The Impact of Climate Change on Grain Production: The Case of French Cereals

Matthew Gammans, Pierre Mérel, and Ariel Ortiz-Bobea

Cereal yields have grown considerably over the past several decades in many regions of the world, but rising temperatures pose an emerging threat to this progress. Our analysis of over six decades of French weather and yield data sheds light on the potential impacts of climate change on cereal yields and contextualizes these impacts relative to expected future technological progress.

Cereal yields have grown considerably over the past several decades in many regions of the world, but rising temperatures pose an emerging threat to this progress. Our analysis of over six decades of French weather and yield data sheds light on the potential impacts of climate change on cereal yields and contextualizes these impacts relative to expected future technological progress.

The impact of future changes in climate on agricultural yields is of interest to farmers, whose livelihood is directly affected, as well as policymakers, who may use projections of climate change impacts to better craft policies that mitigate the extent of warming, adapt institutions and industries to warming, or redistribute resources to compensate those most harmed by climate change. Indeed, there is mounting evidence that warming will harm grain yields in key producing regions. Two important crops that may be affected by climate change are wheat and barley. According to the United Nations Food and Agriculture Organization (FAO), wheat and barley represent the third and fourth most produced grains, with wheat being the second largest calorie source worldwide among all crops. France is a major producer of both crops, producing 5.4% of the world’s wheat and 7.1% of the world’s barley in 2013.

In France, wheat represents over half of total cereal acreage, while barley is grown on 18%. Both wheat and barley can be cultivated as either winter or spring crops, although winter wheat is far more prevalent than spring wheat. Winter crops are typically planted in mid- to late fall and harvested the following July or August. Meanwhile, spring crops are most commonly planted between late February and mid-March and harvested several weeks after winter crops.

Weather conditions may have varying effects on yield at each stage of plant growth. In the fall, excessively cold temperatures may be harmful to winter crops if they occur before the crop has acclimated to low temperatures, a concept known as cold-hardening. During the winter months, excessively warm temperatures may interfere with vernalization, an exposure to cool temperatures necessary to induce more rapid flowering in the spring. In the summer, high temperatures or a lack of rainfall can have adverse effects on photosynthesis and grain-filling, while excessive rainfall can result in flooding and foster mold growth.

Researchers seek to understand the relative importance of these various weather effects on crop yields under current and future climates using a variety of approaches. Process-based approaches typically rely on calibrating a deterministic biophysical model with experimental data. These highly parameterized models allow simulating plant growth and yield formation as temperature, moisture, or atmospheric variables fluctuate on a daily basis. In contrast, statistical approaches rely on large-scale relationships among observed variables, often aggregated over many farms. Our work adopts a statistical approach, using historical weather and yield data from France to obtain estimates of the effect of climate change on French wheat and barley yields.
Effect of Temperature and Precipitation on Yields

Data on crop yields come from the French Ministry of Agriculture and include observations for 88 departments over mainland France from 1950 to 2016. Historical weather data for the same time period were obtained from a detailed gridded dataset for the European Union, which we aggregate to the department level based on the amount of agricultural area contained in each grid cell.

The level of exposure to specific temperatures within each day of the growing season has been shown to be important in predicting crop yields. We therefore compute exposure to various levels of temperature assuming that temperature follows a sine curve passing through the minimum and maximum temperature of each consecutive day. This procedure accounts for the day-night oscillation in temperature as we compute the exposure to every 1°C temperature interval for every day in the growing season.

We sum temperature exposure and precipitation over the spring-summer growing season and, in the case of winter crops, we separate fall and winter growing seasons. We define growing seasons based on a 2006 regional survey of French cultural practices.

Averaging temperature conceals the occurrence of temperature extremes, which may be important for yield determination. Therefore, it is important to account for the full range of exposure to temperatures in a flexible manner in a statistical model predicting the effect of temperature on yields.

To illustrate this, consider two days that both have an average temperature of 28°C. For the first, suppose it was 28°C for 24 hours, while for the second, suppose it was 22°C at night and 34°C during the day. The crop may respond very differently to these conditions.

