Shifting Trends in California Agriculture

California Crop Sectors 1980
Field Crops 45%
Vegetable Crops 24%
Fruits & Nuts 31%

California Crop Sectors 1997
Field Crops 22%
Vegetable Crops 34%
Fruits & Nuts 44%

California Crop Sectors 2006
Field Crops 14%
Vegetable Crops 55%
Fruits & Nuts 31%

California Crop Sectors 2011
Field Crops 39%
Vegetable Crops 24%
Fruits & Nuts 55%
Fruit and Nut Crop Agriculture in California

California Harvested Acres
1997 and 2006

- Strawberries
- Apricots
- Grapes (table)
- Grapes (wine)
- Olives
- Peaches (processing)
- Peaches (fresh market)
- Pears
- Prunes (dried plums)
- Almonds
- Pistachios
- Walnuts

(Figures in Thousands)

Fruit and Nut Crop Agriculture in California

California Crop Value ($B)
1997 and 2006

- Strawberries
- Apricots
- Grapes (table)
- Grapes (wine)
- Olives
- Peaches (processing)
- Peaches (fresh market)
- Pears
- Prunes (dried plums)
- Almonds
- Pistachios
- Walnuts

(Figures in Billions)
US Orchard Acreage by County

California counties with more than 6000 acres of stone fruit and almond (Prunus spp.) production.
California’s Unique Role in US Agriculture

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Hectares</th>
<th>Percent US Production</th>
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<tbody>
<tr>
<td>Almond</td>
<td>158,000</td>
<td>99.9</td>
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<tr>
<td>Walnut</td>
<td>78,000</td>
<td>99.0</td>
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<tr>
<td>Prune</td>
<td>33,000</td>
<td>100.0</td>
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<tr>
<td>Pistachio</td>
<td>32,000</td>
<td>100.0</td>
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<tr>
<td>Peach</td>
<td>25,000</td>
<td>68.6</td>
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<tr>
<td>Apple</td>
<td>16,000</td>
<td>7.8</td>
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<tr>
<td>Olive</td>
<td>12,500</td>
<td>99.9</td>
</tr>
<tr>
<td>Kiwifruit</td>
<td>3,000</td>
<td>100.0</td>
</tr>
</tbody>
</table>

1 hectare = ca. 2.5 acres
Fruit and Nut Crop Agriculture in California

Tree and Vine Crop Acreage 1975 and 1997

- Almonds
- Pistachios
- Walnuts
- Table Grapes
- Wine Grapes

California's Share of Total US Fruit Production
World Fruit and Nut Production

Climate, Phenology and Species Distributions
Phenology

Phenology describes periodic biological phenomena in response to climate.

Bird migrations, insect life cycles, flowering in perennial plant species.

Temperature is the most important factor influencing phenology.

Day length may also play a role.

Adaptations to Seasonal Cycle

Plants have evolved life cycle adaptations to enable them to survive cold winters that would kill growing tissues.

**Annual** plants overwinter as seeds. These plants complete their life cycle and die in a single growing season, going from seed to seed.

**Perennial** plants survive from year to year by physiological mechanisms to avoid freezing damage.
Perennial Plant Adaptations to Winter

**Herbaceous Perennials:** In herbaceous perennial plants, the above-ground parts die back completely. Underground structures pass the winter and produce new shoots in the spring.

**Woody Perennials:** These are tree and shrub species that have physiological adaptations that enable them to survive the seasonal cycle. For deciduous woody perennials this involves a dormant state where the plant is incapable of growth.

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**THE ANNUAL CYCLE OF A DECIDUOUS FRUIT TREE**

Timing of events is species and location specific. The times given here are approximations for common deciduous tree species in California. The double arrows (↑↓) indicate that the events vary considerably among species and locations.
Factors Affecting Climate

Latitude
Altitude
Proximity to large bodies of water
Proximity to hills and mountains

Latitude

Of primary importance in determining climate, affecting temperature, temperature extremes and day length.

