Lecture 2
Agricultural Mechanization
Dr. Kassama
Professor Food Engineering/Processing

Department of Food & Animal Sciences
Alabama A&M University/University of Florida
Postharvest Lecture
Spring 2021
Introduction

- The rate of population growth > world food production (FAO)
- Activist argue that the world cannot continue to support the increasing population
  - Population increment
    - by 50% for every 20 yrs
    - doubling the world population in 40 yrs
- Food production
  - Limitations
    - Land
    - water and etc.
However, food production have kept in good pace with population growth in the past 70 yr

- Green Revolution
  - An important contributing factor to agricultural production
Introduction

- Green Revolution
  - An important contributing factor to agricultural production
    - Technological development
      - Improve irrigation systems
      - Crop breeding programs
      - Agricultural chemistry (development of potent fertilizers)
      - Agricultural machinery (pre and post harvest machineries)
Introduction

- Vegetable production

<table>
<thead>
<tr>
<th>Crop</th>
<th>Area planted</th>
<th></th>
<th>Area harvested</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2016 (acres)</td>
<td>2017 (acres)</td>
<td>2018 (acres)</td>
<td>2016 (acres)</td>
</tr>
<tr>
<td>Artichokes</td>
<td>6,800</td>
<td>7,200</td>
<td>6,900</td>
<td>6,800</td>
</tr>
<tr>
<td>Asparagus</td>
<td>27,600</td>
<td>27,600</td>
<td>22,900</td>
<td>25,900</td>
</tr>
<tr>
<td>Beans, lima</td>
<td>26,000</td>
<td>24,550</td>
<td>25,100</td>
<td>25,350</td>
</tr>
<tr>
<td>Beans, snap</td>
<td>249,600</td>
<td>221,800</td>
<td>235,400</td>
<td>237,100</td>
</tr>
<tr>
<td>Broccoli</td>
<td>132,300</td>
<td>129,600</td>
<td>114,900</td>
<td>131,300</td>
</tr>
<tr>
<td>Cabbage</td>
<td>59,000</td>
<td>62,900</td>
<td>58,300</td>
<td>56,800</td>
</tr>
<tr>
<td>Cantaloupes</td>
<td>60,200</td>
<td>64,900</td>
<td>62,300</td>
<td>59,000</td>
</tr>
<tr>
<td>Carrots</td>
<td>78,900</td>
<td>80,200</td>
<td>80,800</td>
<td>77,500</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>41,900</td>
<td>46,700</td>
<td>44,100</td>
<td>41,900</td>
</tr>
<tr>
<td>Celery</td>
<td>33,700</td>
<td>32,800</td>
<td>30,400</td>
<td>33,100</td>
</tr>
<tr>
<td>Corn, sweet</td>
<td>498,300</td>
<td>484,800</td>
<td>494,600</td>
<td>478,400</td>
</tr>
<tr>
<td>Cucumbers</td>
<td>119,600</td>
<td>119,100</td>
<td>114,300</td>
<td>114,700</td>
</tr>
<tr>
<td>Garlic</td>
<td>30,100</td>
<td>33,000</td>
<td>33,000</td>
<td>30,100</td>
</tr>
<tr>
<td>Honeydews</td>
<td>12,100</td>
<td>11,600</td>
<td>14,900</td>
<td>12,100</td>
</tr>
<tr>
<td>Lettuce</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head</td>
<td>143,000</td>
<td>141,500</td>
<td>120,700</td>
<td>142,300</td>
</tr>
<tr>
<td>Leaf</td>
<td>69,500</td>
<td>67,500</td>
<td>69,900</td>
<td>69,300</td>
</tr>
<tr>
<td>Romaine</td>
<td>106,200</td>
<td>118,000</td>
<td>101,500</td>
<td>105,100</td>
</tr>
<tr>
<td>Onions</td>
<td>154,000</td>
<td>154,700</td>
<td>135,100</td>
<td>147,900</td>
</tr>
<tr>
<td>Pea, green</td>
<td>151,500</td>
<td>144,700</td>
<td>141,000</td>
<td>139,300</td>
</tr>
</tbody>
</table>
### Introduction