Figure 1. Temperature-Yield Relationship

Note: Graphs at the top of each frame represent percentage changes in yields if one day at 0°C or below is replaced by one day at a given temperature, holding the total number of days in the season constant. The blue line indicates the step function specification and the red line indicates the polynomial specification. The 95% confidence interval for the polynomial regression is shown in gray. Histograms at the bottom of each frame show the average temperature exposure over the sample.
two days, despite the fact that they have the same average temperature. To ensure that our model is sufficiently flexible, we test two flexible functions of temperature: a step function and a polynomial. The step function allows the effect of each 2°C interval (0–2°C, 2–4°C, etc.) to be different, while the polynomial function allows each temperature to have a different effect, but imposes that the effect of two adjacent temperatures not be too different. In addition to a flexible function of temperature exposure and a quadratic function of total precipitation, we also control for time-invariant factors such as soils through the inclusion of department fixed effects and for technological progress, allowing time trends to be different in each of France’s 21 regions.

The effect of temperature on yields can be seen in Figure 1. The step function and polynomial response functions are quite similar qualitatively. Exposure to temperatures above 32°C are associated with yield declines for all three crops, although the extent of the damaging effects varies significantly across crops.

Spring barley, the crop most negatively affected by temperatures above 32°C, is also adversely affected by more moderate warm temperatures between 16–30°C. Both winter crops appear to benefit from cool temperatures between 7–11°C, although the effect is more pronounced for winter wheat. Graphs of the cold season temperature-yield relationship, not included here, suggest that exposure to temperatures below –6°C in the fall months is harmful, while the effects of winter temperatures are less important.

**Climate Change Impacts**

We project the impact that future climate change will have on wheat and barley yields relative to a world without climate change, based on the weather-yield relationships estimated on historical data. These impacts assume that land use and technology are held constant, with only the climate changing. The magnitude of the impacts naturally depends on the climate model or Global Circulation Model (GCM) and the assumed future trajectory of greenhouse gas emissions that we rely upon.

We project impacts under five GCMs and three possible trajectories of future atmospheric greenhouse gas concentrations outlined by the International Panel on Climate Change. These trajectories, called Representative Concentration Pathways (RCP), range from the mildest “RCP 2.6,” which would require worldwide carbon emissions to begin decreasing immediately, to the most severe “RCP 8.5,” representing a “business-as-usual” trajectory in which emissions continue to increase throughout the 21st century. We project climate change impacts for a mid-century period, 2037–2065, and an end-of-century period, 2071–2099. The impacts are relative to the baseline period of 1977–2005.

The average impact, across all climate models, for each crop and time period are presented in Figure 2 for RCP 2.6, 4.5, and 8.5. The error bars represent a range of plus and minus one standard deviation from the average. In the mid-century horizon, winter wheat and winter barley face declines of 6–10% depending on the RCP scenario. The impact on spring barley is predicted to be more severe, with yield declines ranging from 12–18%.

End-of-century impacts are roughly comparable to the mid-century projections in the low-emissions case, but far larger for mid- and high-emissions scenarios. For winter wheat, RCP 8.5 is associated with a yield decline of 21%, while winter barley yields are projected to fall 18% for the same scenario. Again, the impact on spring barley yields is much larger, with losses ranging from 13%–34% across RCP scenarios.

**Comparison with Other Studies**

Our results indicate that climate change will negatively affect French cereal yields, although the extent of the damage varies widely depending on the emissions scenario being...
considered. The negative impact on wheat yields is consistent with the findings of many agronomic studies relying on process-based models. A 2015 statistical study on Kansas wheat yields by Tack et al also finds deleterious effects of climate change, although of very different magnitudes. We find that 5°C of warming would decrease French wheat yields by 24%, while Tack et al find that the same warming would decrease Kansas wheat yields by 50%.

