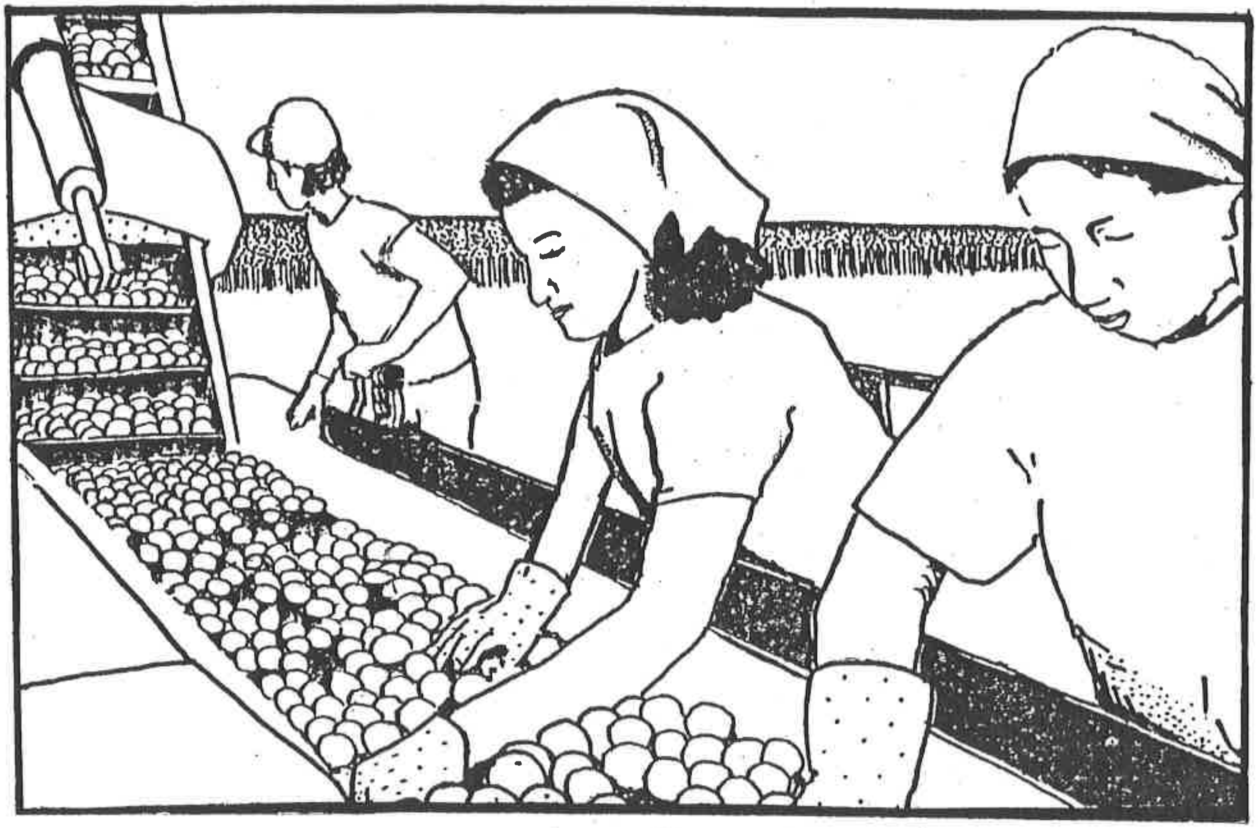
Labor's Dwindling Harvest



The Impact of Mechanization on California Fruit and Vegetable Workers

California Institute for Rural Studies

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"When the cotton picker was developed, agricultural intellectuals including agricultural economists should have studied the problems of adjustment forced on cotton field hands, should have assessed the social costs, should have devised institutional reforms to cushion the shock and the cost-- a cost which should have in some way been shared by cotton producers, the cotton processing and merchandising industry and, of course, by the cotton consumers. Had we done so who can now say how much less frightening would be our civil rights, urban ghetto and urban living problems? And partly because we failed to learn from that experience, we go blindly forward developing tomato harvesters, field lettuce cutters and field lettuce packing technologies, milk production factories, and the thousand and one other forms of improved technological efficiencies. Economists as institutional policy analysts must take note of the ecologists' argument that the conventional business economist's blindness to "externalities" is scandolous; that all externalities are truly part of the social cost of an activity; and that he who creates a product with social cost should be responsible for paying for it."

M. M. Kelso and J. S. Hillman
"Social and Political Dilema of the Agricultural Industry and Agricultural Institutions"
Western Agricultural Economics Association
4th Annual Meeting, Corvallis, Oregon, July, 1969
Proceedings, 1969

SUMMARY

Although California farm production is expanding, labor saving technologies are reducing the number of farm jobs. Fragmentary data suggest that an increasing portion of the remaining farm work is being performed by Hispanics, women, and temporary farm workers.