- **Fruit production**

---

#### Fruit Production — Idaho, Oregon, Washington, and United States: 2019 and Forecasted August 1, 2020

<table>
<thead>
<tr>
<th>State</th>
<th>2019 (units)</th>
<th>2020 (units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apples</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oregon</td>
<td>150.0</td>
<td>180.0</td>
</tr>
<tr>
<td>Washington</td>
<td>7,600.0</td>
<td>7,400.0</td>
</tr>
<tr>
<td>United States</td>
<td>11,018.0</td>
<td>10,650.0</td>
</tr>
<tr>
<td>Cranberries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oregon</td>
<td>558,000</td>
<td>530,000</td>
</tr>
<tr>
<td>United States</td>
<td>7,917,000</td>
<td>8,970,000</td>
</tr>
<tr>
<td>Grapes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Washington</td>
<td>391,000</td>
<td>430,000</td>
</tr>
<tr>
<td>Wine</td>
<td>201,000</td>
<td>260,000</td>
</tr>
<tr>
<td>Juice</td>
<td>190,000</td>
<td>170,000</td>
</tr>
<tr>
<td>United States</td>
<td>6,871,000</td>
<td>7,180,000</td>
</tr>
<tr>
<td>Peaches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Washington</td>
<td>11,150</td>
<td>12,500</td>
</tr>
<tr>
<td>United States</td>
<td>681,600</td>
<td>645,500</td>
</tr>
<tr>
<td>Pears</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oregon</td>
<td>236,000</td>
<td>250,000</td>
</tr>
<tr>
<td>Washington</td>
<td>330,000</td>
<td>390,000</td>
</tr>
<tr>
<td>United States</td>
<td>729,000</td>
<td>800,000</td>
</tr>
</tbody>
</table>

1 A barrel weighs 100 pounds.
Introduction

- Great Depression
  - Farmer Difficulty
    - Maintain profitable and competitive
- Strategies
  - Raising profit
    - By lowering cost per unit and
    - Increasing output
  - Limitation
    - World War II
    - End of the Bracero Farmworker program
    - Although the program in 1964
    - There was labor scarcity during WW-II
Introduction

- Harvesting
  - Labor shortage
- Technological Development
  - Increase out
    - While lowering cost
  - Improve their competitive position
- Harvest Mechanization
  - Reduce cost
  - Ability to expand acreage
  - Replacing diminishing labor pool
Introduction

- Bracero Program
  - Spanish Term for manual Laborer
    - United States signed the Mexican Farm Labor Agreement with Mexico In 1942
    - Agreement guaranteed the following:
      - Decent living conditions
      - Sanitation, adequate shelter and food
      - Minimum wage of 30 cents per hour
  - Terminated in 1964
Mechanization

- What is Mechanization???
  - Applications of suitable machinery for:
    - Production
    - Processing
      - Agricultural products
  - Continues increase in productivity
    - Reducing cost of production
    - Reducing losses
    - Enhance efficiency
    - Increase profitability
Mechanization

- What is Mechanization???
  - In-the-nutshell
    - Better farm power input
      - Farm power
        - Manual labor
        - Agricultural tools
        - Draft animals
        - Tractors
## Mechanization

- **Cost**

<table>
<thead>
<tr>
<th>Power unit</th>
<th>180 hp</th>
<th>150 hp</th>
<th>Combine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current value</td>
<td>$75,000</td>
<td>$52,000</td>
<td>$90,000</td>
</tr>
<tr>
<td>Salvage value</td>
<td>$7,500</td>
<td>$5,200</td>
<td>$9,000</td>
</tr>
<tr>
<td>Hours of ownership left</td>
<td>12,000</td>
<td>12,000</td>
<td>3,000</td>
</tr>
<tr>
<td>Annual hours specified</td>
<td>642</td>
<td>603</td>
<td>157</td>
</tr>
<tr>
<td>Additional hours used</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Current no. of hours</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Equiv. list price</td>
<td>$75,000</td>
<td>$49,000</td>
<td>$90,000</td>
</tr>
<tr>
<td>Repair Factor 1</td>
<td>0.007</td>
<td>0.007</td>
<td>0.04</td>
</tr>
<tr>
<td>Repair Factor 2</td>
<td>2</td>
<td>2</td>
<td>2.1</td>
</tr>
<tr>
<td>Eng. estimated life (h)</td>
<td>12,000</td>
<td>12,000</td>
<td>3,000</td>
</tr>
</tbody>
</table>

### Calculated costs (based on ownership period)

<table>
<thead>
<tr>
<th>Item</th>
<th>180 hp</th>
<th>150 hp</th>
<th>Combine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest cost ($/h)</td>
<td>$7.07</td>
<td>$5.22</td>
<td>$34.65</td>
</tr>
<tr>
<td>Depreciation ($/h)</td>
<td>$5.63</td>
<td>$3.90</td>
<td>$27.00</td>
</tr>
<tr>
<td>Tax/housing/ins. ($/h)</td>
<td>$1.17</td>
<td>$0.86</td>
<td>$5.73</td>
</tr>
<tr>
<td>Repair cost ($/h)</td>
<td>$6.30</td>
<td>$4.12</td>
<td>$12.05</td>
</tr>
</tbody>
</table>

### Actual costs

<table>
<thead>
<tr>
<th>Item</th>
<th>180 hp</th>
<th>150 hp</th>
<th>Combine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest cost ($/h)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depreciation ($/h)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tax/cousing/ins.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repair cost ($/h)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Annual costs

