables, other tree nuts, other fruits, and other field crops are also important. In addition to perennial crops, individual annual crops such as strawberries and lettuce are major sources of revenue. Furthermore, a long list of high-value-per-acre vegetables, none of which contribute much to acreage, account for a revenue share rivaling that of grapes and almonds. Grape revenue is enhanced by very high revenue per acre in some select wine-growing regions along the coast.

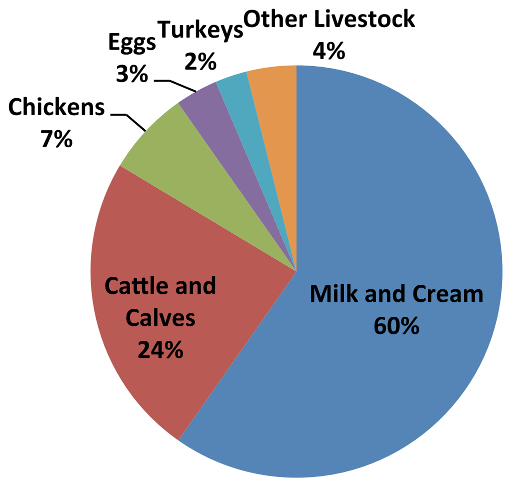
Figure 2. California Crops Cash Receipts, 2010–2012



Source: USDA-ERS (2013a).
Note: Average total crop cash receipts = $29.4 billion.

Figure 3 completes the revenue picture by illustrating the value of production of livestock industries in California. The dairy industry, which produces milk and cream, dominates with more than 60% of the farm value of production. California's dairy industry is almost exclusively confinement based and emphasizes intensive feeding of grains, protein crops, hay, and silage. Some of the dairy industry uses northern coast pasturelands, which replace some of the hay and silage that is fed to cows in confinement dairies in the Central Valley and southern California.

Figure 3. California Livestock and Dairy Cash Receipts, 2010–2012

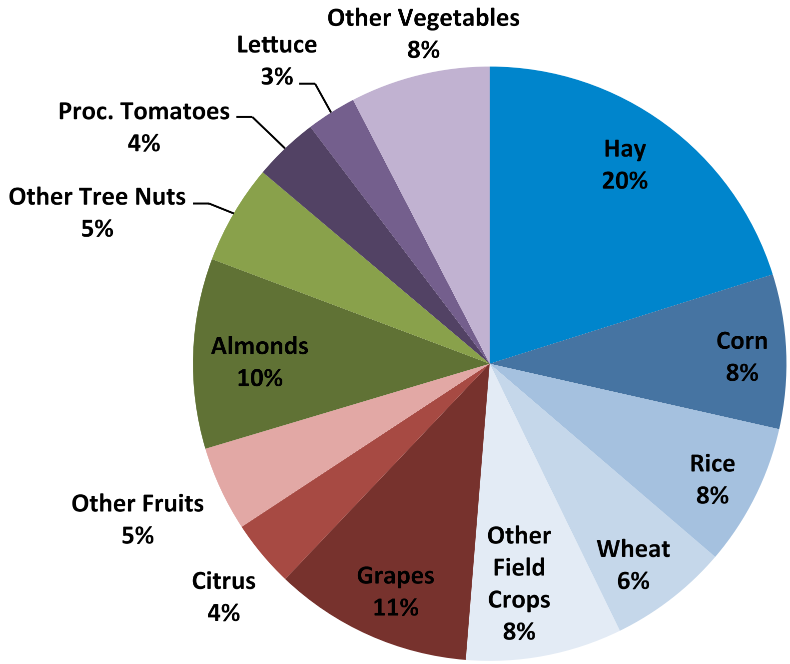


Source: USDA-ERS (2013a).
Note: Average total livestock and dairy cash receipts = $11.4 billion.

The cattle industry comprises two segments. The cow/calf and feeder calf segment of the cattle industry uses the pasture and rangeland that is found mainly in the mountains and northern valleys, with some supplemental feeding of hay during times when pastures are not available. The feedlot industry in California starts with steers and heifers that are fed to reach approximately 1,300 pounds and that are then sold for slaughter. The feedlots use rations of grain, protein supplements, and hay until the animals reach slaughter weight. In California, a major share of feedlot steers, some 300,000 head in Imperial Valley alone, come from calves produced by milk cows (Imperial County Agricultural Commission 2012). These calves typically enter the feedlot weighing 300 pounds and are fed high-grain diets for a year before they are marketed. This segment of the feedlot industry relies on the large nearby dairy herd and the availability of grain shipped efficiently from the Midwest (Peck 2005).

Figure 4 describes the average distribution of crop acreage in California from 2010 through 2012. Of the 7.34 million acres, just more than half was planted to field crops, including hay, corn for silage and grain, rice, wheat, cotton and other grains and oilseeds, and a few miscellaneous crops. Most of the rest of the land was devoted to tree and vine crops, including grapes, almonds, citrus and other fruits, and tree nuts. Less than 15% of the cropland was devoted to vegetables, including processing tomatoes.

Figure 4. California Crop Acreage, 2010–2012



Source: USDA-ERS (2013a).
Note: Average total crop acres = 7.3 million acres.

Table 1 provides acreage share for individual crops. Alfalfa hay accounts for about one million acres, or about 13% of crop acreage in the state. Almonds account for more than 10% of acreage follows by rice, other hay, grapes, and wheat for grain (including both irrigated and dryland winter wheat and durum wheat). Table 2 includes the most recent available data (2013) from the USDA on "prospective plantings"—what farmers told USDA enumerators that they planned to plant in spring 2013 (or had already planted in the case of winter wheat). Prospective plantings tend to be relatively good forecasts in California, where spring weather is seldom a major factor for planting. Much of the plantings for oats, barley, wheat, and corn are for forage, not for grain.

Table 1. Crop Acreage and Acreage Shares for Major California Crops

Product	2008	2009	2010	Share 2010
	1,000 acres			
Hay, Alfalfa	1,030	1,000	930	12.9
Almonds	680	720	740	10.3
Rice	517	556	553	7.7
Hay, Others	580	540	550	7.6
Grapes, Wine	482	489	489	6.8
Wheat	545	500	455	6.3
Corn, Silage	495	385	425	5.9
Cotton	268	186	303	4.2
Tomatoes, Proc.	279	308	270	3.8
Walnuts	223	227	227	3.2
Grapes, Raisin	221	216	216	3.0
Lettuce, All	220	204	203	2.8
Oranges, All	188	186	183	2.5
Corn, Grain	170	160	180	2.5
Pistachios	118	126	137	1.9
Broccoli	116	117	123	1.7
Grapes, Table	83	84	84	1.2
Barley	60	55	75	1.0
Dry Beans	52	69	63	0.9
Plums, Dried	64	64	63	0.9
Avocados	66	65	58	0.8
Carrots	64	62	57	0.8
Peaches	56	53	50	0.7
Lemons	47	47	46	0.6
Onions	45	44	42	0.6

Source: USDA-NASS (2013a).
Note: These 25 crops represent all crops accounting for more than 0.5% of acreage in 2010. Several high-value-per-acre crops, such as strawberries and some vegetable crops, are among the top revenue commodities in California not included in this table.

Table 2. Actual and Prospective Planted Acres of Grains and Other Field Crops in California

	2011	2012	2013[a]
	1,000 Acres	1,000 Acres	1,000 Acres
Corn[b]	630	610	560
Oats and barley[b]	300	350	290
Wheat[b]	790	750	700
Hay	1410	1550	1450
Rice	585	561	550
Sunflower	44	51	53
Cotton	456	367	280
Chickpeas and Dry Edible Beans	68	70	60
Sweet and Spring Potatoes	47	48	43

Source: USDA-NASS (2013f).

[a] Prospective plantings

[b] In 2011 and other recent years, California grew about 15,000 acres of oats and 75,000 acres of barley for grain. The rest of the planted acreage is for forage use—hay or grazing. The prospective planting survey ensures no double counting. Similarly, most corn is grown for silage, not grain, and about 250 to 300 thousand acres of wheat is grown for forage in most years.

Consistently reported data on the regional distribution of crops within California is less available than data for the state as a whole. Table 3 uses the 2007 Census of Agriculture (the most recent available until the 2012 Census data are released in a year or two). The first panel shows that grapes are the dominant tree and vine crop along the north and central coast. In southern California, which includes the south coast, grapes, oranges, avocados, and lemons are important. The latter two crops are included in "other," because they are insufficiently significant statewide to be listed separately. The Sacramento Valley grows almonds and walnuts and a large variety of stone fruits, such as peaches and prunes, none of which are important to acreage statewide. The San Joaquin Valley, by far the largest crop region in the state, grows grapes, almonds, and many other crops, including citrus.

Hay is the only significant field crop along the north and central coast and in southern California. Hay, rice, which alone represents half the region's field crop acreage, and wheat are important in the Sacramento Valley. The San Joaquin Valley devotes a significant share of acreage to all the field crops except rice. Since 2007, the region has produced less cotton and more silage and other forage crops.

Table 3. Share of Regional Acreage, by Crop, 2007

Share of Regional Fruits and Nuts Acreage					
Crops	**Central, Northern Coast**	**Southern California**	**Sacramento Valley**	**San Joaquin Valley**	**California Total**
Grapes	88.6	16.7	9.7	33.5	34.4
Almonds	0.6	0.0	33.0	32.5	26.7
Walnuts	0.7	0.1	25.1	6.2	8.0
Oranges	0.0	16.8	0.1	7.7	6.5
Pistachios	0.2	0.5	0.0	5.4	3.6
Other	9.8	65.8	32.0	14.7	20.8
Share of Regional Field Crop Acreage					
Crops	**Central, Northern Coast**	**Southern California**	**Sacramento Valley**	**San Joaquin Valley**	**California Total**
Hay	67.0	61.8	20.8	29.4	36.3
Rice	-	-	48.6	0.6	12.6
Cotton	-	3.5	0.4	20.1	11.2
Corn, Silage	1.3	1.2	1.5	19.6	10.9
Wheat	1.4	9.9	10.4	7.7	8.3
Haylage	14.5	2.2	1.2	11.4	7.2
Corn, Grain	1.4	-	7.5	4.9	4.5
Other	14.3	21.5	9.6	6.4	9.1
Share of Regional Vegetable Acreage					
Crops	**Central, Northern Coast**	**Southern California**	**Sacramento Valley**	**San Joaquin Valley**	**California Total**
Tomatoes	2.1	1.8	87.5	53.8	31
Lettuce	49.4	25.2	0.1	3.2	21
Broccoli	17.2	19.8	0	1.9	9.7
Other	31.3	53.1	12.5	41.1	38.4

Source: USDA-NASS (2007).

Vegetable acreage is small for each crop except processing tomatoes and lettuce. Processing tomatoes are grown in the Sacramento and San Joaquin valleys, while lettuce is grown in southern California and along the northern and central coast. Table 3 does not list separately a sizeable share of vegetable acreage. Many individual vegetable crops are grown in all the main crop regions of California.

GHG Profile for California Agriculture

According to assessments of the California Air Resources Board (CARB), livestock accounts for 23.15 million metric tons and crops account for 8.25 million metric tons of GHG emissions annually. The livestock emissions comprise 69% and 25% of the agricultural total, respectively. The remaining 6% are unattributed to one or the other (CARB 2011; Lee and Sumner 2013).

The livestock emissions are dominated by the dairy production, which accounts for about 70% of the livestock total or about half the agriculture total. Enteric fermentation accounts for about 40% of the dairy total; manure management contributes the other 60%. Beef cattle account for about 12% of livestock emissions, again split between manure management and enteric fermentation. Pork, poultry, and other animals (horses, sheep, goats, and so on) contribute a very small share of these emissions. Another 15% of livestock emissions are not allocated to a particular livestock industry (CARB 2011; Lee and Sumner 2013).

Crop emissions are not available by specific industry or commodity with the exception of methane emissions from rice, which account for about 0.4 million metric tons of CO2e, or about 5% of the crop total. As noted above, rice is about 8% of the crop acreage in California (Figure 4), but a much smaller share of revenue. CARB (2011) does provide summary data by crop practice. Nitrogen fertilizer use accounts for about two-thirds of crop emissions; another 17% is attributed to crop residue burning.

Several observations follow from this brief summary. First, the outlook for dairy production and especially numbers of dairy cows is a major factor in projections of GHG emissions from California agriculture. Second, the beef industry is also important. Much of that industry comprises grazing on dryland pastures in the hills of California and makes some use of seasonal pastures in the Central Valley. The other part of the beef industry comprises intensive feeding of steers and heifers, many of which are animals culled from the California dairy industry.

Third, although crop production accounts for three-quarters of the revenue from California agriculture, it accounts for one-quarter of the GHG emissions. Fourth, the major forage crops, alfalfa hay, and other hay and silage all provide feed to the local dairy and beef industries. Hence, adjustments in the dairy industry are also critical to changes in crop mix in California. Finally, there is no evidence that likely or economically feasible changes in that crop mix would have significant impacts on GHG emissions, with perhaps one exception. Lee and Sumner (2013) summarize results from Garnache (2013), who finds that reallocation of land use among field crops would have relatively small impacts on GHG emissions compared to changes in cropping practices. The Garnache data are for the Central Valley and do not include tree and vine crops. The coastal valleys of California have small crop acreage and concentrate on high-revenue-per-acre vegetable and fruit crops. The tree and vine crops are important in California, and no current assessments of their emissions per acre are available.

The one exception to the emissions profile presented above is likely alfalfa hay, which as a legume uses very little nitrogen fertilizer and leaves nitrogen for the subsequent crop in rotations (Frate et al. 2008). Because neither nitrogen fertilizer and nor residue burning apply to alfalfa, it likely contributes much less per acre to GHG emissions in California than most competing crops. Nitrogen use and residue burning together are estimated to contribute about 7 million metric tons CO2e of GHG emissions. This total applied to about six million acres (the California total minus alfalfa) implies a little more than one ton per acre for a typical crop in California. Assuming that the difference between alfalfa and other crops is equal to one ton of CO2e per acre, the implications of shifts in alfalfa acreage for GHG emissions can be assessed.

California Cropland Rental Rates and Prices

Cropland rental rates and prices reflect expected returns to land, factoring in all revenues and non-land costs. Rental rates reflect expected one-year net returns to operating cropland. Associated land prices include long run expectations and may include the probability of capital gains from converting land to non-farm uses. Considering land with a low change of conversion to non-farm uses, the ratio of current rent-to-land prices reflects current gains to ownership compared to future price gains. Examining cropland rental rates and capital values can therefore provide some insights into expectations of the current and future profitability of crop production.

For example, the average rental rate of California irrigated cropland in 2013 was \$365 per acre or about 2.9% of the irrigated cropland capital value (what it costs to buy the land) of \$12,500 (Table 4). Five years ago, in 2008, the rental rate was $360 per acres, also about 2.9% of the capital value then of $12,300. This nominal rate of return to holding cropland is relatively low compared to other investments, given the risk of investing in any specific parcel of land. This return rate implies either a relatively high expectation of gains from converting land to non-farm uses or optimism about future net returns from farming. However, low market interest rates also mean that opportunities for non-farm investment have been relatively unattractive. This pattern of land prices and rental rates also tells us that the economics of farming in California has not improved. The lack of capital gains in farmland prices reflects little change in expectations except that over the past five years, as more land is shifted to trees and vines and general inflation has continued at between 1% and 2% per year, real cropland prices have fallen.

