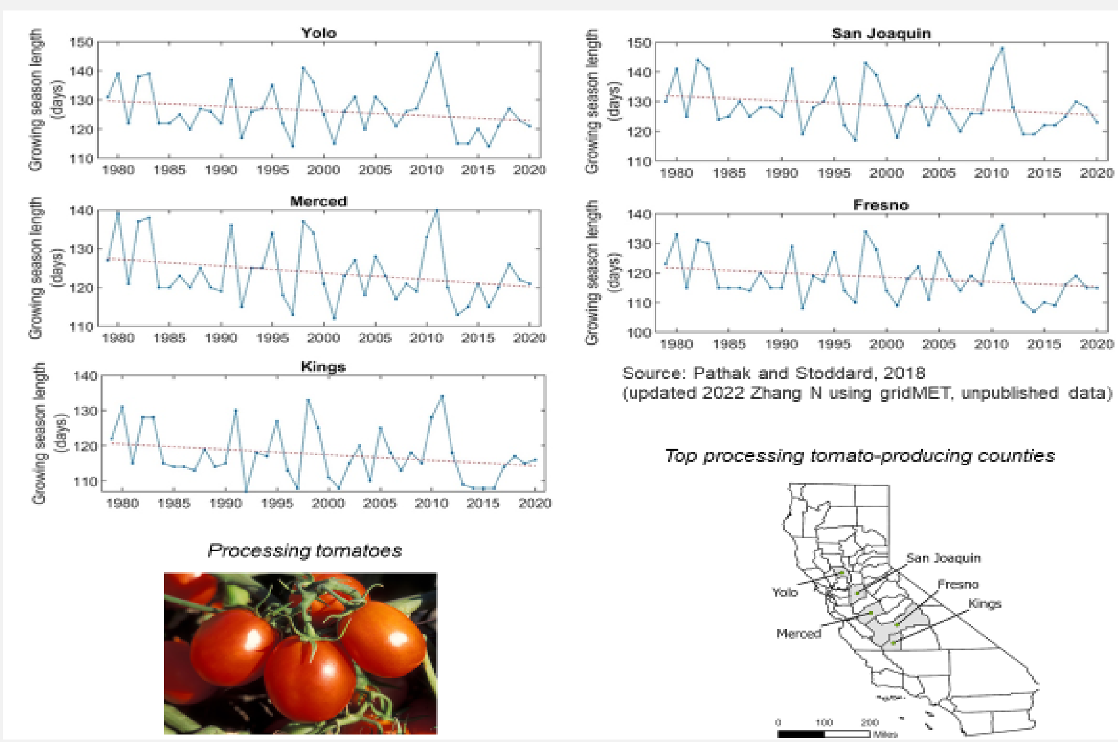
FRUIT AND NUT MATURATION TIME

With warming air temperatures, one walnut variety and several prune varieties in the Central Valley are maturing more rapidly, leading to earlier harvests. Temperature-based estimates indicate that processing tomatoes are also maturing faster.