Fruit and vegetable harvest mechanization has an important impact on the farm labor force, for it can eliminate a large number of hand-harvest jobs, often in a very short period of time. For such technology to be adopted, it must result in a substantial cost savings to the farm operator. Harvest mechanization also involves changes in production practices, in handling, in processing and/or packing systems, and often a change in the product itself.

Harvest mechanization has eliminated tens of thousands of hand-harvest jobs in California since 1950, while creating a much smaller number of machine-harvest jobs. The new work is of different skill level, strenuousness, and safety than hand-harvest work. Much of it is performed in different production areas, by a new work force. Harvest mechanization has resulted in severe unemployment in localized labor markets. It has also prevented unionization of farm employees.

With commercial use of new technology regarded as the measure of its feasibility, 13 fruit and vegetable crops were selected for detailed study. All facets of each technology were described, as well as the cost savings, the recent trends in adoption, and the factors which may affect the future rate of adoption.

Information on current employment was combined with estimates of the productivity of hand-harvest and machine-harvest labor, and a range of

assumptions about future adoption in order to construct a projection of anticipated net reduction in farm jobs. Using average annual employment for 1975-1977 as a base, it was estimated that mechanization of the harvest of these 13 crops will cause a net reduction of at least 38,126 peak harvest jobs by 1982, but not more than 128,176 jobs by 1987. On the average, each of these jobs provides 6 weeks of employment. This displacement represents 1½% to 5% of total California farm employment in the base period, and will be concentrated in certain counties. The projection includes most of the displacement expected to occur as a result of the mechanization of fruit and vegetable harvests which employ more than 40,000 work-weeks of labor in California. This category of employment accounts for 17% of the 1977 total California farm employment. Other technologies are expected to reduce the remaining 83% of farm work.

Public policy recommendations include:

1. Federal legislation to establish workers' rights to job security;
2. Federal legislation to guarantee farm workers the right to form and join labor organizations;
3. Elimination of the 10% investment tax credit for capital investments which reduce employment;
4. Reform of the land-grant college system so that it might aid farm workers;
5. Re-design and expansion of adjustment assistance programs for rural people;
6. A comprehensive field study of California farm workers;
7. Consideration by the appropriate regulatory agencies of the increased environmental impact of chemicals used to facilitate harvest mechanization.

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Mechanization has eliminated tens of thousands of harvest jobs in California since 1950. Fragmentary data suggest that Hispanics, women, and temporary workers are performing an increasing portion of the remaining farm work. Mechanization has created fewer machine harvest jobs of different skill, strenuousness and safety; it has resulted in severe unemployment in local labor markets, and has prevented farm employee unionization. New harvest technologies for 13 fruit and vegetable crops were described, along with the ancillary changes in production practices, handling, packing, processing and product. Cost savings and the rate of adoption of the technologies were also considered. A projection of their impact on California farm employment anticipates a net reduction of at least 38,126 peak harvest jobs by 1982, but not more than 128,176 jobs by 1987. Other technologies are expected to reduce non-fruit and vegetable harvest labor demand. Public policy recommendations include job security, labor law and tax legislation; reform of the land-grant colleges and rural adjustment assistance programs; and a field study of Calif. farm workers. Numerous references on mechanization and Calif. farm employment.

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CHAPTER I

TECHNOLOGY AND CALIFORNIA FARM EMPLOYMENT

By many measures, California agriculture is a thriving industry. With the completion of new, publically financed water projects, the amount of irrigable land in the state increased 84% since 1940 (see Figure 1-1). On a national basis the value of agricultural production is rising rapidly, with California's keen competitive position enabling it to increase its relative share of U. S. farm production (see Table 1-1).

Fresh California produce commands a premium in the market place, for it is shipped in seasons when most other areas are not in production. California processors pack a substantial portion of the nation's canned fruits and vegetables. The state has become the nation's principal production area in a great number of agricultural commodities. It produces virtually the entire national crop of a number of fruits and vegetables including apricots, dates, figs, olives, raisin grapes, canned peaches, persimmons, pomegranates, artichokes, and brussells sprouts.

Despite this apparently bright economic picture of California's largest industry, there is the disturbing paradox that the state's wealthiest agricultural areas have high levels of unemployment (see Table 1-2). This unemployment varies with the seasonal change in agricultural employment.

The expansion of California agriculture has not created new jobs. Although acreage in labor intensive fruit and vegetables are at record levels, each year there are fewer jobs for California farmworkers, and there are fewer farmers on the land.