Table 4. Recent Cropland Prices and Rental Rates in California, Florida, and Iowa

Year	Land/ Rental	California	Florida	Iowa[a]
		$/acre	$/acre	$/acre
2013	Price Irrigated	12,500	6,300	*
	Price Average	10,190	5,580	8,600
	Rent Irrigated	365	240	*
	Rent Average	280	87	255
	Rent/Price Ratio Irrigated	0.029	0.038	*
	Rent/Price Ratio Average	0.027	0.016	0.030
2012	Price Irrigated	12,000	6,400	*
	Price Average	9,810	5,730	7,300
	Rent Irrigated	340	205	
	Rent Average	267	103	235
	Rent/Price Ratio Irrigated	0.028	0.032	*
	Rent/Price Ratio Average	0.027	0.018	0.032
2008	Price Irrigated	12,300	7,790	*
	Price Average	9,880	6,980	4,260
	Rent Irrigated	360	200	*
	Rent Average	290	117	170
	Rent/Price Ratio Irrigated	0.029	0.026	*
	Rent/Price Ratio Average	0.029	0.017	0.040

Source: USDA-NASS (2008a,b; 2012a,b; 2013b,d).

[a] Iowa has no reported data on price of irrigated cropland, and its share of irrigated cropland rented is too small for useful data.

For comparison, in 2008, the ratio of rental rates to cropland prices in Iowa was 3.9, and over the subsequent five years, the value of cropland has doubled. Clearly, investments in Iowa cropland, in general, have been much more profitable than investments in California cropland. In 2013, the ratio of rents-to-cropland values in Iowa was about 3.0, reflecting expectations of future capital gains similar to those gains in California. But, unlike California, where capital gains have not materialized, in Iowa the present rent-to-price ratio follows five years of very rapid farmland price increases. Prices of corn and soybeans, primary crops in Iowa, were extremely high from 2008 to the middle of 2013, and the state's 2013 land prices and rental rates reflect continuing expected high returns. In addition to market returns, expectations of crop insurance subsidies and other farm program payments (including ethanol demand mandates) are built into rental rates and cropland prices in Iowa much more so than in California. Table 4 also shows cropland prices and rental rates for Florida, which has a crop profile more like that of California than Iowa.

The best regional and by-crop data are available from annual publications of the California Chapter of the American Association of Farm Managers and Rural Appraisers (ASFMA). California Chapter ASFMRA 2013 data are summarized here.

Generally, prices for farmlands (excluding those with prospective urban development rights and those sold as home sites) are highest in regions with high-revenue-per-acre specialized land, such the intensive avocado, lemon, strawberry, and vegetable growing regions in coastal valleys, and in regions growing high-priced winegrapes on the coast. In these areas, land prices are $100,000 per acre and up in the Napa Valley and $25,000 to $100,000 in other regions. No land rental rates are applicable, because orchards and vineyards are not typically rented. When land prices for orchards and vineyards are quoted, they include the producing trees and vines. Because orchard and vineyard development costs can be from $20,000 per acre or more, and because the time to initial commercial harvest can range from 3 to 10 years, the capitalized value of the trees and vines is significant. Of course, the older the trees and vines, the nearer they are to replacement and the lower the value.

In the Central Valley, the highest land values are in high-soil-quality regions suitable for almonds and other tree and vine crops. Prices range from $5,000 to $25,000 per acre; prime walnut and peach orchards command higher prices, and land for prunes and olives, lower prices. Prices generally rise from north to south, but to have any significant value, farmland must have adequate and secure access to irrigation water. The *2007 Census of Agriculture* (USDA-NASS 2009) reported about eight million irrigated acres on farms in California in 2007 and about 7.6 million acres of harvested cropland with 7.5 million acres that on farms with irrigated land.

The price of winegrape land is higher in the northern San Joaquin Valley, where higher-priced grapes are produced, than in the southern San Joaquin Valley. In the central and southern San Joaquin Valley, pistachio orchards, which take many years to reach maturity and tend to be relatively young, are among the highest-priced land. Generally, cropland is in the $10,000 to $15,000 per acre range if the water source is secure, The range tends to be higher toward the eastern side of the southern valley. Here, land and developed orchard and vineyard prices reflect the substantial capital investment of growers and other farmland owners.

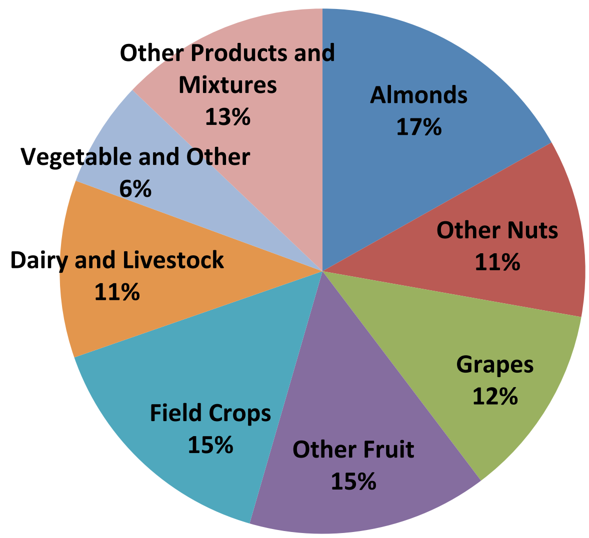
Farmland in California represents a major capital asset. In California, availability of irrigation water is crucial to the value of cropland. In recent years, cropland prices have been stable, as have land rents. The ratio of rent-to-land price below 5%, which is a relatively low return on a risky asset, suggests general optimism about long-term growth in land prices.

DEMAND-SIDE DRIVERS OF GLOBAL AND U.S. AGRICULTURAL MARKETS

California Agricultural Exports and Global Market Developments

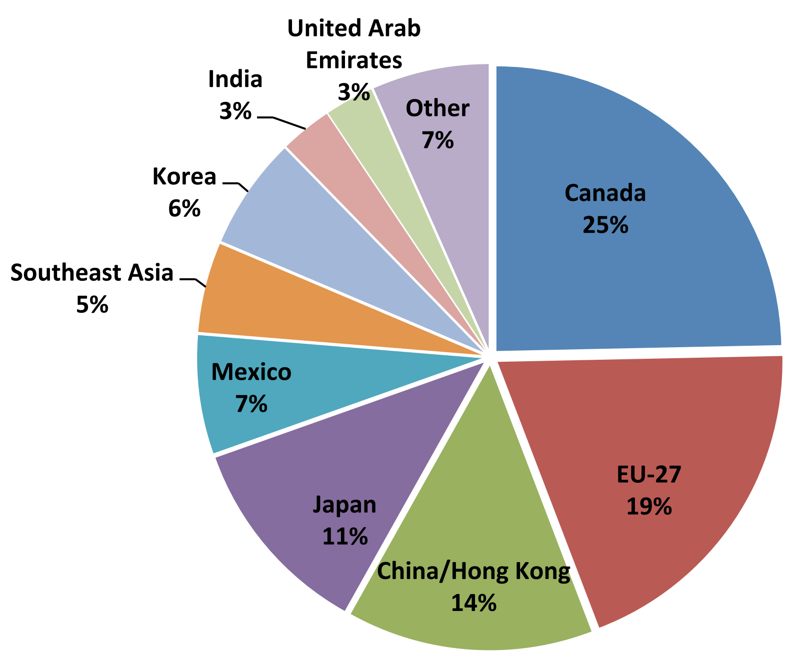
California agricultural exports are diversified across products and destinations (Figure 5 and Figure 6). Exports include dairy and other livestock products and a variety of crops. Some crops such as almonds and cotton are primarily exported. A small but growing share of dairy production is exported mostly in the form of non-fat products. Even within commodities such as grapes, exports include wine, table grapes, raisins, and grape juice. Vegetables remain mostly in the U.S. market, with the exception of shipments to Canada.

Figure 5. California Agriculture Export Value, by Commodity Group, 2011



Source: UC AIC (2012).
Note: Total value = $16.9 billion.

Figure 6. California Agricultural Exports, by Major Destination, 2011

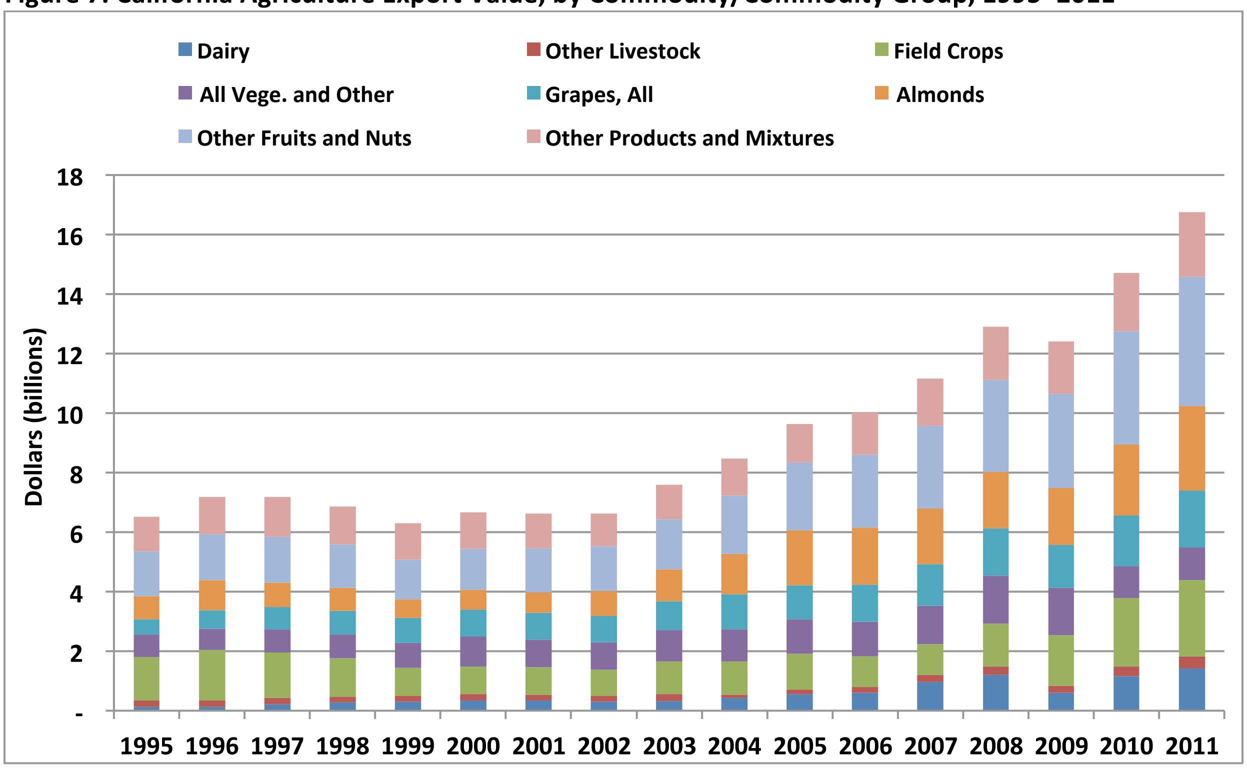


Source: UC AIC (2012).
Note: Top 15 countries = $13.8 billion.

The Mexican economy plays a particularly important role in California agriculture. Mexico is the fifth largest destination for California agriculture if the European Union is treated as a single destination and China and Hong Kong are treated as another single destination. Mexico is a particularly important market for California dairy products, and a large variety of other products are destined for the growing share of middle class consumers. Mexican agriculture is also a major competitor with parts of the California fresh produce industry in the California and Canadian markets. Produce shipments from Mexico derive from the parts of Mexican agriculture that match the product quality and safety standards of California growers, and several large California produce growers maintain operations on both sides of the border. Income growth in Mexico will raise wages there, but will also help generate better infrastructure and input market access, which lowers production costs for farming operations in Mexico. Whether the net effect will be to raise or lower these per unit costs remains unclear. Mexico has also been the main source of hired farm labor in California. But income growth in Mexico and poor job prospects in California have reduced flows of farm workers to the latter. Reduced access to Mexican immigrant workers will continue to raise farm production and processing costs in California (Martin 2013).

Exports have grown over the past decade in nominal terms (Figure 7). At the same time, exports as a share of production rose from about 18% in 1999 to 25% in 2011(UC AIC 2012). The growth of almonds as a share of exports parallels production of almonds. Wine exports have also grown, as have dairy products. Exports were about one-quarter of California farm production in 2010 and 2011. The main commodity trends behind this growth have been the expansion of tree nut production, which has long had a large export share, and the increasing share of milk production that is exported (UC AIC 2012).

Figure 7. California Agriculture Export Value, by Commodity/Commodity Group, 1995–2011

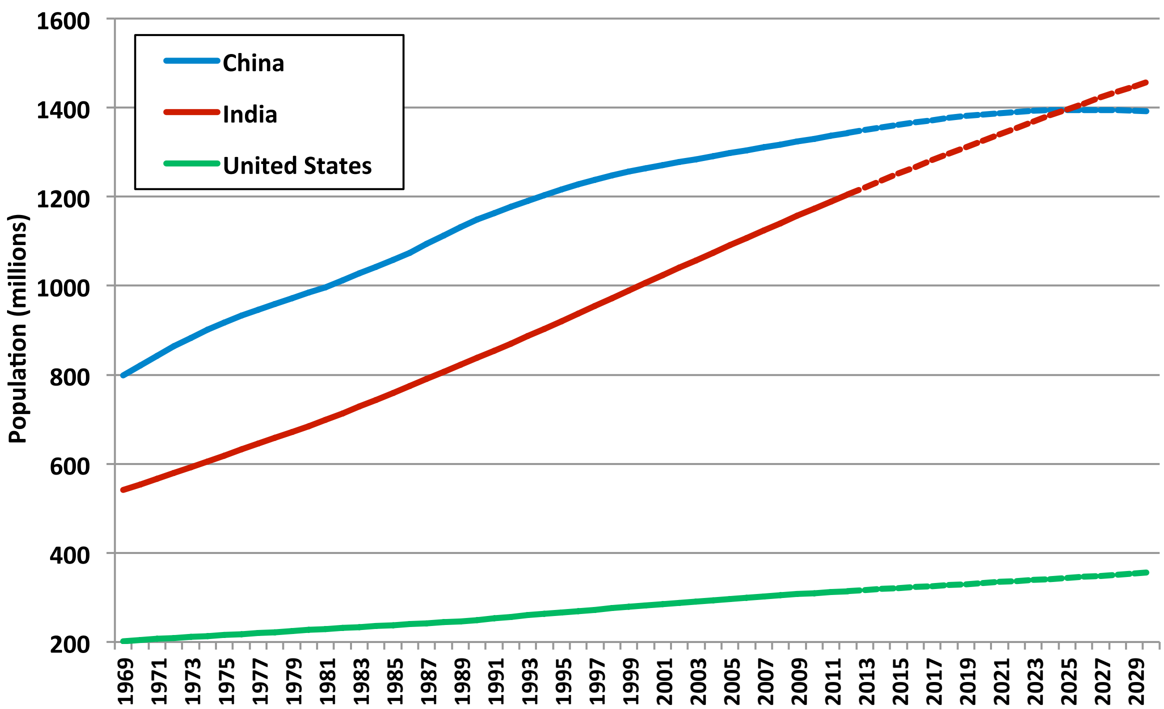


Source: UC AIC, *California Agricultural Export Data,* 1995–2011.

These data document that global agricultural import demand affects the prospects for California agriculture. Fresh citrus and processed tree and vine crops are crucially dependent on export markets. Several field crops such as cotton, rice, and hay have important export markets. Among vegetables, only processing tomatoes depend heavily on exports (UC AIC 2012).

Figure 8 shows projections of population growth through 2030 for China, India, and the United States. U.S. population growth will continue, while China's will gradually end about 2030 or so. The largest of the developing countries, India has still expanding population growth to the end of the 21st century. With shrinking populations in Europe and the rich countries of Asia, population growth from 2020 through 2050 will occur in developing countries, particularly in Africa over the next 50 years. These high-growth developing countries are not now the major markets for California farm exports, but between now and 2030, their income and population growth could substantially expand these markets.