Update to 2018 Report

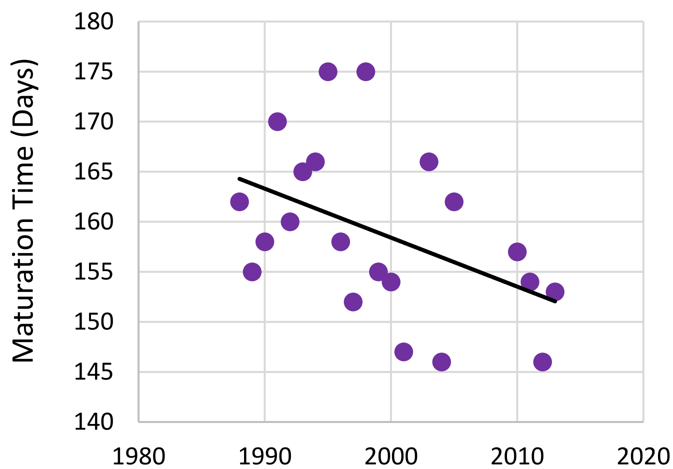
Processing tomatoes are a type of tomato that eventually get canned, dehydrated, or turned into paste, puree, ketchup, tomato sauce, or tomato juice. California accounts for 95 percent of the nation’s and 30 percent of the world’s processed tomatoes. Fresno, Kings, Merced, San Joaquin, and Yolo counties in the Central Valley are the top five tomato-producing counties in the state. Processing tomatoes have been maturing faster over the past four decades in these counties (Pathak et al., 2018). The estimated length of the tomato growing season—the period between planting (March 15) and maturity (harvest)–in these five counties has been declining (see Figure A). These estimates were derived from temperature data using a “growing degree day” model to calculate the accumulation of “heat units”. When sufficient heat units are accumulated, tomatoes reach maturity. As temperatures increase, heat units accumulate faster and maturation occurs earlier. Consequently, estimates from 1979 to 2020 show that processing tomatoes in these counties are reaching maturity about 6 to 8 days earlier.

Figure A. Tomato growing season length at top processing tomato-producing counties, 1979-2020



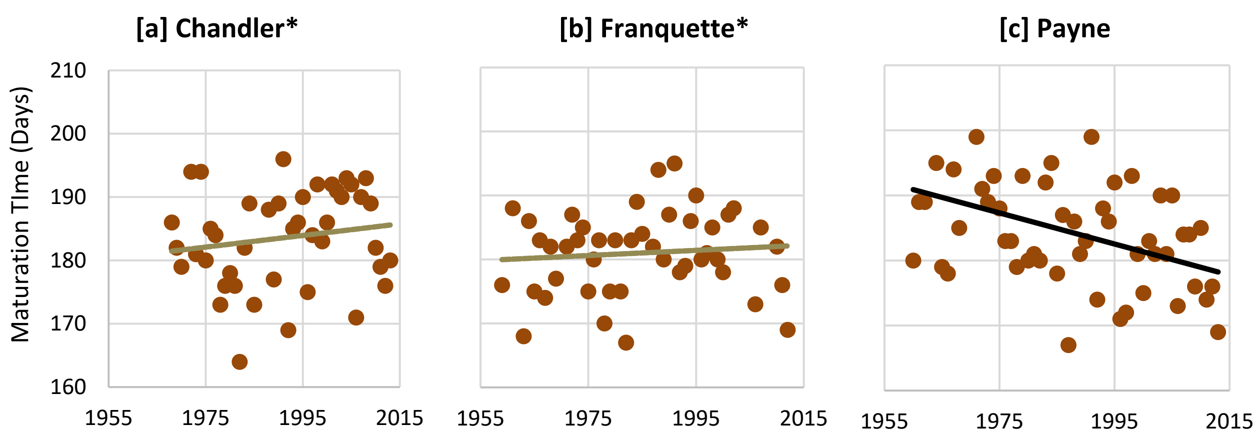
The sections below are unchanged from the 2018 report.

Figure 1. Prune maturation time in Parlier



Source: Jarvis-Shean et al., 2016

Figure 2. Walnut maturation time in Davis (3 cultivars)



**Trend not significant (dashed line)*

Source: Jarvis-Shean et al., 2016

What does the indicator show?

Figure 1 shows maturation times for California prunes and Figure 2 shows three cultivated walnut varieties ("cultivars"), grown respectively in two Central Valley locations: Parlier (Fresno County) and Davis (Yolo County). "Maturation time" refers to the period between bloom and harvest — specifically, flowering and fruit maturity for the prune, and leaf-out and first harvest for the walnut.

From 1988 to 2013, prune maturation (Figure 1) time decreased on average by about 12 days. The maturation time for one of the walnut cultivars, the Payne walnut (Figure 2[c]), similarly decreased by approximately 11 days since 1960. Maturation times for two other walnut cultivars, the Chandler and the Franquette (Figure 2[a] and [b]), have remained relatively constant since 1968 and 1959, respectively.