<table>
<thead>
<tr>
<th>Item</th>
<th>180 hp</th>
<th>150 hp</th>
<th>Combine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest cost</td>
<td>$4,537.50</td>
<td>$3,146.00</td>
<td>$5,445.00</td>
</tr>
<tr>
<td>Depreciation</td>
<td>$3,610.18</td>
<td>$2,349.89</td>
<td>$4,242.86</td>
</tr>
<tr>
<td>Tax/housing/ins.</td>
<td>$750.00</td>
<td>$520.00</td>
<td>$900.00</td>
</tr>
<tr>
<td>Repair cost</td>
<td>$4,043.40</td>
<td>$2,480.03</td>
<td>$1,894.22</td>
</tr>
</tbody>
</table>

† Bold face values represent calculated data. Single underlined values require input data. Default values are provided by the program for the single underlined input data but these default values should be replaced with known values, if available, to address the specific application. Actual costs should be provided as input in the “Actual costs” section, if known.
Benefit/Cost

- Example: Benefit-Cost analysis

- Means
  - Benefit/cost ratio = 1.06
  - For every dollar spent $1.06 is made
  - Hence, the rate of return of 6%
Mechanization

- Innovation and Mechanization

https://www.youtube.com/watch?v=uSRKMatFBR0&list=PLLjlfxpbnG1YF2m7tvApfiR5NXParpvGP&index=18
Mechanization

- Example: Benefit Cost analysis

Table 1. 2007 Cost per acre and ton: California processing tomatoes (direct seeded)-Sacramento Valley (Yield of 35 tons per acre: mechanically harvested at 37.5 tons per hour)\(^1\)

<table>
<thead>
<tr>
<th>Costs</th>
<th>$/ac</th>
<th>$/ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Total (All)</td>
<td>$2.283</td>
<td>65.20</td>
</tr>
<tr>
<td>Operating</td>
<td>1,737</td>
<td>49.60</td>
</tr>
<tr>
<td>Harvest: Mech. Pick &amp; Haul</td>
<td>279</td>
<td>8.00</td>
</tr>
</tbody>
</table>

- B. Minimum price to make profit over Operating Costs
  - Total Cost
    - $50.00
    - $65.00

- C. Estimated hand picking cost
  - (fresh-market tomato technology)\(^2\)
  - $3,000
  - $86.10

---

\(^1\) Harvest: Tomato harvester is operated 20 hours per day in two 10 hours shifts, 4 laborers ride harvester and work as manual sorters, machine has one driver, and two bulk truck drivers haul tomatoes from machine to processor
Mechanization

- Tomato
  - UC-Davis harvester
    - Patent 1960
    - It cut the plant at the soil level and shakes
  - Manual labor
    - Need at least 12 people to sort the fruits
    - Labor requirement of 2.9 hours/ton
    - vs 5.3 hours per ton for manual labor
Mechanization

- Tomato Harvesting

Fig. 1. Typical harvest labor use and annual production of processing tomatoes in California, 1960–1997.
Mechanization

- Tomato Harvesting

UC Davis Biological and Agricultural Engineering

What decade was each machine built in?

1968

2008
Mechanization

- Tomato Harvesting
Mechanization

- Tomato Harvesting
Mechanization

- Cucumber Harvesting
Mechanization

- **Tomato Harvesting**
  - **Impact**
    - Reduce harvest cost
    - Made California farmers competitive
      - CEDD reported 20,000 to 40,000 labor in 1996
      - Cannot afford $332 million in additional wages (57.7 million hours multiplied by $5.75 per hour) and remain competitive in the global market
Mechanization

- Harvesting Oranges (Florida)
  - University of Florida (2008-2009)
    - Total cost of producing Valencia oranges
      - About $282 per ton ($253 operating cost)
      - Hand picking and transportation to the roadside
        - $119 or about 42% of the operating cost
        - Picking is of grave concern
Mechanization

• Harvesting Oranges (Florida)
  • Not very successful
  • Less than 10% adoption
  • Major drawback
    • Lack of competitive advantage with Brazil
    • Damage to the tree
      • Beaten-up looking-nature of mechanically harvested trees
      • Though no impact on reduced yield was observed
Mechanization

- Harvesting Oranges (Florida)
Mechanization

- Harvesting Oranges (Florida)

Figure 7. Coe-Collier trunk shaker and receiver harvesting oranges in Florida
Mechanization

- Harvesting Oranges (Florida)
- Tree canopy shaker
Mechanization

- Harvesting Oranges (Florida)
- Tree canopy shaker with catchment table
Mechanization

- Harvesting cherry (Florida)
- Tree canopy shaker with catchment table
Mechanization

- Harvesting grape vine
- Tree canopy shaker with catchment table
Mechanization

- Future
  - Driven by Benefit/cost factors
  - International competitiveness
  - Lots of adaptive technological development
    - Particularly in the deciduous fruit trees
Mechanization

- Robotic Application in Agriculture

https://www.youtube.com/watch?v=NO8PmqEIOcc
Mechanization

Current research projects

- Robot-aided harvesting.
- Virtual harvesting.
Mechanization

Design Issues

- Could actuator arrays achieve high picking efficiency and speed?
- How many arms (∼ 30k/arm)?
- How much do branches interfere?
- What types of arms?
- In what configuration?
- ...
- How can we evaluate alternative designs?