Figure 8. Population Growth with Projections, 1969–2030



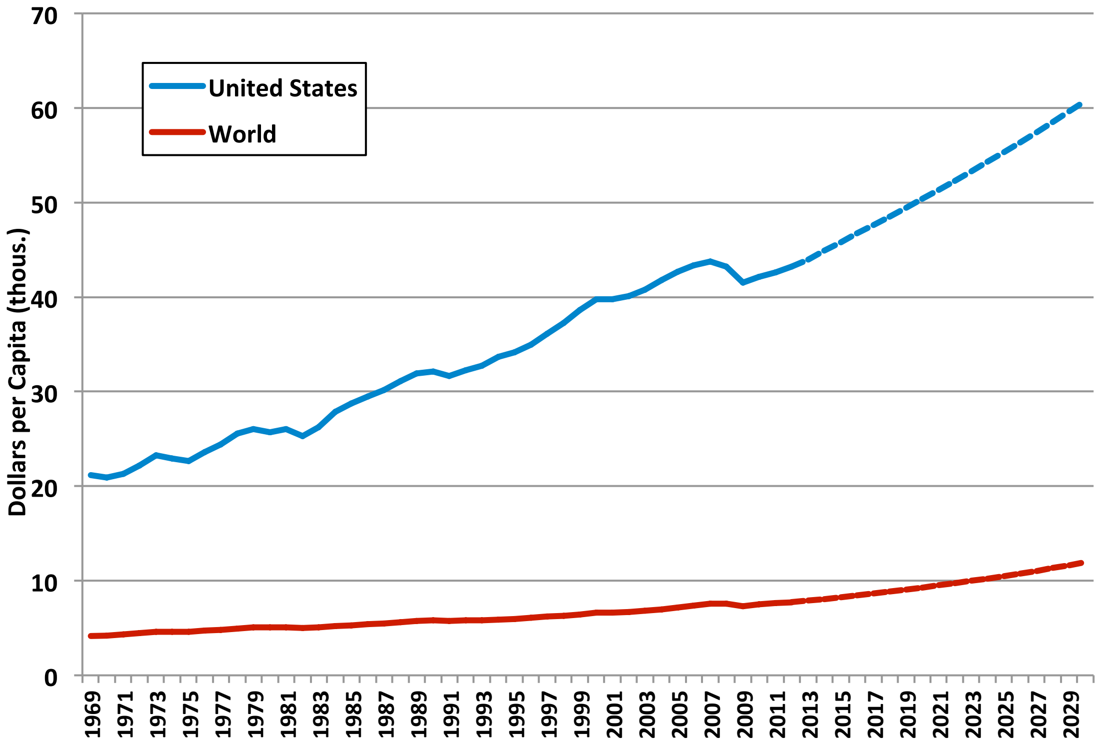
Source: USDA-ERS, *International Macroeconomic Data Set.*

Food demand generally grows with population. However, the poorest consumers, where much of the population growth is projected over the next 20 years, tend to consume diets high in starch, such as root crops and grains. Growth in population among the world's poor does little to drive consumer demand for California crops. Demand for animal products, fruits, tree nuts, and vegetables depends on population growth among consumers in the United States and other high- and middle-income markets.

Consumer income growth, among high- and middle-income consumers and at the level that allows the poor to begin to adopt diets richer in animal and horticultural products drives demand for the kind of agricultural products in which California specializes. Growth in overall food demand does not keep pace with income growth. As average income rises for those at middle incomes and higher, overall food demand hardly grows at all. Demand for animal products and imported horticultural products does grow with income as grains and other starches are replaced in the diets of the poor. Figure 9 shows that the

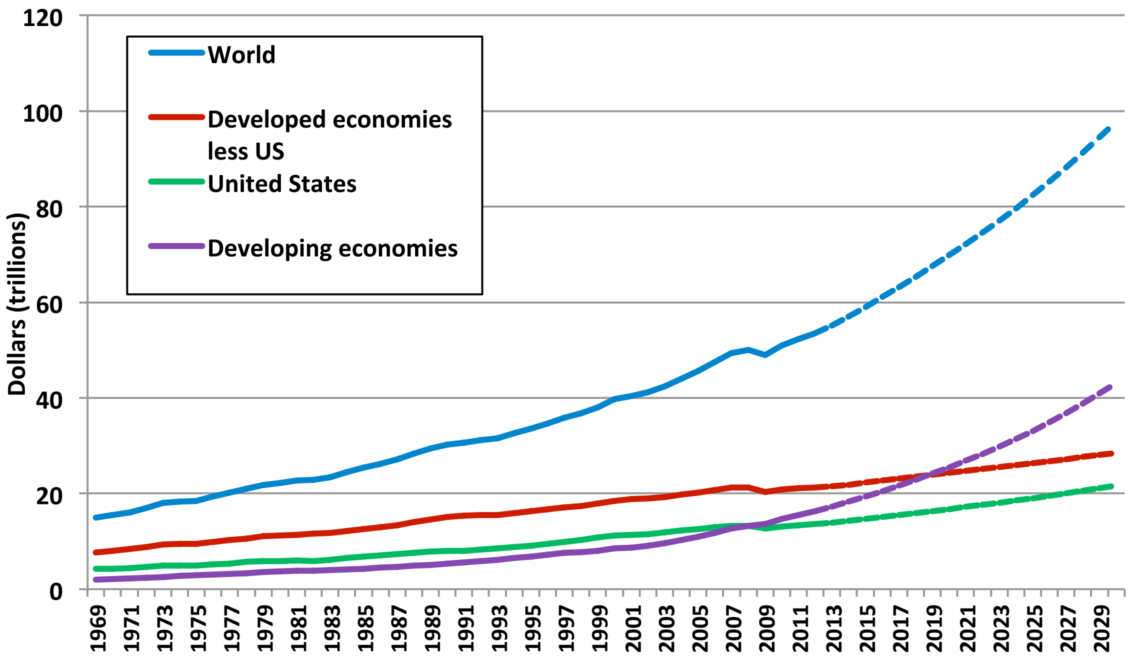
World Bank projects global per capita income growth, and Figure 10 shows rapid total income growth is expected to continue, increasing demand for agricultural products produced in California. Prospects for tree nut exports to grow with incomes are high, and the USDA projects rapid growth in dairy product demand in Asia over the next decade (USDA-ERS 2013b). Recent analysis of prospects for hay exports indicates opportunities in markets where local dairy production (using imported hay) grows (Putnam, Matthews, and Sumner 2013).

Figure 9. Real GDP per Capita Income Trends and Projections, 1969–2030



Source: USDA-ERS, *International Macroeconomic Data Set.*

Figure 10. Real GDP Totals and Projections, 1969–2030

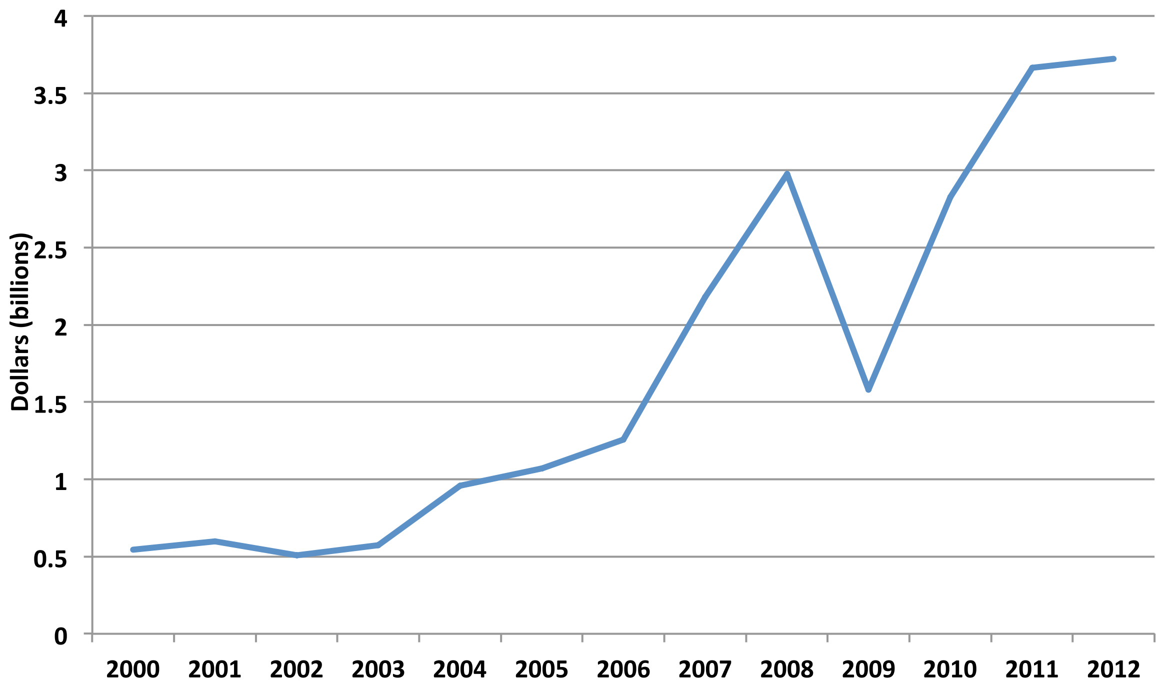


Source: USDA-ERS, *International Macroeconomic Data Set.*

In the absence of a detailed market-by-market, product-by-product analysis of future demand for California agricultural output, this report uses the trends and principles outlined above to draw some broad inferences. The export data summarized in figures 5 through 8 documents the pattern of export growth by destination and commodity.

Consistent with income growth, exports of California dairy products and hay to Asia have increased substantially. Imported hay is an input to domestic dairy production in countries such as Japan, Korea, China, and Saudi Arabia where land or irrigation water is scarce. These same countries are markets for imports of milk powders. Figure 11 shows that U.S. dairy exports (about 30% from California) have grown rapidly in recent years. U.S. dairy production costs have declined as market demand has grown. The massive dip in 2009 was the result of a collapse in dairy prices, not a reduction in quantities exported. The most important economic issue facing California agriculture is potential changes in the competitiveness of the California dairy industry relative to producers in the rest of the United States and in other countries. Because dairy is so important economically and to GHG emissions, this report considers changes in its economic prospects in substantial detail.

Figure 11. U.S. Dairy Export Value, 2000–2012



Source: U.S. International Trade Commission, *Interactive Tariff and Trade DataWeb*.

Exports of California tree nuts continue to grow, with large market shares in developed and developing countries. In most markets, these products have relatively low per capita consumption and, therefore, large potential for expansion where their healthy image encourages consumption and where numbers of middle-income consumers are growing.

California wine exports also respond to increasing numbers of middle-income consumers in Asia. Increased exports to northern Europe depend on increased wine consumption and on California wine replacing wine from other sources more than on income growth.

California rice export growth has relied on openings in markets that buy the japonica rice type produced in California. International agreements under the authority of the World Trade Organization (WTO) have helped to expand exports to Japan, Korea, Taiwan, and China (Sumner and Lee 2000). The Trans-Pacific Partnership trade negotiations may facilitate further openings. Almost all California cotton is exported for processing in Asia. Final consumption of the cotton textile products is global. The overall global cotton textile market is positively related to global population and income growth, especially in poor countries.

Domestic Demand

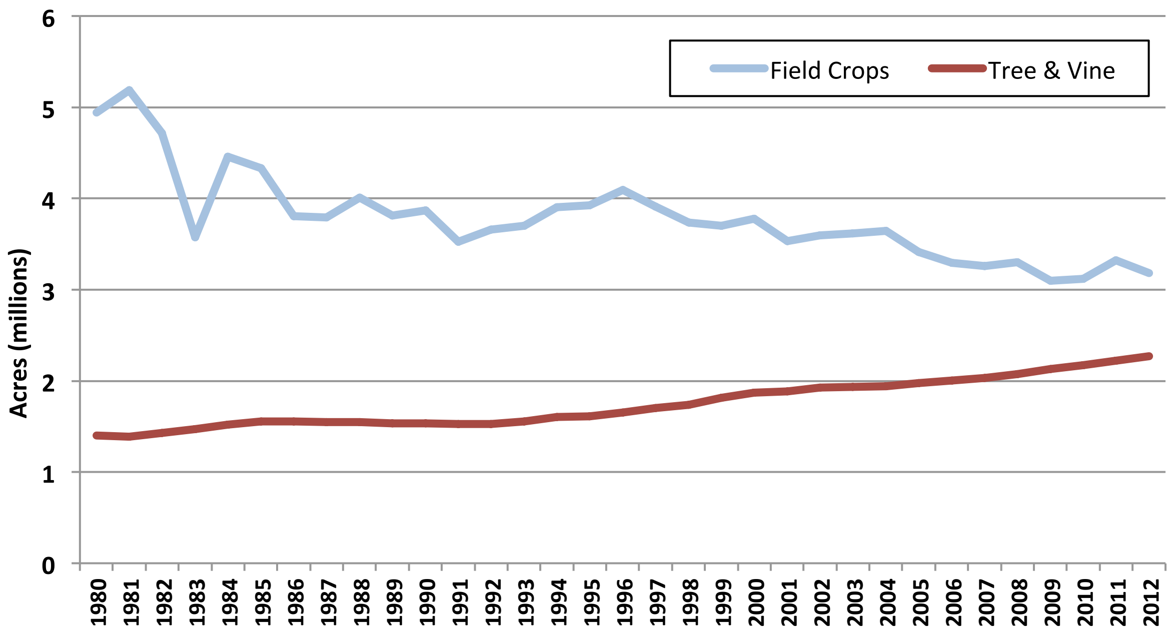
Despite substantial growth in exports over the last decade, California agriculture continues to rely most on U.S. domestic demand. About three-quarters of California agricultural output is marketed in the United States (UC AIC 2012). California is the dominant source in the U.S. market of much of what it produces, including tree nuts and many fruits and vegetables. For those products, overall growth in the U.S. market is the main source of increased domestic demand. Other products, including dairy and wine, face competition from other domestic production regions or imports.

Moderate income and population growth in the United States will gradually expand markets for California agricultural production. Given the variety of its growing conditions, California will continue to market a variety of output to U.S. consumers.

IMPORTANT ACREAGE AND PRODUCTION TRENDS

How might current patterns of acreage and production change over the next two decades? Figure 12, which plots trends in three decades of acreage for aggregates of crops, shows that acreage for the main irrigated field crops (cotton, alfalfa, wheat, corn for silage, corn for grain, and rice) fell from about 5 million acres in 1980 to about 3.2 million acres in 2012. Processing tomatoes, which tend to substitute for grain, hay, and other field crops in cropland rotations, are included in the total for field crops, but barley and oats, which are often grown on land without irrigation, as well as many minor crops are excluded in these data. Over the same three-decade period, the main tree and vine crops (grapes, almonds, walnuts, pistachios, and citrus) have expanded from about 1.4 million acres to about 2.3 million acres.

Figure 12. Annual Acreage of California Tree and Vine as well as Main Field Crops and Processing Tomatoes, 1980–2012



Source: USDA-NASS, *Acreage,* 1960–2013.