Why is this indicator important?

California accounts for an estimated 96 percent of the prunes grown in the US, with about half consumed domestically and half exported. The state currently supplies about 40 percent of the world's prunes (Lazicki et al., 2016). The prune industry in California is dependent on a single cultivar, the "Improved French Prune."

California growers produce 99 percent of the commercial US supply of walnuts with about a third of the crop exported (Geisseler and Horwath, 2016). The industry generates $1.4 billion in farm gate revenue annually (net value after subtracting marketing costs) and supports some 60,000 jobs directly and indirectly (California Walnut Board, 2017).

Climatic conditions following flowering and leaf-out for fruits and nuts are critical to the development of a robust crop. In general, shorter maturation times lead to smaller fruits and nuts. Because larger fruits command a premium price, this change can lead to a significant loss of revenue for growers and suppliers. For prunes, this can be somewhat offset by fruit thinning earlier in the year, which can promote larger fruits. This is not practical for walnuts, due to the size of the trees.

Shorter maturation times mean that crops are ripening more quickly. This results in a shorter timeframe for harvest and processing. During harvest season, farmers draw on a limited supply of workers and equipment. If the harvest timeframe shortens, hiring workers and renting equipment can present challenges. Thus, a compressed harvest schedule puts farmers at risk for significant loss of crop quality.

The trend toward earlier maturation for some cultivars of walnuts has some positive impact. Walnuts are often harvested in October — the beginning of the rainy season in the Central Valley. Rain immediately before or during the harvest can be catastrophic, making it difficult to properly dry the nuts, leaving them vulnerable to mold growth. The earlier in the season that walnuts mature, the less likely they are to encounter rain at harvest time.

Warming is expected on an annual, seasonal, and even daily basis in California, with impacts differing by region. The significant, overall outcome of warming is the likely reduction in yield of some of California's most valuable specialty crops, particularly perennial crops.

What factors influence this indicator?

Temperature influences how fast the fruits on a plant develop and mature. Following a period of dormancy in the winter (see *Winter chill* indicator), fruit and nut trees begin to bloom by opening flower or leaf buds. Prune trees have flower buds that produce flowers and vegetative buds that produce leaves. Flowering occurs before vegetative bud break. Walnuts have male buds that produce pollen and mixed buds that produce leaves and female flowers. Leaf emergence precedes the opening of the female flowers (Ramos, 1997).

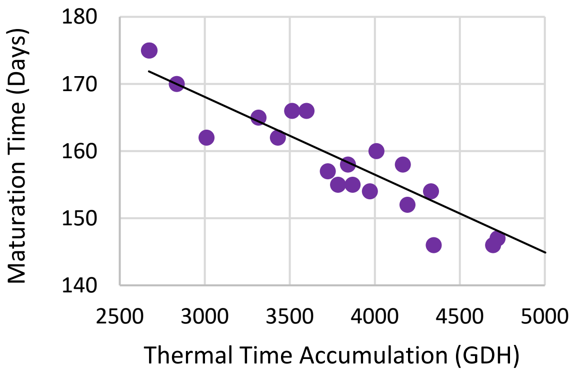
During the first 30 to 90 days after bloom, the amount and duration of warm weather experienced by the plant — referred to as heat accumulation — is the most significant factor that determines harvest timing. This period occurs during the months of April, May, June and July, depending on the variety of walnut. With warmer temperatures, the fruit or nut develops and matures more quickly, leading to an earlier harvest. However, temperatures that are too high (such as during hot days in the Central Valley) can slow development as trees divert energy from fruit development towards self-cooling and preventing or repairing heat damage (Jarvis-Shean et al., 2016)

Different crops have different heat requirements for fruit development; these requirements are typically expressed as ***thermal time accumulation***. In its simplest form, thermal time measures the difference between a given temperature and a certain threshold or base temperature, and the length of time this difference occurs in a day or other unit of time. Thermal time accumulation is calculated by summing hourly thermal time. A fruit or nut reaches maturity when it has accumulated sufficient thermal time. “Growing degree hours” (GDH) is a commonly used unit of thermal time accumulation.