Labor saving technology has led to a steady erosion in agricultural

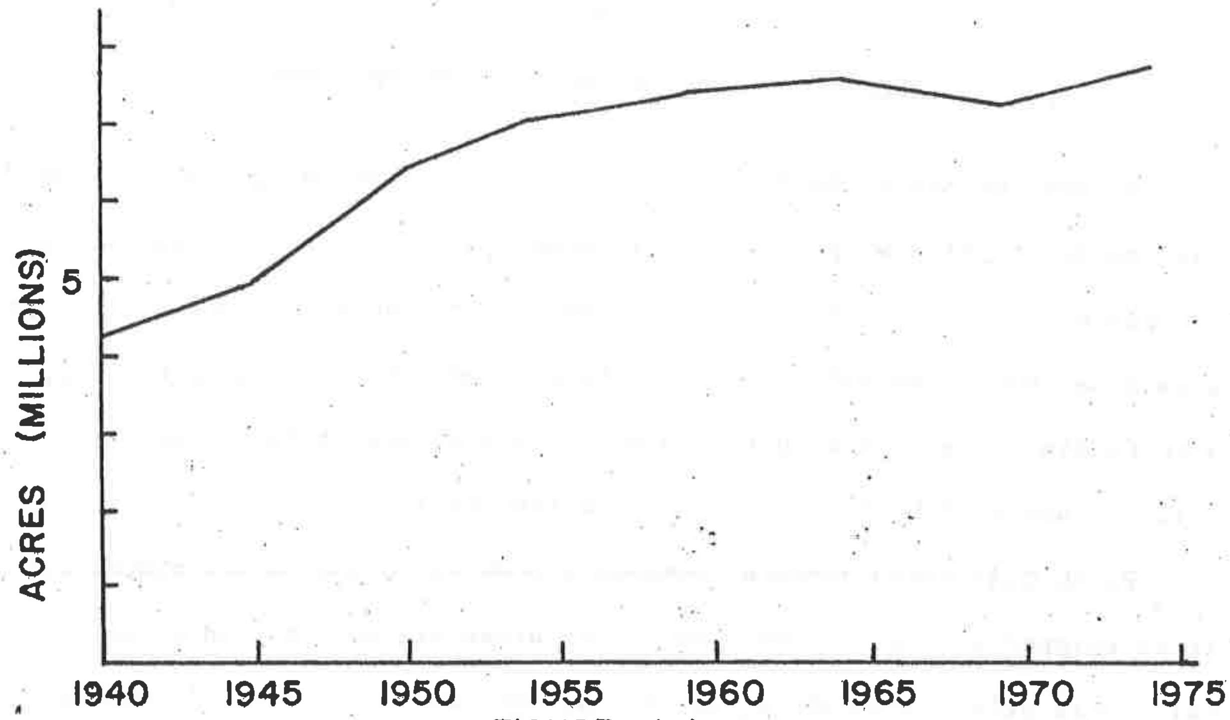

FIGURE 1-1
CALIFORNIA IRRIGATED ACREAGE

Table 1-1
U. S. and California Farm Income
Cash Receipts from Farming
(1,000 dollars)

Year	California	United States	California as % of U.S.
1945	1,592,367	20,013,832	7.96%
1955	2,632,650	29,263,899	9.00%
1965	3,751,249	41,638,650	9.01%
1975	8,500,926	90,370,272	9.41%

employment. Increasing amounts of capital are being invested in all phases of agricultural production, reducing the demand for farm labor. Labor's share in the value of production is dwindling. The capital requirements of agriculture are becoming so high that only the best financed, large scale operators can stay in business.

Tractor drivers disc and plow the fields with broader implements pulled by higher horse-power equipment, allowing more land to be prepared in a single day of work. Precision listing, seeding, and cultivation, along with use of new herbicides, has brought dramatic decreases in the need for early season thinning and hoeing labor (1). Automatic thinning machines are reducing hand hoe labor even further (2).

Drip irrigation and automated sprinkler irrigation systems take the place of shovel and siphon tube, and reduce the need for irrigation labor to water the crops. Developments such as pneumatic pruning shears can cut winter employment in pruning vineyards in half (3).

It is harvest mechanization, however, that has had the greatest impact on labor, for it is during the peak harvest season that most workers earn their livelihood. Fruit and vegetable farms hire nearly 71% of the state's farm workers (see Table 1-3), and pay nearly 54% of the state's farm wages (see Table 1-4). It is during the harvest that the majority of the persons employed in California agriculture earn most of their annual income. The adoption of harvest machinery can eliminate 90% or more of the harvest time employment in a particular crop, sometimes in a very short period.