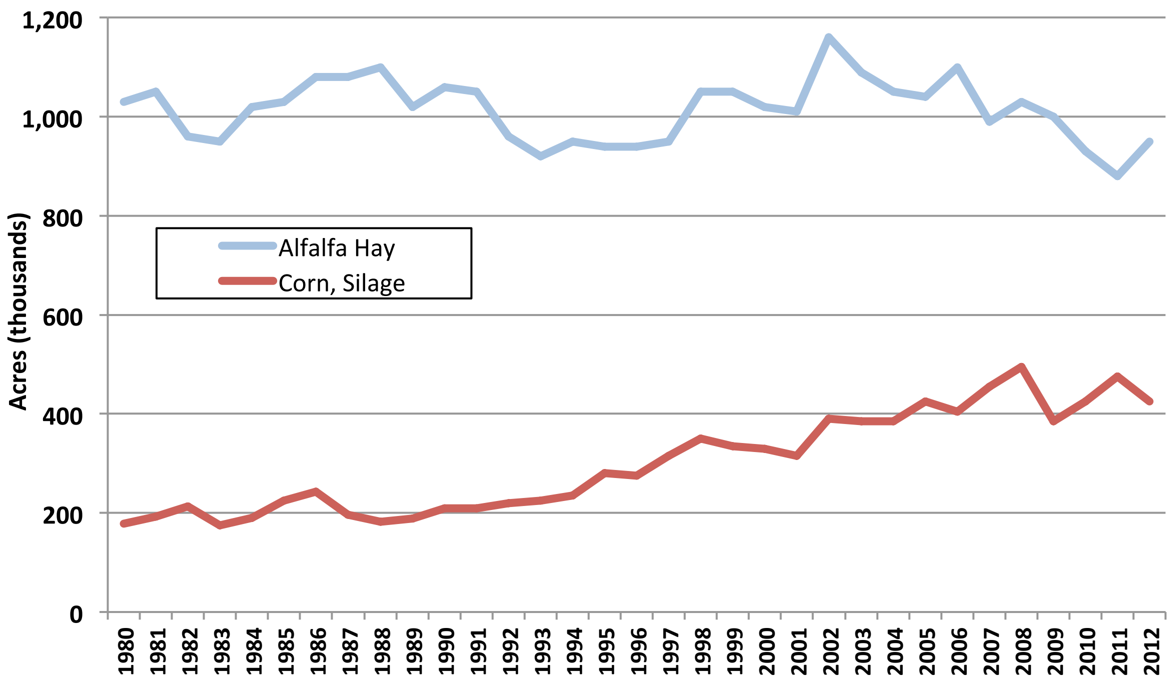
Tree nut acreage has grown rapidly over more than a decade, fueled by increasing global demand and California's strong comparative advantage based on its climate and growing conditions. Labor use is moderate, and large farms are able to provide long-term, almost year-around employment. The main check on expanded acreage is profitability of field crops and hay as demand for livestock products continues to grow and the competiveness of winegrapes in the Central Valley is renewed.

Grape acreage has experienced gradual ups and downs for several decades. Currently, the U.S. market for wine is expanding. The United States recently became the highest volume market for wine compared with other countries. Wine is shipped into and out of the United States in both bulk and packaged forms, and trade has increased. Demographics suggest continued expansion in wine demand. The challenge is for California's production costs to remain globally competitive at each price range (Sumner 2010).

Corn silage and alfalfa hay production in California are closely tied to the dairy industry: if the dairy industry declines, hundreds of thousands of acres of land will be freed for planting of other crops. Some hay is used as a seasonal supplement to pasture for California's beef cattle industry, and some is exported to the dairy industry in Asia, but the bulk of production is used in the dairy industry. Crops that compete with hay and silage in the San Joaquin Valley include processing tomatoes, wheat, cotton, and the major tree nuts and grapes, especially winegrapes.

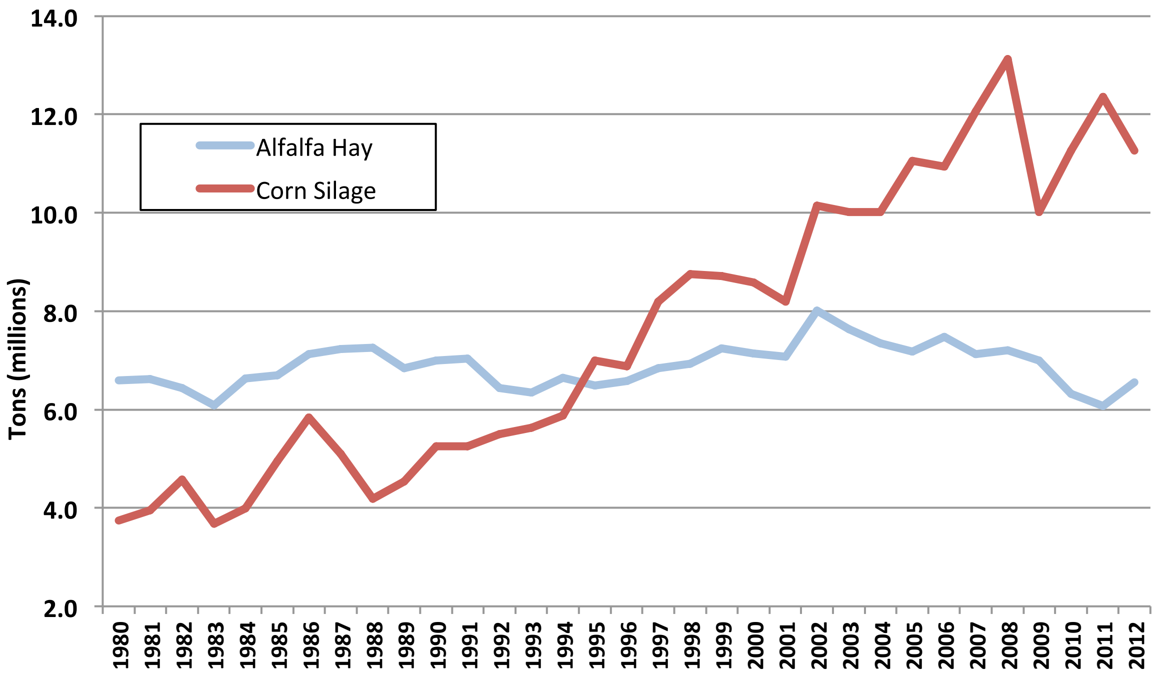
While acreage in silage has doubled over the last decade, alfalfa acreage has fallen from its peak in 2002 (Figure 13). This transition is reinforced by production data. The increase in dairy cow numbers and production appears to have stimulated growth in corn silage production rather than growth in alfalfa production (Figure 14). Alfalfa hay tends to be used in the beef and horse industries and is exported in increasing quantities. Corn silage, along with other silage and haylage (hay that is chopped green and allowed to ferment) products, is more closely tied to the confinement dairy industry.

Figure 13. Annual Acreage of California Alfalfa Hay and Corn Silage, 1980–2012



Source: USDA-NASS, *Acreage,* 1960–2013.

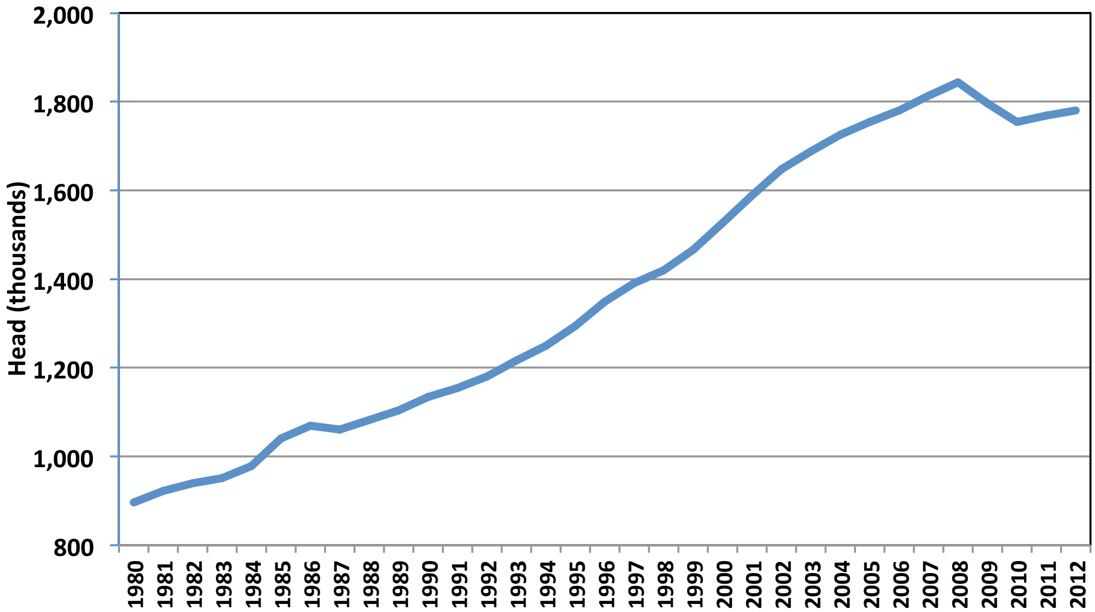
Figure 14. Annual Production of California Alfalfa Hay and Corn Silage, 1980–2012



Source: USDA-NASS, *Crop Production Annual Summary*, 1981–2013.

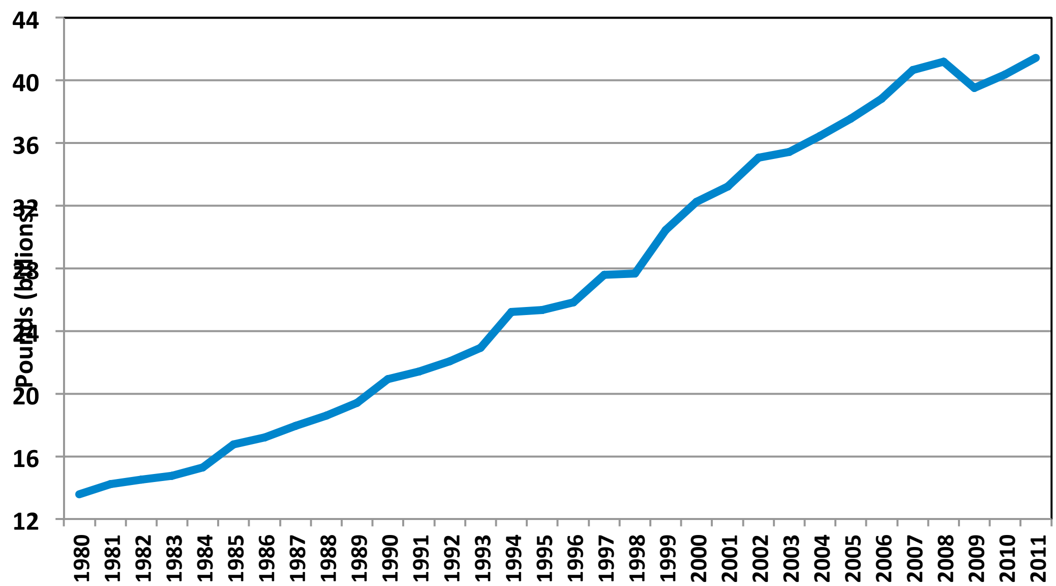
Trends in the dairy industry, which has important linkages to the forage crops and the feedlot industry, are summarized in figures 15, 16, and 17. All three production measures—numbers of cows, milk production, and production per cow—rose substantially until 2008. The industry has faced increased air and water quality regulatory pressures in (Sneeringer and Hogle 2008; Zhang 2013). In addition, milk prices have been generally low and highly variable, and feed prices have been high. In response, cow numbers and milk production have fallen, while production per cow has jumped as low-productivity cows were culled. A sustained decline of the dairy industry would have profound effects on California agriculture.

Figure 15. Numbers of California Milk Cows, 1980–2012



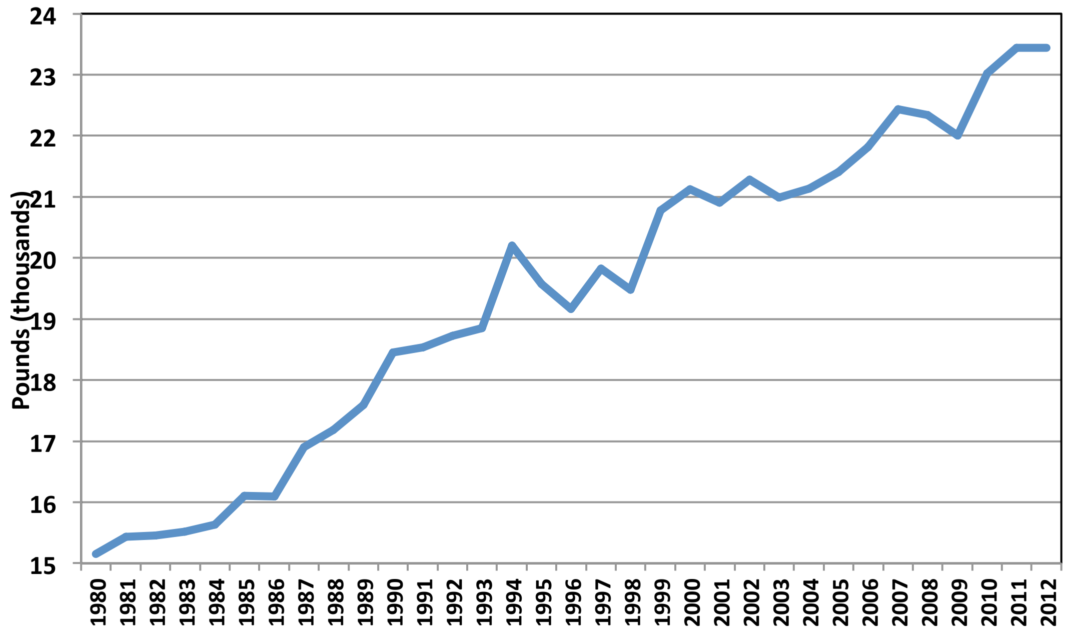
Source: USDA-NASS (2013c).

Figure 16. California Milk Production, 1980–2012



Source: USDA-NASS (2013c).

Figure 17. Milk Production per California Milk Cow, 1980–2012



Source: USDA-NASS (2013c).

Production of fluid milk, which is sold within California, is likely to continue to stagnate, as it has over the past decade in California and nationally. As a share of production, fluid milk has now fallen to about 8% of milk fat and about 15% of non-fat milk solids. USDA projects that demand for processed dairy products is likely to expand rapidly in export markets, especially in Asia (USDA-ERS 2013). The California dairy industry is well placed geographically to export to the Pacific Rim. That means cost considerations, relative to global competitors, are most important. Feed costs have been high for all dairy producers. The industry model of large herds per farm with much hired labor and little use of pasture has become the standard low-cost system in the United States (MacDonald and McBride 2009).

Environmental policy, especially policy related to water quality and air quality, in California's Central Valley has encouraged the industry to gradually lower cow numbers and perhaps even production (USEPA; CEPA-CVRWQCB 2013; Canada et al. 2012; Harter and Lund 2012). Some of this decrease may be due to the costs that environmental policy adds to expanding dairy herds or starting new dairies, and some may be due to policy-related operations costs. But another factor in the decrease is simply the refusal of local authorities to allow additional cows in their local jurisdictions (Sneeringer 2011).

The egg industry in California declined substantially from highs in the 1970s as other regions adopted the technologies, practices, farm size, and management originated in California. After stabilizing for the past decade or so, the industry will remain in California if cage size regulations are applied to all eggs consumed in the state and not just those produced in the state (UC AIC 2010). Regulatory and court decisions are expected to interpret laws from 2008 and 2010 that regulated minimum housing space for egg-laying hens (Sumner et al. 2008). Egg and poultry trends may foreshadow prospects for the important California dairy industry.