This difference could possibly be due to differences in baseline climate, as the Kansas climate is substantially warmer than the French climate and thus the effect of additional exposure to high temperatures may be more detrimental in Kansas. Differences in the modelling approach may also explain the difference. The Kansas study uses a degree-day model that imposes slightly more structure on the weather-yield relationship than either the step function or polynomial specification used in our study. Finally, we are unable to rule out the possibility that data differences, including different levels of aggregation in the weather and yield data, contribute to the difference.

### Technological Progress and Adaptation

Cereal yields in France have risen substantially over the past half-century. Since 2000, yields have averaged 6.1, 5.8, and 4.7 metric tons per hectare (MT/ha) for winter wheat, winter barley, and spring barley, respectively, compared to 1.9, 1.7, and 1.7 MT/ha during the 1950s. Even though the rate of growth has slowed over time, technological improvements will likely continue to increase yields in the near future, despite the counteracting effects of climate change. Our empirical results can be used to calculate the expected net impact of technological progress and climate change on yields.

The average net impact across climate models for each crop, RCP scenario, and time horizon are shown in Figure 3. Our results suggest that, relative to the 1977–2005 baseline, mid-century yields will be 14–32% higher depending on the crop and RCP scenario. For RCP 2.6 and 4.5, the end-of-century net impacts are quite similar to those in the mid-century case. The results for RCP 8.5 are more striking. Under these more severe climate changes, winter barley yields would be only 6% higher than in the baseline period while the negative effects of climate change would neutralize all of the expected technological progress for winter wheat and spring barley.

These estimates assume that farmers do not alter land use patterns in response to climate change. Although shifting production to cooler regions represents one potential adaptation mechanism, it is not without costs. New areas may have lower soil quality than current production regions and high fixed costs will prevent many farmers from easily shifting their operations onto new land. A second adaptation action consists in shifting to more resilient crops. Indeed, French farmers have been increasingly shifting from spring to winter barley since the 1960s, a trend that our results suggest may continue. Investment in the research and development of heat-tolerant crop varieties and improved farming practices, beyond the technological progress implied by our estimates, may also palliate the negative impacts of climate change on cereal agriculture.

### AUTHORS’ BIOS

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### Suggested Citation:

Crop Rotations Can Increase Net Returns in Organic Strawberry and Vegetable Production Systems

Aleksandr Michuda, Rachael Goodhue, Joji Muramoto, and Carol Shennan

Crop rotations aimed at suppressing verticillium wilt disease in organic strawberries pose a dynamic tradeoff to growers. Using broccoli (a non-host crop) and other crops in the rotation, reduces current revenues but increases future strawberry yield and revenues. Trial results suggest that crop rotations can be sufficiently effective at reducing the strawberry yield penalty due to verticillium wilt for commercially viable organic production systems.

Providing adequate plant nutrients and building effective system-based pest management strategies are critical challenges in organic strawberry and vegetable cropping systems on California’s Central Coast. Growers must achieve economic sustainability while meeting these challenges. Long-term economic sustainability of organic production systems requires the development of integrated fertility and pest management strategies that also seek to reduce negative impacts of agriculture on nearby natural ecosystems and environmental quality.

Organic strawberries obtain a premium in fresh markets. Figure 1 plots organic and conventional strawberry prices at the Salinas-Watsonville shipping point over the last 10 years reported by the U.S. Agricultural Marketing Service. On average, organic strawberries sold for $0.68 more per pound, approximately a 25% premium over conventional prices. Despite this, organic strawberry growers do not realize higher net returns, due to higher costs of cultivation and lower yields, so there is a need to enhance the commercial viability of these systems in the presence of disease.

The work reported here was conducted as part of the California Collaborative Research and Extension program, which has the goal of building a research and outreach network for producers of organic strawberries and vegetables on California’s Central Coast. The centerpiece of the project is a replicated rotation study conducted at the University of California, Santa Cruz, Center for Agroecology and Sustainable Food Systems farm. The trial was conducted from November 2011 to November 2015 at a site that has been under organic management for 40 years.