Fruit or nut maturity represents the first possible harvest date. The timing of maturity is partially determined by the timing of flowering. Generally, a tree that blooms earlier will also be ready to harvest earlier. Consequently, changes in harvest readiness date can be due to changes in flowering dates as well as changes in temperature after flowering. Time to Maturity tracks the time between flowering and maturity, and thus the influence of temperature on changes occurring after flowering.

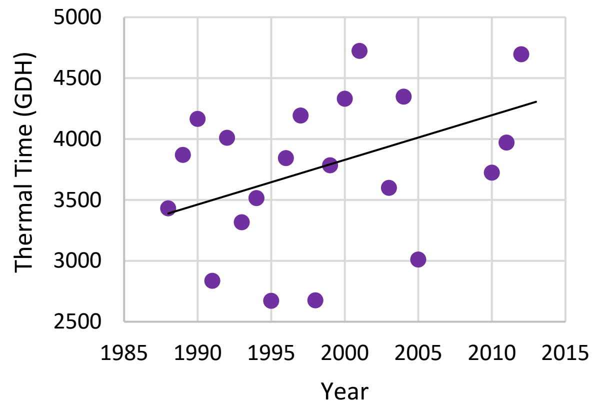
As shown in Figure 3, prune maturation time responded very strongly to thermal time accumulation: the greater the thermal time accumulation in a given season, the shorter the maturation time. In fact, thermal time accumulation for French prunes in Parlier has been increasing since 1988 (Figure 4) — a trend consistent with the decreasing season length. There is, however, too much variation in the data to make any strong conclusions at this time. If thermal time accumulation in Parlier continues to increase as the trend suggests, prune maturation times will most likely continue to shorten with increasing temperatures projected with climate change. Since 1931, minimum temperatures have been increasing for most months of the year in Parlier, while maximum temperatures have been decreasing.

Figure 3. Prune maturation time in response to thermal time accumulation in Parlier



Source: Jarvis-Shean et al., 2016

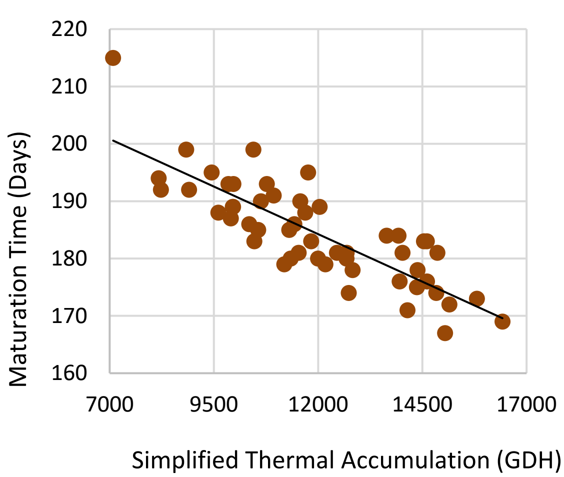
Figure 4. Thermal time accumulation for prunes in Parlier



Source: Jarvis-Shean et al., 2016

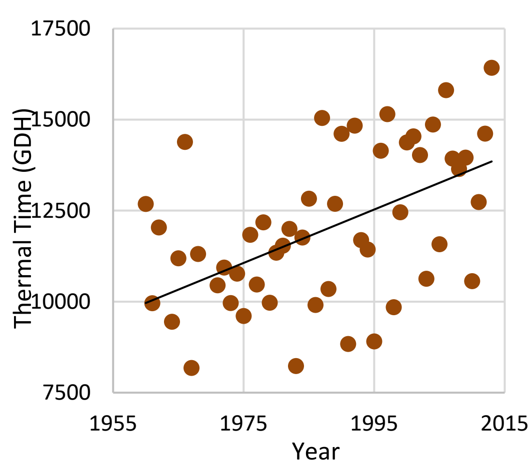
Of the three walnut varieties, only Payne showed a significant decreasing trend in maturation time length over the past 60 years. As with the prune, Payne maturation time responded strongly to thermal time accumulation, showing decreasing maturation times with increasing thermal time accumulation (Figure 5). Payne thermal time accumulation has been increasing since 1960 (Figure 6), indicating that maturation time for these walnuts will shorten with warming conditions associated with climate change. Although maturation times for both the Chandler and Franquette walnuts did not change appreciably over the past 46 and 54 years, respectively, thermal time accumulation for both cultivars increased over time, and showed a strong relationship with maturation time (not shown). Researchers anticipate that maturation times for these cultivars will likely shorten in the future with increasing thermal time accumulation.