NATIONAL AND GLOBAL PROJECTIONS FOR THE NEXT DECADE

Several national and international organizations provide 10-year baseline projections for acreage production and prices for main field crops and livestock commodities that are important on a national scale. In addition, the USDA provides 10-year projections for selected aggregate horticultural crop categories. The latest USDA projections were released in March 2013 (USDA 2013). Data underlying the USDA baseline projections can be used to assess potential markets for California agriculture (USDA 2013).

Expanding global population affects exports of wheat, rice, and basic grains. Population is growing rapidly in the Middle East and Africa and continues in South Asia. East Asian population growth has slowed and will turn negative in China before 2040. Populations in developed countries outside the United States, including in Europe and East Asia, are or will soon be shrinking.

Income growth in developed countries (including the United States) is projected to be moderate at best, but rapid growth in the developing countries of East and South Asia will continue, increasing the number of consumers who are upgrading their diets. Food product exports generally will grow in the developing world, where income is growing rapidly. But they will also grow where newly open markets allow exports that were not allowed before—for example, South Korea because of the free trade agreement and Japan if it joins the Transpacific Partnership free trade negotiations and an agreement includes liberalization for agricultural commodities.

Table 5 shows the 10-year USDA baseline projections for major field crops of interest in California. Substantially lower nominal prices for corn (26% lower than 2011 prices) and 12% higher prices for rice are forecast. National corn production rises with growth in per-acre yields of about 2% per year by 2022. Wheat and cotton acreage decreases, while rice acreage increases, suggesting that cattle production would rise only slightly from currently depressed levels. Prices also rise relative to already fairly high prevailing prices. Broiler and egg prices are expected to rise by about 20%, even as production rises. The outlook for dairy is for a continuation of recent trends, including stable herd sizes and rising production per cow. USDA expects national milk prices to rise only slightly in nominal terms.

Table 5. National 10-Year Baseline Projections for Major Commodities in California

Main field crops

Commodity			2011	2012	2013	2022	(2020–2022)/ (2011–2013)
Corn	Acres	(mil)	92	97	96	92	0.96
	Production	(bil bu)	12.4	10.7	14.4	15.2	1.20
	Price	($/bu.)	6.22	7.60	5.40	4.85	0.74
Wheat	Acres	(mil)	54.4	55.7	57.5	50.0	0.90
	Production	(bil bu)	2.0	2.3	2.2	2.1	0.96
	Price	($/bu.)	7.24	8.10	7.20	6.2	0.81
Cotton Upland,	Acres	(mil)	14	12	9	11	0.89
	Production	(mil bales)	14.7	16.8	13.2	16.4	1.10
	Price	($/lb)	0.88	0.68	0.68	0.73	0.96
Rice	Acres	(mil)	2.7	2.7	2.7	3.2	1.19
	Production	(mil cwt)	185	199	192	250	1.29
	Price	($/cwt)	14.30	15.00	15.20	16.90	1.12

Eggs and major meats

Commodity			2011	2012	2013	2022	(2020-2022)/ (2011-2013)
Beef	Production	(bil lbs)	26.2	25.6	24.5	26.3	1.03
	Price	($/cwt)	113	121	127	129	1.07
Broiler	Production	(bil lbs)	36.8	36.5	36.1	41.7	1.13
	Price	(cents per lb.)	47	51	53	63	1.23
Eggs	Production	(bil doz)	7.7	7.7	7.6	8.1	1.05
	Price	($/dozen)	0.98	1.00	0.99	1.20	1.20

Dairy

Item			2011	2012	2013	2022	(2020-2022)/ (2011-2013)
Cows	Head	(millions)	9.2	9.2	9.1	8.9	0.97
	Milk/Cow	(thou lbs)	21	22	22	2	1.17
	Production	(bil lbs)	196	200	200	230	1.14
	Price	($/cwt)	20.1	18.6	19.6	20.8	1.06

Source: USDA-ERS (2013b).

These projections suggest a continuation of the long-term shift away from grains and cotton in the San Joaquin Valley. Rice prospects look positive on a national scale. No dramatic changes in the national dairy situation are suggested.

California produces a small share of all the commodities listed in Table 5 with the exception of milk, for which the California share of national production is about 20%. California is a price taker for all these crops, not just because the national production share is small, but also because many products tend to be marketed globally. Although California produces a medium grain japonica style of rice not produced in the southern States, its share of the relevant global rice market is less than 5%. Consequently, in long-term forecasts, California production of the crops listed in Table 5 takes prices as given, and changes in California output does not affect market prices. However, California has unique conditions that make it sometimes diverge from national acreage and production, if not price, trends.

Table 6 summarizes U.S. baseline projections for production, exports, and imports of vegetables, fruits, and tree nuts, in which California plays a much larger role in national and global markets. Aggregates mask considerable differences across these crops. Changes in price indexes since the 2005 base year are available for some crop aggregates.

Table 6. National 10-Year Baseline Projections for Fruits, Tree Nuts, and Vegetables

Crops	2011	2012	2013	2022	(2020–2022)/ (2011–2013)
Vegetables, fresh and for processing, excluding potatoes and pulses					
Production (mil. lbs.)	77,903	81,030	83,133	87,932	1.08
Exports ($ mil.)	5,734	6,113	6,292	8,165	1.31
Imports ($ mil.)	9,637	10,033	10,800	15,804	1.49
Citrus, fresh and processed; price index reflects a weighted average					
Production (mil. lbs.)	23,596	23,474	23,148	21,146	0.91
Exports ($ mil.)	1,036	1,009	1,426	1,502	1.29
Imports ($ mil.)	525	516	604	850	1.49
Price Index	102.0	110.1	113.4	137.4	1.24
Non-citrus fruit, fresh and processed; price index reflects a weighted average					
Production (mil. lbs.)	42,256	40,823	41,027	42,911	1.03
Exports ($ mil.)	3,356	3,833	3,966	5,388	1.40
Imports ($ mil.)	6,600	7,101	7,396	10,671	1.46
Price Index	93.1	95.1	96.5	109.0	1.13
Tree nuts, main tree nuts; price index reflects a weighted average					
Production (mil. lbs.)	5,168	5,367	5,475	6,543	1.2
Exports ($ mil.)	5,147	6,106	7,000	10,063	1.59
Imports ($ mil.)	1,714	1,801	2,000	3,107	1.61
Price Index	130.0	138.3	138.9	145.2	1.06
Wine					
Exports ($ mil.)	1,264	1,321	1,373	1,935	1.41
Imports ($ mil.)	4,777	5,084	5,400	8,116	1.53

Source: USDA-ERS (2013b).

Vegetable production increases only gradually, while exports and imports both expand in value terms. Net exports (exports – imports) are projected to grow in value, but exports are projected to grow more slowly than imports. Production of citrus products declines, while the price index rises by 24% and the import growth exceeds export growth. The citrus aggregate includes orange juice, which is grown primarily in Florida and faces some serious economic and pest control issues. California specializes in fresh citrus, but with much better long-term prospects. USDA projects non-citrus fruit production to remain roughly stagnant, while prices rise and exports and imports both grow substantially. With respect to fruit, much of the import quantity does not compete directly with domestic production because of different seasonal patterns or because the United States simply does not produce much tropical produce such as bananas. However, for example, table grapes in the spring (an import season) may substitute for table grapes in the early summer (a domestic season). Some evidence suggests, but no carefully designed studies have documented, that fresh fruit availability in the off season has reduced demand for processed fruit products. Again, these are national projections and fresh fruit apples, of which California produces a small share, are the largest single commodity.

Tree nuts are clearly a bright spot for the California agricultural economy: production rises by 20%, while exports grow and prices rise slightly. California is the major U.S. producer of all major tree nuts except pecans. Wine exports and imports have both been expanding rapidly for a decade, and the USDA expects this rapid growth to continue.

ECONOMIC FUNDAMENTALS AND THE FUTURE OF CALIFORNIA AGRICULTURE

California farm commodities generally face long-term average prices that are determined outside the state's cost and production conditions. Exceptions include a few small acreage crops, such as winegrapes from particularly famous locations, and in terms of annual revenue and acreage, almonds, because California produces a large share of the world almond crop and exports almost all the almonds entering global trade. Silage and, to a lesser extent, alfalfa hay are also exceptions because of the high cost of hauling and the local nature of the market. Hence, if local conditions were to contract supply, the market would respond by bidding up the local price and perhaps cutting quantity rather than by importing large quantities of silage from outside the state. This pattern would hold over a long horizon.

On the supply side, the biological lags in production of livestock and perennials and the costs of crop mix adjustments mean that short-term supplies have a limited response to actual or expected price changes. However, unlike the Corn Belt, California has no single crop or set of rotation crops dominating the available land or water. In California, land and water constraints apply to crops as an aggregate, not to any single crop. Therefore, over a 20-year horizon, crop acreage can respond to any changes in crops' relative profitability or growers' anticipation of such changes. Of course, growers must consider multi-decade horizons for perennial crops, and views about future relative profitability are, naturally, disparate. Hence, crop mix changes gradually as orchards or vineyards reach the end of their economic life or as short-term shocks in field crop prices delay or accelerate planned changes
.

In short, acreage planted and commodity output for individual California crop and livestock commodities (or commodity groups) adjust to changes in relative prices, because no single crop or livestock enterprise uses a large share of relevant local land, water, and farmer expertise. The exceptions are some small acreage crops such as strawberries or avocadoes, which use a large share of the locally suitable land, and the cow-calf industry, which uses rangeland with little or no other commercial use.

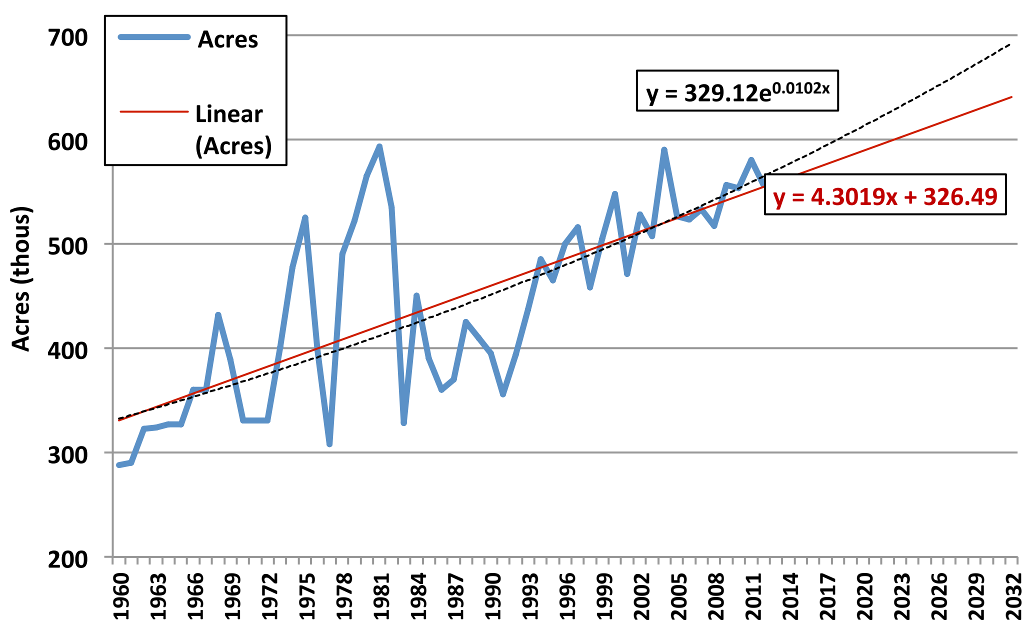
The implication is that, over a 20-year horizon, quantities are flexible. If the economic incentives change, California acreage and livestock numbers are likely to adjust substantially. Economic projections must emphasize assessing the main demand-side drivers and the likely drivers of changes in relative cost conditions across commodities. Total acreage and irrigation water constraints apply to the sum of all crops grown in a region, and productive land and water will not be left unused.

TRENDS AND PROJECTIONS FOR THREE MAJOR CROPS

Figures 18, 19, and 20 illustrate how acreage and yield for three major California crops have evolved over 50 years and illustrate linear and exponential trends to project for another 20 years. The crops account for about 1.8 million acres of irrigated cropland, mostly in the Central Valley.

Figure 18 shows how rice acreage hit a low of about 400,000 acres in the wake of water shortages, depressed prices, and mandatory acreage set asides under federal farm programs in the 1990s. Rice acreage has grown to about 550,000 acres since. Both linear trends (4.3 thousand acres per year) and exponential trends (about 1% per year) indicate that rice acreage will total substantially more than 600,000 acres by 2030. However, the total availability of land suited to rice in the Sacramento Valley is about 600,000 acres. Exceeding this acreage would require a remarkable breakthrough in technology or prices. But the main advantage of rice relative to other California crops is that it relies on the Sacramento Valley's abundant water availability and soils that hold water for flooding. The rice-growing region is surrounded by trees, vines, and other crops that will have higher revenue per acre unless rice prices jump compared with prices for competing crops that are also grown in the northern Central Valley. Therefore, the most likely scenario is that rice acreage will stabilize below 600,000 acres.

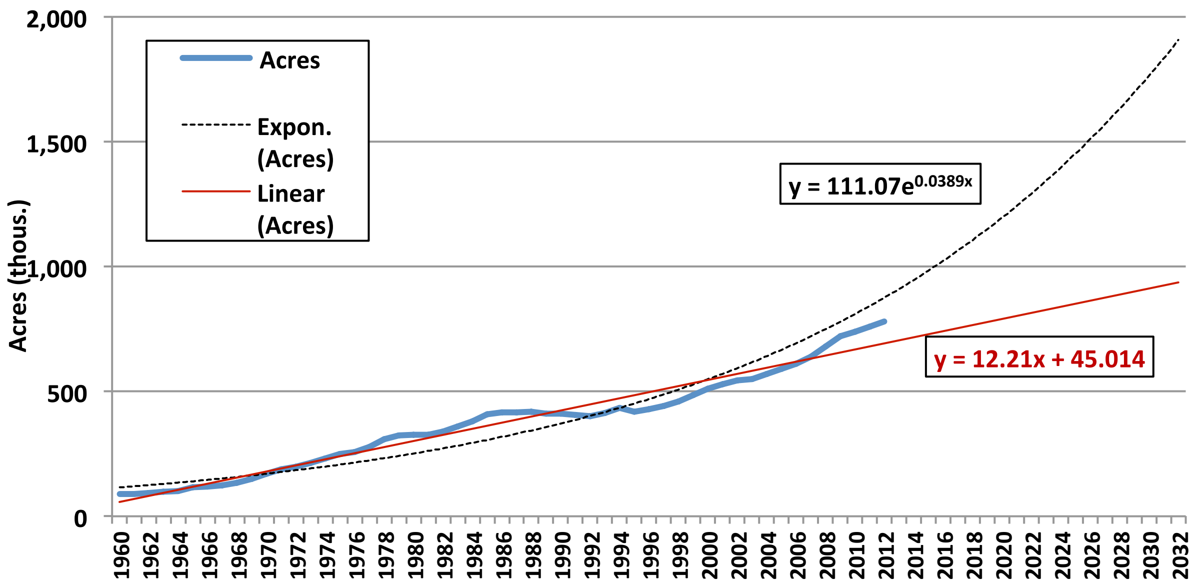
Figure 18. Trends and Simple Projections of California Rice Acreage, 1960–2032



Source: USDA-NASS (2013a).

Figure 19 shows that almond acreage has grown from about 100,000 acres in 1960 to more than 700,000 acres in 2012. Yield per acre also has increased rapidly, and demand has grown to keep prices from collapsing. Almond acreage has spread throughout the Central Valley. Almonds are found near rice fields in the north and next to citrus and cotton in the south. The pace of acreage increase has accelerated since 1995. A constant percentage trend growth of about 3.9% per year would imply almost 2 million acres by 2030. A linear trend of about 12,000 acres per year would not reach 1 million acres by 2030. Adding substantially more almond acreage would mean lowering the acreage of other crops. One scenario that could open sufficient land for almond production would be a reduction in the dairy industry, which would release land from silage and hay production. Even in this case, almond plantings would compete with new acres of fruit crops grapes, walnuts, pistachios, and vegetable crops, especially processing tomatoes.