The main purpose of this trial was to design a rotation to suppress verticillium wilt. This piece will discuss the results and their implications regarding economic sustainability. Verticillium wilt (in this case, caused principally by *Verticillium dahliae*) is a soil disease that can cause major damage to strawberry yields, and strawberries are very susceptible to it. The pre-plant soil fumigation used for the suppression of verticillium wilt in conventional cropping systems cannot be used in organic ones. Suppressive crop rotations are a potential alternative permitted under the rules governing organic production.

The rotations included in the trial were of different lengths, and included different combinations of crops with varying revenue potential and susceptibility to wilt. Two-year rotations were repeated twice during the four-year trial. Strawberries were planted in the final year of each rotation: years 2 and 4 for the two-year rotations and year 4 for the four-year rotations. The trial used a “split-split-plot” experimental design.

**Figure 1.** Daily Organic and Conventional Fresh Strawberry Prices at the Salinas-Watsonville Shipping Point: January 2006–December 2016


Organic
Conventional
The site was divided into four blocks of sixteen plots each. Within a block, these sixteen plots were divided into two-year and four-year rotations. Within rotations of each length, half of the plots grew a revenue-generating cash crop, such as lettuce or cauliflower, which was more susceptible to wilt. The remaining plots grew a non-host crop, broccoli, which suppresses verticillium wilt, thus increasing future strawberry yields.

Each of the four—within a cash crop treatment—was then assigned a different fertility cover crop treatment: mustard-seed meal, a low-nitrogen cover crop mix, a high-nitrogen cover crop mix, or fallowing. The soil fertility treatments were used in the first and third years. In total, there were 16 treatments, each with four replicates. Due to the small number of replicates, pairwise statistical comparisons were not feasible. Table 1 summarizes the rotations studied.

### Table 1. Crop Rotations Included in Trial

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<thead>
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<th>Year 3</th>
<th>Year 4</th>
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Two-year rotations:

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<tr>
<td>5b</td>
<td>CC Lettuce ASD-Strawberry CC Lettuce ASD/Strawberry</td>
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<td>6b</td>
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</tr>
<tr>
<td>8b</td>
<td>Fallow Lettuce ASD-Strawberry Fallow Lettuce Strawberry</td>
</tr>
</tbody>
</table>

*: Cereal/legume cover crop

**: Cereal/legume cover crop plus compost and supplemental organic fertilizer based on soil tests prior to vegetable crops

***: Mustard Seed Meal

****: Anaerobic soil disinfestation prior to planting strawberry

The two vs. four-year rotations: second year strawberry net returns

Rotations can reduce pest and disease pressure, but also reduce net revenues. In this cropping system, strawberries are a very high-value crop on a per-acre basis, so rotating with other crops reduces net revenues significantly—all else equal. Using the yields per acre for organic strawberries and organic broccoli in the UC Cooperative Extension Cost and Return Studies, revenues per acre were around $61,000 for strawberries in the fourth year and around $10,000 for broccoli, a difference of roughly 83%. However, a reduction in the pathogens causing verticillium wilt can increase future strawberry yields and offset this reduction in net revenues.

Trial results found that the greater reduction of pest and disease pressure in the four-year rotations outweighed the reduced revenue from only one year of strawberry production. Comparing strawberry yields for two- and four-year rotations with the same cash crop choices, year 2 yields were much lower than year 4 yields. However, this comes with the caveat that a new bed shaper was used in the fourth year to create more favorable conditions for strawberry plants, after second-year
yields were reduced due to poor drainage and lower than normal bed heights. In year 2, strawberry net revenues were negative for all two-year rotations due to low yields. These lower returns were due to a higher incidence of verticillium wilt in the soil.

Net revenues for all treatments are summarized in Figure 2. From this figure, we can see the relationship between cash crop choice and year 4 strawberry revenues. The years in which a given rotation grew lettuce or cauliflower saw large current revenues compared to broccoli, which realized small or even negative returns. But, rotations with broccoli saw substantively larger strawberry revenues at the end of the rotation than those that did not. This highlights the tradeoff between using crops that generate more revenues per acre, lettuce or cauliflower, and non-host crops like broccoli. This tradeoff exists for both two-year and four-year rotations, independent of the difficulties with year 2 strawberry production noted earlier.