Figure 5. Payne walnut maturation time in response to thermal time accumulation in Davis



Source: Jarvis-Shean et al., 2016

Figure 6. Thermal time accumulation for Payne walnut in Davis



Source: Jarvis-Shean et al., 2016

No definitive conclusions can be drawn regarding trends in the maturation times of three almond cultivars, given the short period for which observations are available (nine years).

Technical considerations

<u>Data characteristics</u>

Climate data:

Temperature data were obtained from the National Climatic Data Center of the National Oceanic and Atmospheric Administration (Menne et al., 2015) and from the California Irrigation Management Information System (CIMIS). CIMIS, developed by the California Department of Water Resources and the University of California at Davis, is a repository of climatological data collected at more than 100 computerized weather stations throughout California.

Temperature data were retrieved from stations closest to the fruit and nut orchard locations. When data was missing from a primary station, temperature data from a nearby station were used to supplement the dataset. In Davis, for days when climatological data was absent from the primary station, temperatures from other surrounding locations were used in a model to estimate Davis temperatures.

Temperature time series going back to 1988 (prune) and 1960 (walnut) were analyzed to match up with the duration of maturation time.

Spring thermal time accumulation was calculated using the Growing Degree Hours (GDH) model of Anderson et al. (1986). This model counts the highest GDH accumulation at an optimal temperature of 25 degrees centigrade (°C); at temperatures above a minimum (4°C) and below a maximum (36°C), heat accumulates at fractions of the highest possible amount.

Prune bloom/leaf-out data and walnut maturity/harvest data:

Flowering onset and maturity data for prunes were provided by the University of California Dried Plum/Prune Cultivar Development Program. Full bloom is defined as when 50 percent of the flower buds on the tree have opened. The maturity date is defined as when the fruit can withstand 3 to 4 pounds of pressure (a penetrometer measures the pressure necessary to force a plunger of specified size into the pulp of a fruit).

The leaf-out and harvest data for walnuts were obtained from the University of California at Davis Walnut Breeding Program. Leaf-out is defined as the time at which 50 percent of the vegetative buds have started to open. The harvest date is the time at which the hull, the outer fleshy part, separates from the shell of the nut.

<u>Strengths and limitations of the data</u>

The prune and walnut orchards from which data were collected were at the same or nearby locations over the entire study periods. The walnut dataset is long by phenology data standards, with an average of 44 years of observation, a minimum of 35 years, and a maximum of 59 years, depending on cultivar. The prune dataset, although 25 years in length, provides sufficient information for evaluating phenology trends. In both cases, it would be advantageous to have records of walnut and prune phenology at multiple locations. Not only do crops responses change at different latitudes, but the climate effects may vary throughout California. Evaluating data at multiple sites would allow for a better understanding of how climate change may be affecting different agricultural regions within the state.

To measure prune maturity, the amount of pressure a fruit can withstand when punctured, is a very precise and consistent method. For walnuts, the measure of harvest readiness (hullsplit) is affected by humidity. Higher humidity accelerates nut maturity and can introduce uncertainty in timing of harvest readiness date.

For both the prune and the walnut data sets, a small number of researchers were collecting prune bloom/leaf-out data and walnut maturity/harvest data measurements. Researchers trained their successors to ensure consistency in data collection over time.

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