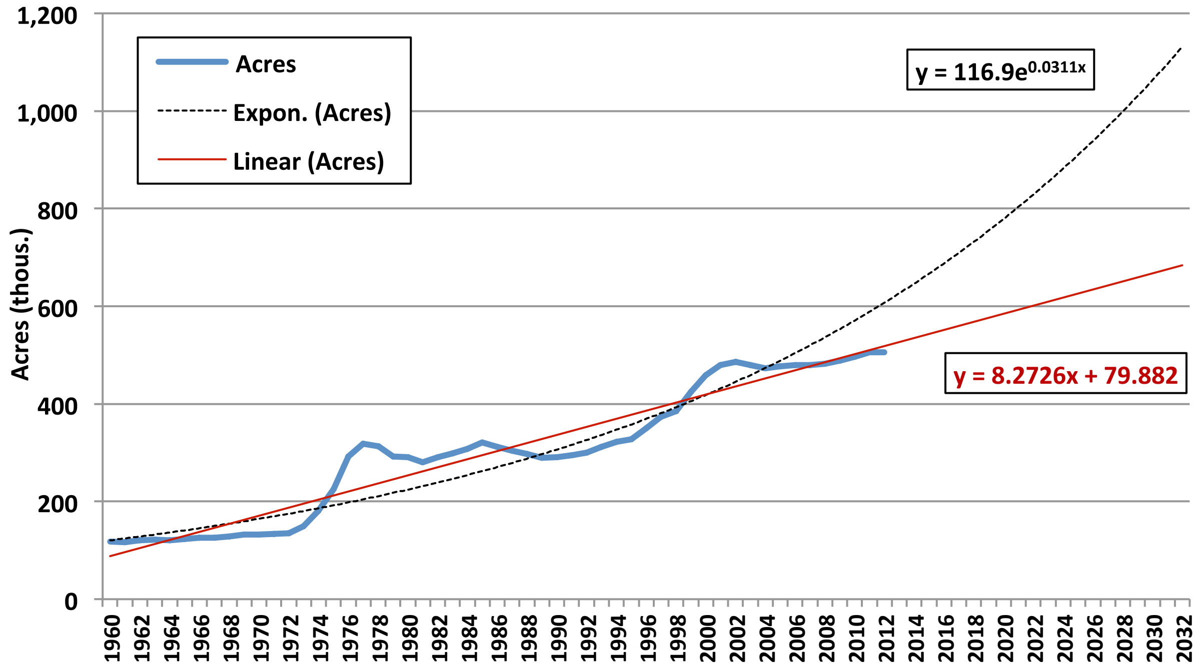
Figure 19. Trends and Simple Projections of California Almond Acreage, 1960–2032



Source: USDA-NASS, *Acreage,* 1960–2013.

Figure 20 shows that winegrapes have been through several "plant and pull" cycles over the past 50 years. These "cycles" have generally been related to consumption shifts. Such shifts occurred from 1970 to 1975 and from 1992 to 2000. Acreage has been stagnant since 2000. The complexities of the winegrape market and its potential to influence other parts of California agriculture warrant further discussion based on recent analyses of Lapsley (2010, 2011, 2012, 2013).

Figure 20. Trends and Simple Projections of California Winegrape Acreage, 1960–2032



Source: USDA-NASS (2013a).

SAN JOAQUIN VALLEY WINEGRAPE ACREAGE IN 2030

California produces about 90% of the winegrapes in the United States and competes primarily with wine from other wine-growing regions of the world for consumers in U.S. domestic markets and global markets (Wine Institute 2013). Most wine sells for less than $7 per bottle, and most winegrapes are produced in high-yielding vineyards in the Central Valley (Fredrickson 2013). California's coastal wine industry specializes in high-priced varietals on land that otherwise is used for grazing or growing some deciduous tree fruits and vegetables.

Grapes in the San Joaquin Valley are also used for raisins and table grapes. These two specialized industries compete for land with winegrapes. There is some overlap in use of grapes so that when low-end winegrape prices are high and raisin prices are expected to be low, some raisin grapes shift into production of low-priced white wine.

The UC Agricultural Issues Center assessed prospects for winegrapes in 2010 at a symposium of wine economists. Of note, Sumner (2010) examined the world market context, and Lapsley (2010) examined the trade-off across crops and the supply of and demand for California winegrapes.

Since 2010, wine prices have increased and so has winegrape acreage. In 2012, California supplied approximately 60% of all wine consumed in the United States. Winegrape crush districts 11, 12, 13, 14, and 17—essentially the San Joaquin Valley from just below Sacramento to Bakersfield—produced 75% of all the grapes crushed in California (CDFA1980– 2013b). These grapes were used to produce inexpensive table wines. The future of winegrapes in the Central Valley depends on demand for California wine and competition for land from other crops, such as almonds and walnuts.

In 2012, the United States consumed about 350 million cases of wine. Considering both population growth and a decrease in the percent of non-drinkers from 40% to 30% of the adult population, a market of 450 million cases of wine is likely in 2030 (Fredrikson 2013; Lapsley 2013). This increase of 100 million cases is equivalent to about 240 million gallons or about 1.45 million tons of grapes. If California maintains its 60% share of the U.S. market and the Central Valley continues to produce approximately 75% of all grapes for wine, just more than one million tons of additional grapes would be required from the Central Valley. The northern San Joaquin Valley (districts 11 and 17) averages between 8 and 12 tons per acre and produces 30% of the Central Valley total; District 13 (southern and central San Joaquin Valley) has historically averaged 12 to 14 tons an acre (CDFA 1980–2013b). Assuming 2012 proportions in 2030, districts 11 and 17 would supply an additional 300,000 tons and would require an additional 30,000 acres at 10 tons per acre, an expansion of almost 40% from the current 84,000 acres. The southern and central San Joaquin Valley, primarily District 13, would need to supply 700,000 tons, which, at 14 tons per acre, would require 50,000 new acres in addition to districts 12, 13, and 14's current 130,000 acres (CDFA 1980–2012b).

An expansion of 50,000 acres is certainly possible: in 2001, districts 12, 13, and 14 had more than 170,000 winegrape-bearing acres. During the past decade, grape prices averaged only about $250 a ton in the southern and central San Joaquin Valley. As vineyards reached the end of their productive lifespan, growers switched more than 40,000 acres to other crops, principally almonds, pistachios, and walnuts (CDFA 1980–2012a,b; Lapsley 2012). Whether the significant increase in demand for wine in 2030 will be met with California grapes or with imports is the main question. California has also been exporting an increasing amount of bulk wine to Europe and Asia (Sumner, Lapsley, and Rosen-Molina 2011).

The main purchasers of Central Valley grapes—Gallo, the Wine Group, and Constellation—are also importers of bulk and bottled wine. Imports grew from 22% of U.S. consumption by volume in 2001 to 35% by volume in 2012 (Lapsley 2013; Sumner, Lapsley, and Rosen-Molina 2011). However, foreign production has stabilized or declined as vineyards were pulled in Europe and Australia. In 2011, U.S. wineries began to meet some of the anticipated new demand for wine by offering higher prices and contracts to encourage additional acreage. By 2012, average District 13 prices had risen to $376 a ton, a 38% increase over 2010 (CDFA 1980-2013b*)*. This price increase makes winegrapes a more attractive crop. However, as Fuller and Alston (2012) showed econometrically, demanded for California winegrapes and those from particular regions in California fall significantly when prices rise, limiting the price increases and therefore winegrape acreage increases in the Central Valley.

In summary, if the next two decades follow recent patterns, about two-thirds of the projected increase in demand will come from California acreage and one-third from bulk imports, keeping the import share roughly constant. This increased demand would require an additional 660,000 tons of grapes from the Central Valley. Given demand for higher-priced wines made from grapes with specific flavors and characteristics, the northern San Joaquin Valley (districts 11 and 17) will increase its winegrape acreage by perhaps 40,000 acres and supply 400,000 tons, while the southern San Joaquin Valley will supply 260,000 gallons, which at 15 tons per acre will require an additional 17,500 acres. According to this scenario, the northern San Joaquin Valley makes a major shift to winegrape acreage, and the southern and central San Joaquin Valley makes a small expansion in that acreage.

THE DAIRY AND FORAGE CONNECTION IN THE CENTRAL VALLEY

The national dairy industry has experienced several recent episodes of very low margins between milk prices and feed prices. High prices for corn, soybeans, and forage crops have not stopped periodic declines in milk prices to levels at which almost every dairy farm was losing equity; many have left the industry in recent years (Balagtas and Sumner 2012). California dairy farms have been among those facing severe losses. California livestock farms import most of the grain and protein crops (soybeans mainly) that they use. High grain prices generally represent a net loss to California agriculture (Sumner, Balagtas, and Yu 2013).

California dairy farms also face a growing set of environmental, labor, and other regulations that add to costs and the complexity of their business. These pressures appear to be a consequence of livestock farming in an urban state and in a region with a large human population (CEPA-CVRWQCB 2013; Anderson 2013; U.S. EPA 2013; Sneeringer 2011; Canada et al. 2012). Cows produce manure that causes environmental issues from ground and surface water quality to air quality (CEPA-CVRWQCB 2013; U.S. EPA 2013; Sneeringer, 2011; Canada et al. 2012). In addition, California now has rules on treatment of farm animals, especially egg-laying hens and hogs, which may be extended as applicable to the much more important dairy industry (Sumner et al. 2008). Most California milk is processed in large plants making cheese or milk powder or butter. Less than 20% of the milk is used for beverage products (CDFA 2013). Because dairy products are traded nationally and globally and a significant share of California production is exported, higher costs of California processors translate into lower prices for farm milk, which is expensive to haul long distances.

Even as the California dairy industry was expanding rapidly, these concerns have encouraged some farms to expand their operations outside of California or to shift altogether to other locations (Anderson 2012). No comprehensive research has yet evaluated the costs of regulations and other California concerns on dairy farm operations. However, some progress has been made in modeling of processing plant operation costs and implications for dairy prices and the competitive position of the California dairy industry (Zhang 2013).

The potential for declines in numbers of cows in California, with consequent changes in acreage of silage and hay, demands further detailed analysis. Such analysis is the most important step in assessing whether some significant economic shock may change existing land use trends and patterns, especially in the San Joaquin Valley (Anderson 2012, 2013).

As a preliminary exercise, this report considers the consequences of using all the corn silage in the Central Valley for dairy. Assuming corn silage's role in the dairy ration did not change, a 10% reduction in cow numbers would engender a 44,000-acre reduction in corn silage. Conservatively assuming that about 90% of Central Valley alfalfa is used by dairies and none of the hay outside the Central Valley is used in dairies, a 10% reduction in cow numbers would imply a 55,000-acre reduction in alfalfa hay acreage. In total, a 10% reduction in cow numbers would free up about 100,000 acres of cropland and the associated irrigation water.

A reduction in cow numbers (rather than the increase that has occurred for the past 20 years) would have direct GHG implications. The average GHG emissions in California are about 9.2 MTCO2e per cow, and dairy alone accounts for half the agricultural GHG emissions compared to about 20% of agricultural revenue (CARB 2011). The cropland implications associated with dairy production would also have potentially important effects, because alfalfa and corn silage account for about almost one-quarter of California's irrigated cropland, and most of that forage is used for dairy cows.

PROJECTIONS OF CALIFORNIA DAIRY PRODUCTION AND FORAGE ACREAGE USING UNIVARIATE AUTOREGRESSIVE AND MOVING AVERAGE (ARMA) AND VECTOR AUTOREGRESSION (VAR) TIME SERIES TOOLS

By far the largest agricultural industry in California as measured by gross revenue, dairy is also a major land use driver, especially in the Central Valley. By creating incentives for local production of hay and other forage, dairy production affects the availability of land for other uses, especially tree and vine crops and extensive vegetables such as processing tomatoes. This report details projections of three variables—number of cows, milk production per cow, and alfalfa and silage acreage—to show important potential changes in California agriculture. It forecasts trends in California dairy and forage production using standard and well-regarded statistical techniques that attempt to learn from the past to project into the future. These approaches are used heavily in economics and finance.

Methodological Approach

For a univariate time series approach, this analysis estimated autoregressive moving average (ARMA) models for each variable of interest. These models ignore explicit consideration of economic or physical structure or relationships and interactions among other variables. They consider only the history of each variable of interest and focus on slowly evolving lags of behavior, moving average movements, and, in some cases, long-term trends.

For a time series approach incorporating economic considerations, this analysis estimated structural vector autoregressive (VAR) models. Such models have been applied to economic forecasting for decades and make use of economic relationships across interconnected variables, possibly including outside variables that are not of direct interest but that drive changes over time. Stock and Watson (2001) showed that in general, VARs have proven to be powerful in terms of data description and forecasting; structural VARs can capture relatively richer dynamic properties of multiple time series.

Kilian (2009) proposed a structural VAR model to disentangle supply and demand shocks in the crude oil market. Baumeister and Kilian (2012) used various approaches, including ARMA and VAR models and evaluated forecasts. This analysis modified the structural VAR model of Kilian (2009) and adapted it with structural assumptions that specify interactions among feed prices, milk prices, number of cows, milk per cow, and forage acreage. These simple and plausible structural assumptions allow identification of the variance matrix of the analysis' structural VAR model to obtain impulse response functions and forecasts for the endogenous variables of interest: California dairy and forage aggregates. In this way, the forecast of each variable reflects the interaction among relevant variables. The economic structure is specified below.

Data

The data used in estimation and forecast can be categorized as prices, California dairy aggregates (numbers of cows and milk per cow), and forage acreage. This analysis uses official U.S. statistics available from the USDA National Agricultural Statistics Service (NASS).

The analysis starts with annual data on the number of dairy cows in California and milk production per cow in California from 1960 through 2012. It constructs quarterly data and uses annual forage acreage statistics divided into four quarters. In the VAR model, it examines the sum of California acreage of alfalfa hay and silage, denoted here as *forage.*

Exogenous prices serve as drivers for the structural VAR model. This analysis uses national soybean meal and corn prices for each year from 1960 to 2012 and for each quarter from 1963 to 2012. National soybean meal prices are only available annually since 1982 and quarterly since 1983. The analysis fills in the missing data with predicted values on Ordinary Least Squares regressions of soybean meal prices on soybean prices. It represents dairy farm prices with the California all-milk price. All prices are deflated by the producer price index from the U.S. Bureau of Labor Statistics.

Statistical Procedures

Details of the ARMA and structural VAR modeling approaches follow.

The ARMA Model

This analysis estimated ARMA models for (1) number of dairy cows in California, (2) milk production per cow in California, (3) alfalfa acreage, and (4) silage acreage. Hamilton (1994) suggests that one principle for evaluating forecasting models is to minimize the mean-squared error (MSE). If the true states of the variables of interest follow ARMA processes, ARMA models and forecasts based on the estimated parameters would be a reasonable way to minimize MSE. A typical ARMA model can be represented as:

$$y_t = \gamma + \sum_{i=1}^{p} a_i y_{t-i} + \sum_{i=1}^{q} \beta_i \varepsilon_{t-i} + \varepsilon_t$$

where p and q are the order of autoregressive and the order of moving average processes, and y_t represents one of the four variables of interest. Lags for AR and MA were chosen on the basis of the shape of autocorrelation function and partial autocorrelation function.