Rotation Costs

Differences in costs affected net returns. Each crop had different costs associated with buying seed, installing irrigation, shaping and cultivating beds, and harvest. Harvest costs accounted for the majority of the costs for all crops. Strawberry harvest was by far the most expensive, often by three to seven times the harvest costs for broccoli or lettuce, due to the extensive use of hand labor.

Crop Prices

Variation in crop prices was also important in determining net returns, especially for lettuce and broccoli. One reason why Figure 2 shows a large discrepancy between net returns from rotations including broccoli and lettuce is due to the differences in their prices. In commercial production, growers must make these decisions before planting—taking into account anticipated market conditions as well as technical factors. Such choices are not addressed in the trial. Instead, fixed rotations were tested. This affected the relative economic performance of the treatments.

Lettuce and broccoli net returns are very sensitive to price differences. To illustrate this, notice that in the third year, broccoli was unprofitable. In July 2014, lettuce had a relatively high harvest price, causing positive returns for the third year of the trial in all four-year treatments planting lettuce in year 3.

We assessed the extent to which unusually high and low prices during the trial drove the relative performance of the various rotations by using average historical prices for each crop. Running an analysis of variance (ANOVA) with average harvest month prices for the four-year trial period, we saw no statistically significant difference between them and the net returns in the primary analysis—suggesting that they are relatively robust to changes in prices. Figure 3 plots net returns by rotation, with primary results and net returns using average prices side by side.
Conclusion
Devising economically sustainable methods for growing organic strawberries is necessary for the industry’s continued growth. The trial examined here considered organic crop rotations designed to be environmentally sustainable while suppressing verticillium wilt. The trial results illustrate the tradeoffs involved in such crop rotations, including the choice of higher net revenue per acre vs. the suppressive benefits of a non-host crop, the increased harvest costs associated with higher yields for strawberries, the highest-value crop, and price variability.

Trial results found that the greater reduction of pest and disease pressure in the four-year rotations outweighed the reduced revenue from only one year of strawberry production.

Returns for strawberries in two-year rotations were relatively low due to net outcome of the tradeoff outlined above. Shorter intervals with non-host crops led to higher incidence of verticillium wilt and lower strawberry yields. When comparing rotations of a given length within the trial, it was difficult to reach firm conclusions regarding the relative profitability of different crop combinations. While broccoli tended to increase future strawberry yields, current revenues from lettuce were higher.

Although more time is needed to evaluate how these crop rotations affect the incidence of disease over multiple repetitions, the Mother Trial demonstrated that crop rotations in organic production systems can be commercially viable. If these crop rotations are bundled with the prospect of some sort of insurance that can help them smooth their returns over time, the commercial viability of the rotations could be enhanced.

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For additional information, the authors recommend:
The Organic Premium for California Blueberries

Hoy F. Carman

California has recently become an important blueberry producer and now accounts for about one-half of fresh U.S. organic blueberry production. California’s “organic premium” that recently averaged $2.28 per pound over the conventional free on board (FOB) price of $2.92 per pound varies by package and over time. Growth of organic blueberry production is expected to continue.

U.S. consumer demand for blueberries has grown dramatically over the last two decades as information on blueberries’ nutritional benefits and antioxidant properties has been disseminated. Production has kept pace with demand as acreage has expanded in traditional as well as new geographic areas in the Southeast and Western United States.

Commercial-scale production of blueberries in California is a relatively recent development. California first reported blueberry statistics in 2005 when there were 1,800 acres of blueberries harvested and production of 9.1 million pounds with a total value of $40.58 million. Harvested acres increased to 3,900 acres in 2010 with production of 28 million pounds and a total value of $75.98 million. Growth continued through 2015 with California Agricultural Statistics Survey (CASS) reporting 5,700 acres of blueberries harvested, production of 62.4 million pounds, and total value of $116.98 million.