In general, the farther a location is from the equator, the longer and colder are its winters.

At the equator days have 12 hours day light and 12 hours darkness, 365 days a year. Summer day length increases and winter day length decreases with distance from the equator.
Large Bodies of Water

Large bodies of water moderate climate.

Coastal regions have much warmer winters than midcontinental areas.

Lakes can be important as well, moderating local climatic conditions.
USDA Map of Cold Hardiness Zones
Factors Affecting Climate in the Western U.S.

In California and the Western U.S. two major factors climate:
The Pacific Ocean and the Continental Air Mass

The more an area is dominated by the Pacific Ocean’s influence, the moister its atmosphere in all seasons, the milder its winters, and the more its rainfall is limited to fall, winter and spring.

Moving inland from the ocean, the continental air mass becomes more important making summers hotter, winters colder and summer precipitation more likely.
Factors Affecting Climate in the Western U.S.

Mountains determine the extent to which the oceanic vs. continental influences are felt.
The Coast Range removes some marine influence.
The Sierra blocks much of the marine influence. East of the Sierra the influence of the continental air mass dominates.
California’s Central Valley has a marine influence to its climate. The marine influence decreases north and south from the San Francisco Bay/Delta area.

Temperature and Plant Growth

Temperature is the most important climatic factor influencing plant growth.

Winter temperatures are of primary importance in determining distributions of perennial species.

Two components:
1. Minimum winter temperatures
2. Chilling
Minimum Winter Temperatures

A plant’s ability to survive winter minimum temperatures is referred to as hardiness. A plant is hardy to the extent that it is able to withstand exposure to temperatures below freezing.

Note that the term “hardy” refers only to surviving cold. It has nothing to do with how tolerant a plant is to other environmental factors.

Plant species vary greatly in their cold hardiness.
Cold Acclimation

Cold *acclimation* (hardening) involves a series of changes that prepares the tree for winter.

As the days become shorter, the buds become increasingly able to survive cold temperatures. This process, known as hardening, proceeds into the winter.

Frost Damage

Hardiness refers to ability of individual plants to survive killing frosts (Winter Kill).

Freezing temperatures can kill or reduce a crop without killing the tree (Frost Damage).
Cold Acclimation

When the plant's chilling requirement is met, dehardening, or deacclimation, begins.

As the buds deacclimate, they become less able to survive cold temperatures.
Dehardening

Frost Damage in Almond
Damage varies at different stages of development
Chilling

Chilling refers to temperatures above freezing to about 45 F.

Some temperate and subtropical perennial plant species require exposure to chilling temperatures for their normal development. Plants that have a chilling requirement typically will not flower and set fruit normally if the chilling requirement is not met.

The extent of required exposure to chilling temperatures varies greatly among species.

There are different methods for measuring chilling. The most common is the sum of hours at temperatures above freezing (32 F, 0 C) and below 45 F (7 C).
Chilling Models

1. Accumulated hours with temperatures below 45F (7C)

2. Accumulated hours with temperatures below 45F and above 32F (0C)

3. Utah Model chill units
   1. 1 Hour < 34 F = 0 chill units
   2. 1 Hour 35-36 F = 0.5 chill units
   3. 1 hour 37-48 F = 1.0 chill units
   4. 1 hour 49-54 F = 0.5 chill units
   5. 1 hour 55-60 = 0 chill units
   6. 1 hour 61-65 F = -0.5 chill units
   7. 1 hour >65 F = -1.0 chill units

Winter chill models

I. Chilling Hours Model (Weinberger Model)

Hourly time step:

\[ \text{Chilling} = \sum_{t=0}^{t} w_{CH} \]

Winter chill models

II. Utah Model

Hourly time step:

\[
\text{Chilling} = \sum_{t_0}^{t} w_{\text{Utah}}
\]


Winter chill models

III. Positive Utah Model

Hourly time step:

\[
\text{Chilling} = \sum_{t_0}^{t} w_{\text{Utah}}
\]

Dynamic Chilling Model

Developed in Israel.