This univariate approach assumes that the endogenous variable at time t is only explained by its own lags and the lags of its error term. This analysis also estimated models with linear and quadratic time trend variables included in the models. For the ARMA models, it presents the estimation for alfalfa and silage acreage separately.

This analysis estimated ARMA models starting with 1960 for annual data and with 1963 for quarterly data. To see if structural change affects forecasts, it also estimated all the models with samples from 1973 and 1983 to determine whether the model structure and parameters are common across samples and to examine the similarity of the forecasts.

The Structural VAR Model

The following structural VAR model is estimated on the basis of annual and then quarterly data as described above:

$$A_0 Y_t = \alpha + \sum_{i=1}^{p} A_i Y_{t-i} + \varepsilon_t$$

where $Y_t = (PF_t, PM_t, NC_t, MC_t, AF_t)'$, p is the order of the vector autoregressive process, PF_t is the price of dairy cow feed calculated as the weighted sum of national soybean meal and corn price, PM_t is the California all-milk price, NC_t is the number of cows in California, MC_t is milk production per cow in California, and AF_t is forage acreage. The A matrices are coefficients to be estimated. Lags were chosen on the basis of log-likelihood ratio and Bayesian information criterion. The chosen lags are the first through third lag for each set of estimation using annual data, with the exception of cases using the sample from 1983 and including the trend variable. Due to colinearity, only the first lag was used in this case. For estimation with quarterly data, the lags are the first and second.

The error term can be decomposed as shown by the following representation:

$$e_t \equiv \begin{pmatrix} e_t^{PF_t} \\ e_t^{PM_t} \\ e_t^{NC_t} \\ e_t^{MC_t} \\ e_t^{AF_t} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{feed\ price\ shock} \\ \varepsilon_t^{milk\ price\ shock} \\ \varepsilon_t^{shock\ in\ number\ of\ cows} \\ \varepsilon_t^{cow\ yield\ shock} \\ \varepsilon_t^{other\ forage\ acreage\ shock} \end{pmatrix},$$

which is written succinctly as $e_t = A_0^{-1}\varepsilon_t$.

This decomposition is based on a specific economic structure that relates these five variables. The order of the variables and the assumption of the triangular matrix A_0^{-1} represent the interaction among these five variables.

Economic Logic of the VAR Model

Feed price shock is driven by and represents random exogenous shocks that affect feed prices. This analysis uses national-level data on corn and soybean prices, which are exogenous to California dairy farmers. Thus, the error term of feed price is only explained by exogenous feed price shocks with no feedback from the other variables.

Milk prices shocks represent that portion of the error term of California all-milk price, which is not explained by feed price shocks. These milk price shocks would include demand-side shocks and supply shocks, due for example to local weather. Also, the California all-milk price is affected by market conditions partly through the state marketing order. The price of feed affects California milk production costs, which are correlated with the national price of dairy products, which are also affected by feed costs.

Shocks in numbers of California dairy cows and milk per cow can be interpreted as unexpected shocks affecting number of cows or yield, such as diseases or weather that do not drive the cost of feed or the price of milk. The error terms for number of cows and milk production per cow are explained by the first two shocks that affect farmers' production decisions and also by unexpected shocks of each variable. This analysis expects the shock from number of cows on milk per cow a_{43} to be small, but it does not impose zero on this term. (In fact, most of the estimated results from using various sample periods show that a_{43} is not statistically or economically different from zero.)

The forage acreage shock represents the part of the error term of total forage acreage not explained by shocks in feed price, milk price, number of cows, or milk per cow. This shock represents exogenous drivers that affect California forage acreage, such as expected prices of substitute crops, demand for exports or for other livestock, and planting-time weather.

The order of the variables in the estimation is important, because the first shock affects all five error terms, and the first error term is affected only by the first shock. Thus, specifying the order is equivalent to assuming the interactions described above. This analysis established the order on the basis of the economic relationships in the California dairy industry. The feed price (corn and soybean meal) is determined nationally and globally with supply primarily from Midwest grain farms and demand from livestock and biofuels. Because state marketing order and national and international milk demand affect California all-milk price, California supply conditions have little effect on mean milk prices. At the other extreme, California's forage markets are tied directly to the dairy supply-and-demand situation. These considerations lead to the specified triangular structure of the VAR model.

This analysis estimated this model for annual and quarterly data both with and without linear time trend variables. To see how the recent unusually high grain prices and low milk pricesaffect 20-year forecasts, these forecasts are based on estimations using data in the sample period, including data up to 2012 and alternatively up to 2007. The structural VAR model estimates parameters that incorporate economic relationships among variables and particularly causation from feed prices to dairy industry outcomes. Because the model is designed to take into account unanticipated changes in exogenous shocks such as feed price changes, it should improve forecasts relative to those of ARMA models.

Results

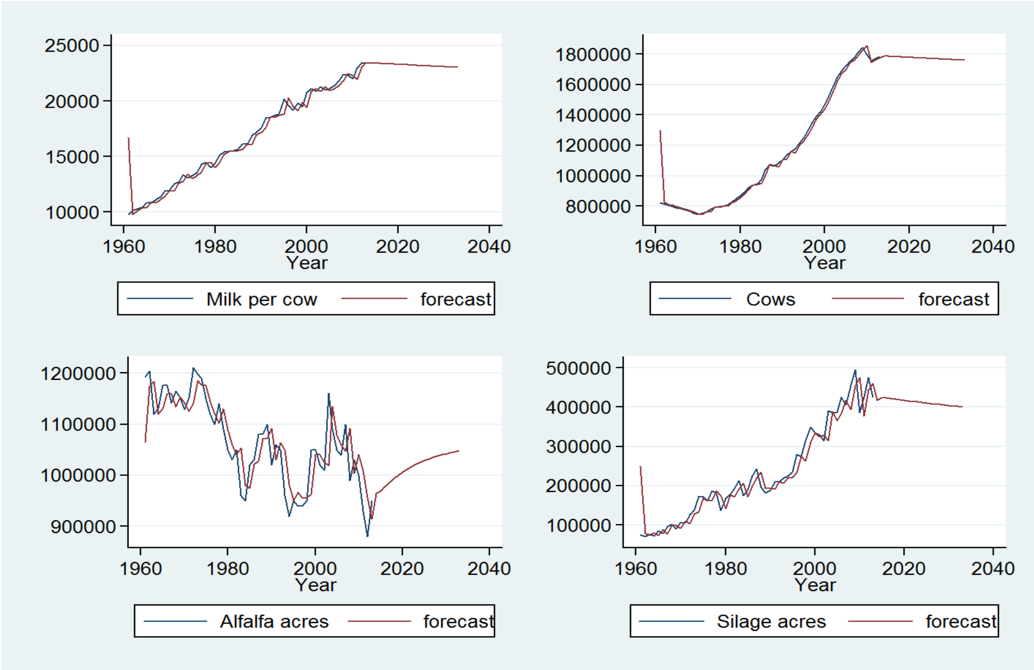
It is easy to estimate a large range of specifications over several data periods, thereby allowing forecasts for each variable of interest. Many such models were estimated and are available from the author. All of the univariate models fit well into the historical sample, and the mean squared errors are small. The important questions are which, if any, forecasts are likely to be accurate. The purely statistical criteria are not useful in this regard. Results and associated forecasts in the full set of alternatives examined differ across plausible specifications. This raises caution about relying solely on forecasts based on purely statistical approaches, even those reflecting relatively complex methods with strong economic foundations.

Highlighted below are four specifications using quarterly data for the full sample with and without trends for both the ARMA. These forecasts make use of the most data available and show the influence of assuming that past simple trends continue to be operative.

ARMA Model Forecasts

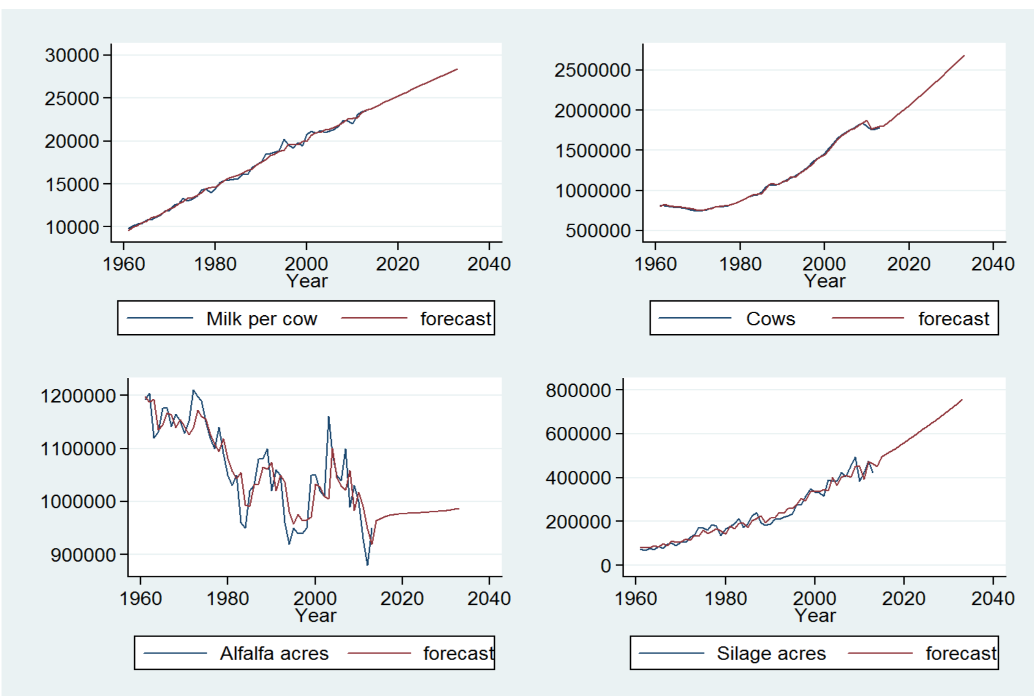
Forecasts from the ARMA model with annual and quarterly data are generally consistent with one another. When trends are included, the forecasted herd size and acreages tend to rise into the future. Models using annual data over five decades with no trends are shown in Figure 21. In these forecasts, milk production per cow and the number of cows would remain steady or slightly decrease in the next two decades. Cow numbers have declined recently, but for this trend to continue for 20 years would be a major departure from the past five decades. Milk per cow has also shown variability, but a reduction over the next 20 years would be unprecedented. Alfalfa acreage increases rapidly in the first few years and then slows, reaching about 1.05 million acres, well below the peak acreage over the period. Silage acreage decreases a little from its recent peaks. With the trend variables included (Figure 22), forecasts show consistent increases in every variable except alfalfa acreage. Alfalfa acreage is projected to be stable over the next 20 years and to remain below one million acres. Consistent with recent history and with increasing numbers of cows, silage acreage is projected to increase by more than 10,000 acres per year over the next two decades to near 750,000 acres.

Figure 21. ARMA Estimation, 1960–2012, and Forecasts, 2013–2032



Source: Author's estimates.
Note: ARMA(1, 1) for milk per cow and cows and ARMA(1, 1/2) for alfalfa and silage were used for estimation.

Figure 22. ARMA Estimation with Trends, 1960–2012, and Forecasts, 2013–2032



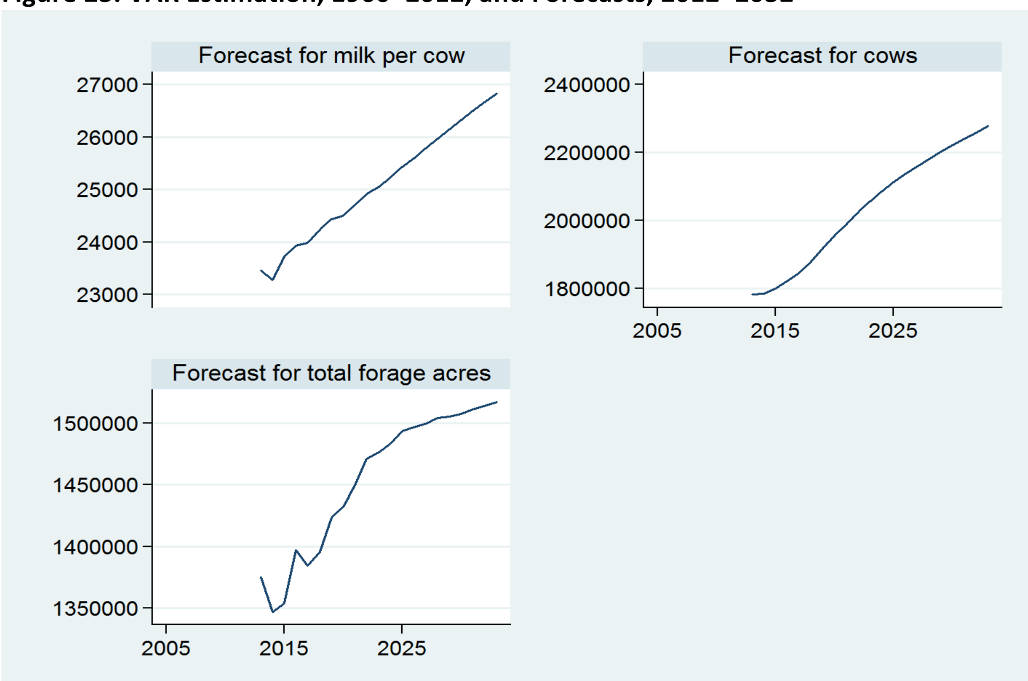
Source: Author's estimates.
Note: ARMA(1, 1) for milk per cow and cows and ARMA(1, 1/2) for alfalfa and silage were used for estimation.

Structural VAR Model Forecasts

The VAR approach brings more data to bear on the forecasts than the ARMA approach, in this case feed prices (corn and soybeans) and milk prices. The VAR approach also makes use of economic relationships such as the effects of feed prices on dairy market outcomes. Of course, neither of these advantages guarantees better forecasts. Compared with results from univariate approaches, the VAR results are more diverse among forecasts from different sample periods.

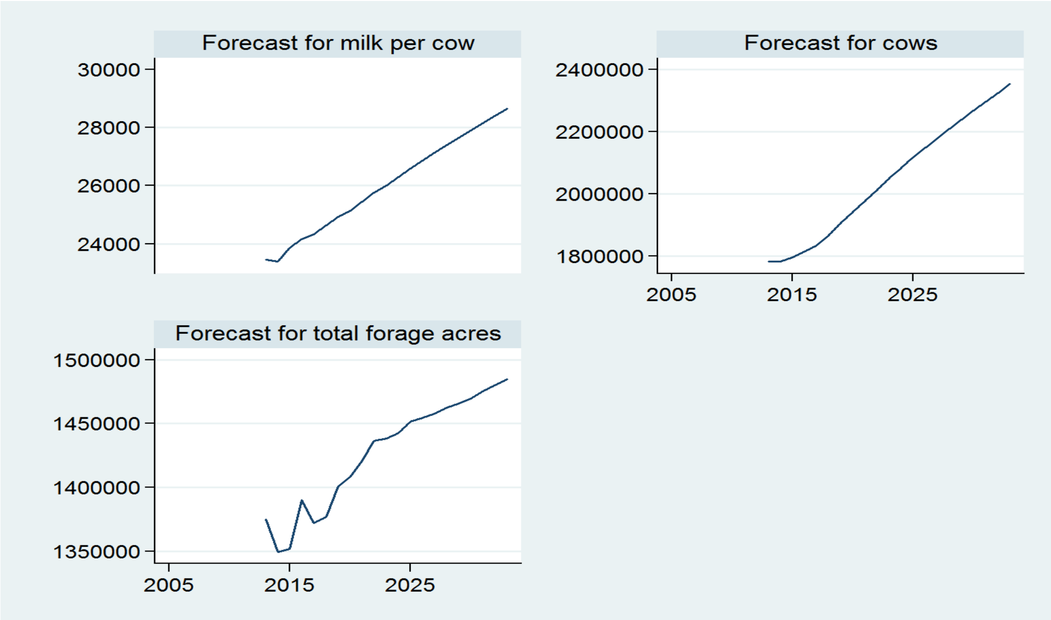
For the VAR models, this analysis combined alfalfa and corn silage into a total dairy forage aggregate acre. Figure 23 shows the VAR model using annual data for the full five decades and including no trend variables. All variables are projected to increase over the next 20 years. Milk per cow rises by about 15%, and number of cows rises by about 25%. Total forage acreages increases sharply and then flattens at just below 1.55 million acres. Including a trend variable (Figure 24), changes neither the directions nor the patterns in forecasts. Milk per cow rises faster, as does number of cows. Forage acreage grows more slowly, remaining below 1.5 million acres.