The increasing total value of production moved blueberries ranking to 46th among all California crops in 2015. The USDA National Agricultural Statistics Service (NASS) reported 2015 blueberry acreage, production, and price statistics for 13 states. In terms of acreage harvested, the top eight states (Michigan, Georgia, Washington, Oregon, New Jersey, North Carolina, California, and Florida) accounted for 95.6% of the U.S. total of 89,820 acres. California ranked seventh in total acreage, fifth in total production, and second for total value of production among all states in 2015.

According to the Census of Agriculture Organic Survey, there were 516 U.S. farms producing fresh organic blueberries from 3,909 harvested acres in 2014. Total U.S. fresh organic sales of 17,881,973 pounds were valued at $60,720,308.

California had the largest organic blueberry production and sales in 2014. It accounted for 63 farms (12.2%) and 941 acres (24.1%) of the U.S. total organic blueberry acreage. California’s fresh organic blueberry sales totaled 8,319,770 pounds (46.5% of U.S. total) valued at $31,202,441 (51.4%).

California blueberries are shipped throughout the U.S. and to a number of export destinations. During the 2016 harvest, California’s largest U.S. market was California, which accounted for 34.75% of California’s total fresh blueberry shipments of 46,493,407 pounds. The largest out-of-state domestic shipments were to Texas, Oregon, Washington, Arizona, New York, Minnesota, Utah, and Pennsylvania. These states collectively accounted for 36.54% of California shipments. Canadian shipments of 5.54 million pounds accounted for 11.9% of California’s volume and made up 67.1% of exports.

California Blueberry Prices

Typically, the price per pound of organically grown blueberries is higher than for conventional production. Prices also vary by package size, with smaller package sizes usually selling for more per pound than larger packages. There is usually a premium for the first portion of the crop-marketing year, and the overall level of prices will vary by year. Prices can also be expected to vary by geographic location. California organic blueberries are among the first domestic fruit on the market when prices tend to be seasonally high.

An important U.S. consumer segment is willing to pay a premium price for organically produced products. Organic producers have argued that higher prices are justified by input restrictions that pose additional costs for organic output and the reduced per-acre yields, further increasing unit costs of production. There is some evidence that increased experience and scale of production has been narrowing the cost differences for selected organic crops. The “organic premium,” however, continues to be a very important factor to producers when deciding to adopt organic production methods, and selecting which organic crops to produce. Organic premiums vary by crop and product, location, stage in the marketing channel and, over time, due to a complex mix of supply and demand factors.

Blueberry Data

California blueberry producers voted to establish the California Blueberry Commission (CBC) in 2009. It was founded March 1, 2010. An important activity of the CBC was to fund the Blueberry Marketing Resource Information Center (BMRIC). The BMRIC collects and provides important real-time marketing data to the industry and also publishes summaries of weekly shipments, pack-out volume, and daily free on board (FOB) prices by size of package (container) in their annual reports. While these data do not cover all California production, they are representative of commercial production.
Organic Blueberry Price Premiums by Package

Weighted average prices per pound by package for California organic and conventional blueberries during the 2016 season are shown in Table 1. The premium per pound, as well as the percentage premium over conventional fruit, are also shown for each package. For the largest volume organic containers, the organic premium ranges from $1 for the pint to $1.04 for the 6 oz. For other packages, the organic premium ranges from $2.74 to $4.04 per pound. An overall weighted average by container for organic and conventional fruit is $5.20 and $2.92 per pound, respectively, which yields an overall average organic premium of $2.28 per pound or a premium of 78% of the conventional price.

Overall in 2016, organic blueberry shipments accounted for about 23.1% of California’s total volume and about 34.8% of total revenue at the first handler level in the marketing channel. BMIRC Statistics reported in the CBC Annual Report shows 2015 organic premiums that are generally similar to those shown for 2016 in Table 1. Overall, the weighted average prices for organic and conventional California blueberries in 2015 were $5.16 and $2.88 per pound, respectively, yielding an organic premium of $2.28 per pound. While average prices were slightly higher in 2016 than in 2015, the overall organic premium was identical at $2.28 per pound.