When Chilling Hours alternate with temperatures above 45°F — as commonly occurs in California — a canceling effect can occur for some of that ‘chill.

The traditional models do not account for this cancelling effect.
Dynamic Chilling Model

Most useful in sub-tropical climates where chilling is often followed by temperatures above the chilling range.

Chilling accumulation is reversible by high temperatures.

When duration and intensity of chilling reaches a threshold, a Chill Portion is accumulated. This is not reversible.

Species vary in their chill portion requirements.

Dynamic Chilling Model

Two step process.

- Precursor
  - Low temperatures
  - High temperatures
  - Intermediate

When the Intermediate reaches a threshold level:
1. A Chill Portion is irreversibly accumulated.
2. The level of the intermediate drops to zero.

Chill Portions
IV. Winter chill models

Dynamic Model

When quantum accumulated

Rate constants

\[ k_{0,1} = A_{0,1} \cdot \frac{E_{0,1}}{T} \]

Temperature (K)


Winter Temperature and Species Distributions

On the basis of cold hardness and chilling requirements, we consider tree-crop species in three general categories.

Tropical

Subtropical

Temperate
Tropical Tree-Crop Species

Temperature Requirements of Tropical Tree-Species

Tropical species do not withstand freezing temperature. Many will not grow well if the temperature drops below 10C (50F). Typically confined to low elevations in the equatorial belt from about 20 degrees North latitude to 20 degrees South latitude.
Examples of Tropical Species

Banana
Coffee
Cacao (chocolate)
Coconut
Mango
Pineapple

Subtropical Tree-Crop Species
Temperature Requirements of Subtropical Tree-Species

Tolerate some subfreezing temperatures.

Require some cool weather for growth and fruit development.

Do not do well in tropical zones.

Grown in low elevations, north and south of the tropical zone.

Latitudinal limits are not well defined because subtropical environments are influenced by local factors: proximity to water, elevation, influence of mountain ranges.

Subtropical Tree-Species

Species generally considered subtropical:
Avocado
Citrus species
Date
Fig
Kiwifruit
Olive
Persimmon
Pistachio
Pomegranate

Degrees of “subtropicalness”

Least Hardy
Avocado and date

Intermediate
Citrus

Most Hardy
Fig, Kiwifruit, Olive, Pistachio

Subtropical species may be evergreen or deciduous.
Climate Requirements for Subtropical Tree-Species

Mean daily temperature in the coldest months between 10-15C (50-60F).

Seasonal temperature ranges with winters sufficiently cold to provide adequate chilling.

Lacking severe winter frosts.

Temperate Tree-Crop Species
Temperate tree species are winter-hardy, able to withstand subfreezing winter temperatures.

Differences in cold hardiness vary among species.

Require exposure to prolonged periods of cold, but above freezing temperature (chilling requirement).

Production areas for temperate fruit and nut species are located between approximately 30 and 50 degrees North and South latitudes.
Climate Limits for Temperate Tree-Species

Winter temperatures not so cold that plants are killed.

Winters not so warm that buds get inadequate chilling.

Sufficiently long growing season to mature a crop.

Subtropical and temperate production areas may overlap. Peaches and oranges are grown together in the San Joaquin Valley.

Growing Season

Refers to number of frost-free days from last frost in the spring to first frost in the fall.
Mediterranean Climate Zones
Characterized by hot, dry summers and cool, moderate winters.
Mediterranean Climate Zones

Ideal for subtropical and temperate orchard-crop production.
Lack of severe, killing winter freeze events.
Long, hot growing season.
Adequate chilling for most species during moderate winter.
Lack of significant precipitation during growing season.

Some temperate species limited by insufficient winter chilling.

Mediterranean Climate Zones

Characterized by hot, dry summers and cool, moderate winters.