Figure 23. VAR Estimation, 1960–2012, and Forecasts, 2012–2032



Source: Author’s estimates.
Note: First, second, and third lags were used in the VAR model.

Figure 24. VAR Estimation with Trends, 1960–2012, and Forecasts, 2012–2032



Source: Author's estimates.
Note: First, second, and third lags were used in the VAR model.

The methodology and data underlying these results are the best available for use of a parsimonious and feasible time series approach, and the forecasts shown in figures 23 and 24 are within a plausible range.

THREE SCENARIOS FOR THE FUTURE OF CALIFORNIA AGRICULTURE

Presented below are three potential scenarios for California agriculture. These alternative futures consider California's overall agricultural production and commodities mix. The focus is primarily on the Central Valley and the dairy-forage nexus, where major adjustments appear most likely and where greenhouse gas (GHG) implications are largest.

The scenarios are based on a synthesis of the information presented above: forecasts, trends, and time series projections as well as resource constraints and current land use patterns and California agriculture's economic fundamentals (effects or lack of effects of supply adjustments on long-run commodity prices, and potential resource and commodity adjustments). This informal forecasting method is used by the USDA, the Food and Agricultural Policy Research Institute, the Organisation for Economic Co-operation and Development, and other organizations that develop projections of national and global agricultural outcomes. Unlike these organizations, however, this report presents alternative scenarios.

The three scenarios appear to be plausible projections of potential outcomes. The underlying reasoning and key facts supporting their plausibility are highlighted where they are not clear. They cover a relatively wide range of outcomes for the dairy-forage nexus.

An important unknown in these scenarios is the availability of irrigation water, especially for the San Joaquin Valley. Radical changes in patterns of precipitation or significant changes in public irrigation infrastructure could increase or reduce the availability and cost of the irrigation water on which most crop production in the Central Valley relies.

These scenarios have important implications for GHG emissions, primarily because they differ in number of milk cows, production per cow, and numbers of dairy steers and heifers in California feedlots.

The alternative scenarios reflect varying assumptions about future changes in California's dairy production as well as about other parts of the state's agriculture economy.

Demand for most major commodities continues to grow along with national and global population and income growth. Labor, land, and water productivity expands and total crop and grazing acreage declines slowly as some land is shifted to urban uses and other land use is diverted away from crops through local, state, and federal restrictions related to water quality. Some crops such as cotton continue to decline gradually, and the shift away from field crops and toward perennial crops continues. But the amount of acreage shifted per year falls, because fewer acres of land suitable for perennial crops remain in field crops. Rice in the Sacramento Valley on land not suitable for perennial crops is likely remain at about 500,000 acres; production gradually increases along with yield growth and markets for high-quality japonica rice expanding both within the United States and in Asia.

Vegetable acreage is likely to remain stable or grow slightly across scenarios as high values per acre and per unit of water allow vegetables to compete effectively in the coastal valleys and in the Imperial Valley in the far south. Processing tomatoes, which are grown in the Central Valley, compete with tree nuts and vines, forage crops, and other field crops. As discussed below, processing tomato expansion is tied to changes in the dairy industry.

Tree and vine crop expansion has continued in the Central Valley for many years as grain and cotton acreage has fallen rapidly. Much less grain and cotton acreage is available to shift to tree nuts and vines in the Central Valley, so if acres of tree and vine crops continue to expand rapidly, it will be at the expense of crops other than grain and cotton.

One source of land hinges on prospects for the California dairy industry. The following scenarios set up three different assumptions about the state's dairy sector over the next two decades. For crops that compete for land with forage, acreage adjusts inversely with dairy production projections.

Scenario 1: No Growth in Dairy Production

Under the no-growth scenario, California milk production remains stagnant for the first time in decades. As productivity per cow continues to climb at about 1% per year, cow numbers fall by about 20% by 2030. The number of cattle in California feedlots also declines, because a high proportion of these animals are dairy steers. This scenario is consistent with challenges in establishing or expanding dairies because of water quality and air quality rules (Anderson 2013; CEPA-CVRWQCB 2013; USEPA 2013; Canada et al. 2012; Harter and Lund 2012). California also faces additional challenges from moderate dairy prices, lower-cost dairy production in other western states and in the Midwest, and dairy policy changes on the horizon (Anderson 2012; Balagtas and Sumner 2012; Sumner, Balagtas, and Yu 2013; CDFA 2013).

As a result of declining milk cow numbers, alfalfa hay acreage falls by 15%; silage acreage, which is more closely tied to dairy cow feeding, falls in line with reductions in cow numbers (20%); and other hay acreage falls by 10%.

Table 7 shows that GHG emissions from the dairy industry fall with declining cow numbers. With a 20% reduction in dairy cow numbers, GHG emissions would fall by about 3.25 million metric tons CO2e per year. In addition, a small reduction in beef feedlot emissions would be expected, assuming that importing feeder cattle from out of state to replace dairy calves from California remained impractical.

Table 7. Projections for California Dairy, GHG Emissions under Three Scenarios

	Current	Dairy projection to 2030		
	2009	**No growth**	**Slow growth**	**Trend growth (20-year trend)**
Percent change in number of cows	-	-20%	-10%	40%
Implied number of Cows (millions)	1.80	1.44	1.6	2.5
Implied total GHG from dairy (MMT)	16.25	13.0	14.6	22.6

Source: Author's calculations using 2009 aggregate estimate of about 9 tons of CO2e emissions per cow.

Another assumption of the no-growth scenario is that alfalfa acreage is replaced by a mix of other crops and that the difference in emissions is approximately one ton per acre—or approximately the average per-acre California crop GHG emissions attributed to residue burning and nitrogen fertilization, according to CARB (2011) as summarized by Lee and Sumner (2013.) Under this simplifying assumption, cutting alfalfa acreage by 20% would increase GHG emissions by about 0.18 million metric tons CO2e.

Even though crop acreage declines only slightly over the next two decades, total GHG emissions from California agriculture would fall significantly under the no-growth scenario.

Under this scenario, upland cotton acreage declines, and tree nut and vine acreages grow to replace cotton and forage acreage. Wheat and other grain acreages decline, while rice acreage remains roughly constant. The long-term trend of replacing field crops with trees and vines continues. Coastal production of vegetables, strawberries, other fruits, and winegrapes continues with relatively little change. No evidence suggests that these changes in crop patterns would have significant effects on GHG emissions, which would be very much less than the more than 3 million metric ton CO2e caused by changes in dairy cow numbers.

The no-growth scenario is also consistent with less use of irrigation water per unit of crop production value in the San Joaquin Valley, because hay and silage use more water per acre than do tree and vine crops.

Scenario 2: Slow Growth of the Dairy Industry

The slow-growth scenario projects slower growth in dairy production compared with growth over the past several decades and a gradual decline of about 0.5% per year in cow numbers compared with an increase in cow numbers in past decades. Because milk per cow continues its trend path of increase, total milk production continues to rise. The scenario is roughly consistent with the past five years of a slightly declining dairy cow herd in California and slow growth in milk production (CDFA 2013). The results are like those outlined in the no-growth scenario, except that all the impacts are more moderate. Forage crop acreage declines slightly and perennial crop acreage grows slightly but below the historical trends.

With a 10% reduction in dairy cow numbers, GHG emissions would fall by about 1.6 million metric tons CO2e per year. As in the case of the no-growth scenario, a small reduction in beef feedlot emissions would be expected. If alfalfa acreage is replaced by a mix of other crops and alfalfa acreage is cut by 15%, GHG emissions would increase by about 0.13 million metric tons CO2e. Total GHG emissions from California agriculture would again fall significantly under this scenario.

Scenario 3: Trend Growth of the Dairy Industry

A continuation of long-term dairy cow numbers and per-cow production trends implies slower growth in perennial crop acreage, because fewer acres of field crops are left to convert to tree and vine crops. In this scenario, cow numbers rise by about 50% over just 20 years. This rate of growth is slightly slower than the trend rate of increase over the past three decades, even accounting for the dip since 2008. To supply sufficient forage for this size of dairy herd, more than 2.7 million cows, requires additional forage and a slowing of expansion of tree and vine crops. A 40% increase in dairy GHG emissions adds 8 million metric tons CO2e to the total for California agriculture. This total is roughly equivalent to current total crop GHG emissions and shows the importance of the dairy industry to the GHG profile for California agriculture.

To meet the demand for forage given land and water constraints, the trend-growth scenario incorporates hay and silage yield increases, some shipment of hay into California, and some shift of hay now used for other purposes, including exports, into dairy feed. The expansion of dairy cow numbers and milk production in California in the past two decades has been accomplished with no new alfalfa acreage. The trend-growth scenario assumes a 5% increase in alfalfa acreage, which if drawn from an average mix of crops would decrease GHG emissions from nitrogen fertilizer and residue burning by 0.04 million metric tons.

New acreage in hay and silage would put extreme pressure on the water and land resources available for other crops. As a result, cotton and wheat acreage would further decrease, and tree and vine crops would expand much more gradually. The trend-growth scenario would require reductions in many crops throughout California if increases in alfalfa and silage were accommodated along with moderate growth in tree nut acreage.

Scenario Comparison

Table 7 shows that in 2009 the dairy industry produced about 16.25 MMT of GHG emissions, which accounts for about 70% of emissions from livestock and about half of emissions from agriculture in California. The no-growth scenario projects the number of cows to decline by 20% and total GHG emissions from dairy to fall to 13.00 MMT, a decrease of more than 3 million metric tons. Under the slow-growth scenario, GHG emissions from dairy fall by 10% to 14.70 MMT. Under the trend-growth scenario, which continues the long-term trend of a 40% increase in the number of cows, total GHG emissions from the California dairy industry increase to 24.38 MMT. The growth of about 8 MMT is itself about 25% of the total GHG emissions from agriculture in 2009.

These projections assume constant GHG emissions per cow. All the projections assume increases in milk production per cow, which generally means more feed per cow. If emissions per cow rise, the estimates presented in Table 7 are conservative. Alternatively, research and development and innovation to reduce emissions per cow might cause the estimates to overstate emissions growth. On balance, the assumption of constant emissions per cow appears a reasonable compromise between these offsetting forces.

SUMMARY

This report has examined background data describing California agriculture, trends in acreage and production, evidence about demand drivers, and national agricultural projections for commodity industries of importance in California. It also presented results of time series forecasts. Finally, based on all these data and on more informal assessments of forces driving dairy market demand and relative costs in California relative to competitive regions, it outlined three potential scenarios for the dairy industry and what they would likely mean for GHG emissions.

If trends of the past three decades continue through 2030, moderate increases in tree nut and winegrape acreage would be expected. Given limits on irrigated cropland, variations in land characteristics, and economic prospects, other tree and vine acreage is likely to remain roughly stable. The continued increase in tree nut and winegrape acreage implies reductions in field crops other than rice. Rice demand and the specialized nature of most rice land suggest that rice acreage will total somewhat less than 600,000 acres by 2030. Processing tomatoes also have a solid future in California, given their significant share of world markets, improving yields, and efficient processing. Field crop acreage overall, including cotton acreage, has declined for a generation and the rate of decline in terms of acres per year cannot continue simply because there are too few acres left in the relevant field crops. Some land now in wheat or other crops is not suitable for vines or tree nuts or has no reliable irrigation water supplies.

Produce and other specialty crop production will continue in California. Strawberries, high-priced coastal winegrapes, lettuce, broccoli, and dozens of other such crops contribute billions of dollars of revenue on relatively few acres while contributing only a small share of total agricultural GHG emissions. (These crops use nitrogen fertilizer at roughly the same rate as other crops—without requiring residue burning—and overall cover only a few hundred thousand acres.) These crops also use specialized land and climate resources. Production will continue, because if costs rise, land prices will fall in the specialized regions that grow these crops. These crops are important for the economics of California agriculture.

Livestock industries may be considered as two industries. The first, extensive beef cow-calf operations, uses pastures in the California hills and mountains as well as seasonal pastures in the Central Valley. The calves are mostly sold out of California for intensive feeding. These cattle emit methane as do any bovine, but they are widely dispersed, and their numbers are unlikely to change much on a long-term basis. Pasture improvements are technically feasible, but economically feasible ways to increase cattle per acre have not been evident, and no increase in cow-calf units per acre has occurred in California in recent decades.

The second livestock industry, intensive feeding operations that include cattle feedlots, broiler and turkey feeding operations, and egg producers, generates localized manure and methane emissions from confined animals. All these operations are under intense regulatory and economic pressure in California. As noted above, the commercial egg industry is unlikely to remain in California if a combination of state and federal regulations mean costly hen housing restrictions apply to California producers but not to their competitors (Sumner et al. 2008; Sumner et al. 2011; Simon 2013). (In that case, eggs would be shipped in, and the hens and the emissions from their manure would remain outside California. The poultry industry itself is small and is not an important contributor to GHG emissions in California.) Other parts of intensive animal agriculture face similar long-term pressures. They balance the costs of shipping grain from the Midwest against the costs of shipping products from other regions. As producers outside California become more efficient and as air and water quality rules in California become relatively more costly, the cattle feedlot industry may move out of state. That industry uses some forage from California but relies primarily on feed from the Midwest. One reason for the California location of cattle feedlot operations is local sourcing of dairy steers. But again, the balance of shipping costs and higher operation costs may imply a shift of some of this industry out of California over the next 20 years.

This report has focused much of its attention on the California dairy industry. As explained above, dairy farming has by far the largest GHG emissions of any industry in California agriculture (about half of the California total). Furthermore, dairy farming is the most prominent industry, but serious economic questions attend its likely growth path.

A no-growth scenario is a radical departure from trends over the past several decades. In that scenario, cow numbers decline and forage acreage would decline as well, opening land for tree and vine crops. Overall agricultural GHG emissions would fall by more than 10%. A slow-growth scenario also deviates from the historical trends but envisions California dairy expanding to satisfy growth in Asian export markets. Dairy processing also must expand slowly, meaning the higher costs of operating in California must be met by higher efficiencies, either in processing or in milk production. GHG emissions fall by about 5% in this scenario. The trend-growth scenario envisions a 40% increase in dairy herd size, reflecting a reversal of economic challenges facing the California dairy industry over the past five years.

It assumes that innovations are made to meet air and water quality regulations and to improve on-farm efficiency. This scenario also reflects higher global milk prices from increased global demand with income growth. Under the trend-growth scenario, California agricultural GHG emissions would rise by 8 million metric tons of CO2e, or by about 25%. Because dairy accounts for about half of California agriculture's GHG emissions and because these emissions have the greatest potential for mitigation, the path of the dairy industry is crucial for assessing GHG emissions projections and planning.

This discussion of the future of California agriculture reflects considerable uncertainty about alternative paths. That said, the continued expansion of tree, vine, and vegetable crops appears likely. The big issue is prospects for California dairy, the industry with the most important implications for GHG emissions.

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