Seasonal Price Comparisons

Blueberries from Florida, California, and Georgia are the first domestic berries on the market each spring. As is typical with many fruit crops, prices are high at the beginning of the season and decrease over time as volumes marketed increase. California’s blueberry harvest ends in late June or early July after harvest volumes from other states, especially Oregon and Washington, have increased significantly.

The relationship between organic and conventional blueberries also tends to change seasonally and by package. Seasonal prices and the organic premium for 6-ounce containers during 2016 are shown in Figure 1. There was little difference in price between California organic and conventional blueberries at the beginning of the season (weeks 1 to 4) but the premium increased as conventional prices decreased faster than organic prices (weeks 4 to 9). Finally, prices and the premium were rather steady for the final four weeks of the 2016 season. The organic premium for 6 oz. packages varied from $0.34 to $0.76 per pound for the first four weeks, increased to a range of $0.96 to $1.88 from weeks five to nine, and then varied from $0.73 to $1.16 per pound for the final four weeks (Figure 1).
Organic’s share of total California blueberry shipments has increased over the last three years. Organics made up 17.2% of total California blueberry shipments in 2014, 19.7% in 2015, and 23.1% in 2016. Preliminary indications are that the organic share of 2017 California shipments will exceed 26%. The organic share of weekly fresh California blueberry shipments begins high and decreases as the season progresses.

Beginning with week 1 (the week ending March 27, 2016), the pattern is illustrated for 2016 in Figure 2. While organic blueberries accounted for 23.1% of all California shipments in 2016, the organic share of weekly shipments continued above that threshold from weeks 1–7. At the end of week 8, one-half of the organic crop but only one-third of conventional production had been shipped.

Comparing information in Figures 1 and 2, one observes that the premium for organic blueberries began to widen in week 5 when the organic share of shipments dropped below 40% and conventional blueberry sales began exceeding 60% of total shipments. The organic share jumps in the last week of California’s season (week 14) because many California producers of conventional blueberries stop picking when prices are reduced by large volume shipments from Oregon and Washington in late June.

**Costs of Production**

Blueberries are an expensive crop to grow and hand harvest is very labor intensive. UC Cooperative Extension budgets for establishing and producing blueberries in both Oregon and California indicate that costs for organic plantings and production are higher than for conventional blueberries. Budgeted yields are comparable for organic and conventional production with mature yields in a range of 16,000 to 18,000 pounds per acre. Cash costs excluding harvest costs for a mature conventional planting in Oregon were estimated at $3,342 per acre while comparable costs for an organic planting were estimated at $5,158 per acre. The higher cash costs for organic production were largely due to higher costs for fertilizer and general labor.

California cultural costs were $3,921 per acre for conventional and $5,856 per acre for organic production. Some of the differences in costs of inputs were due to location and year of the study; the organic budget was for Coastal Counties while the conventional budget was for the Southern San Joaquin Valley. The major cost difference was due to higher costs for weeding and fertilizer for organic production.

The authors of the budgets noted that the risks associated with organic blueberry production are greater than for conventional production due to such things as control of disease and insect infestations that can negatively affect yields and total revenues. Even though risks and per-acre costs of production are higher for organic than for conventional blueberries, the difference can be quickly offset by recent organic premiums that provide a powerful incentive for further increases in California organic blueberry production.

**Concluding Comments**

Growth in California organic blueberry production has outpaced conventional production for several years, and California accounted for about half of the U.S. supply of organic blueberries in 2014. The organic share of California blueberry shipments in 2016 was 23.1% in terms of volume and 34.8% in terms of value. The larger share of value is due to the premium price for organic blueberries.

The organic premium, which averaged $2.28 per pound in both 2015 and 2016 (78–79% of the conventional fresh blueberry price), varies by package and over time. California has some of the earliest domestic blueberry production, with relatively high prices for both conventional and organic blueberries at the beginning of the season. The proportion of shipments that are organic decreases as the season progresses and the organic premium tends to be highest after the first one-third of the season. The growth of organic blueberry production in California, relative to overall California production as well as U.S. organic blueberry production, seems to indicate a comparative advantage for organic blueberries in California. Further growth of organic as well as total blueberry production in California is expected.

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