The intention of this study is to increase understanding of the impact of fruit and vegetable harvest mechanization on California farm workers. The study will first describe what is known about California's farm labor force,

Table 1-2
Months of Highest and Lowest Unemployment
Selected California Counties, 1977

County	Month of Highest Unemployment	Unemployment Rate %	Month of Lowest Unemployment	Unemployment Rate %
Imperial	September	22.5	March	12.0
Stanislaus	March	16.1	September	5.5
Merced	February	14.5	September	5.7
San Joaquin	January	12.5	September	5.3
Madera	February	11.4	September	5.5
Fresno	January	10.1	September	5.3

Source: California Employment Development Department
Report 400 C 1977

Table 1-3
Hired California Farm Labor
By Type of Farm 1974
Number of Workers by Number of Days Worked

Number of days worked	Numbers of Workers			Vegetable, Melon, Fruit and Nut Farms as % of All Farms
	All Farms	Vegetable and Melon Farms	Fruit and Nut Farms	
150 days or more	136,216	29,563	35,253	47.6
25 - 149 days	264,781	61,562	126,772	71.1
less than 25 days	460,346	74,188	281,753	77.3
Total Hired Labor	861,343	165,313	443,778	70.7

Source: U. S. Bureau of Census 1974 Census of Agriculture Vol. I, Part 5 California table 32, page I-82
Includes only farms with sales of $2,500 and over
Farm types as defined by the Standard Industrial Classification

Table 1-4
Hired and Contract California Farm Labor Expense
By Type of Farm 1974

Type of Labor Expense	Farm Labor Expense (1,000 dollars)			Vegetable, Melon, Fruit and Nut Farms as % of All Farms
	All Farms	Vegetable and Melon Farms	Fruit and Nut Farms	
Hired Farm Labor	1,043,349	226,331	305,655	51.0%
Contract Farm Labor	185,372	41,172	89,077	70.3%
Total Labor Expense	1,228,721	267,503	394,732	53.9%

Source: U. S. Bureau of Census 1974 Census of Agriculture Vol. I, Part 5 California table 32, page I-82
Includes only farms with sales of $2,500 and over
Farm types as defined by the Standard Industrial Classification

and identify trends in the labor market (Chapter II). An historical analysis of the mechanization process will follow, in order to describe the conditions under which new technology has been adopted in the past (Chapter III) and to describe its effects on farm workers (Chapter IV).

With this foundation, the report will examine in detail those new harvest technologies which are likely to cause large-scale labor displacement (Chapter V). Combining the historical foundation and the information on new technology, the study will then make projections of changes in farm labor demand (Chapter VI).

The process of farm mechanization has been encouraged by government policy. The land-grant colleges and the U. S. Department of Agriculture have performed millions of dollars worth of horticultural and engineering research that has made harvest mechanization possible. The investment tax credit provision of federal income tax laws grants special incentives to those who purchase capital goods such as tomato harvesters, peach catching frames, or potato diggers. Because public policy supports mechanization, it is incumbent on policy makers to deal with its impact. Suggestions for policy changes are also included in this study (Chapter VII).

Notes.

1. Earle E. Gavett "Labor Used to Produce Vegetables: Estimates by States, 1959" U.S.D.A. Economic Research Service Statistical Bulletin No. 341 (U. S. Gov't. Printing Office, Washington D. C. March 1964)

2. "Mechanical Thinning" California Tomato Grower p. 10, June 1972

3. California Department of Employment "Trends in Mechanization and Farming Methods" California Annual Farm Labor Report p. 12, 1956

CHAPTER II

STRUCTURE OF THE FARM LABOR MARKET

A. Oversupply

United States farm labor has been in chronic oversupply for many years (1). While there may be occasional shortages of farm workers to harvest some crops in certain local areas, there has been an abundant supply of cheap labor through most of the history of the national farm labor market. In California, the immigration of Chinese, Japanese, Phillipino, Hindu, Arab, Black, dust-bowl refugee, and Mexican workers has assured fruit and vegetable farms a steady supply of low paid employees. Several economic observations demonstrate that farm labor continues to be in oversupply.

The spectacular productivity gains of the agricultural sector of the economy are known to greatly exceed corresponding figures in manufacturing industry. Output per worker-hour in agriculture has been increasing at a rate that is 75% greater than increases in manufacturing worker productivity. Yet wage gains in these two sectors show considerable disparity. Wages per hour in agriculture are experiencing an increase four times smaller than in manufacturing. As pointed out by Lamar Jones, the correct interpretation of this situation is that there is an oversupply of agricultural labor (2). Low wage rates and high unemployment are the specific consequences. Rapid technological advances are causing increases in worker productivity, but they are not providing corresponding gains for farm workers.

A second measure of the oversupply of farm labor can be found in the comparison of farm wage rates with non-farm wage rates. By the law of supply and demand, wage rates correlate inversely with excess labor supply.

Gladys Bowles summarized the situation as of late 1965:

> ". . . the relative position of farm workers has actually deteriorated since the end of the War . . . . Even in California, where highest farm wages are paid, on the average, the gap between farm and non-farm (wages) has widened in the last 10 years (3)."

More recent data indicate little, if any, improvement in the wage disparity. Shown in Table 2-1 is a summary of manufacturing and agricultural wages through 1975.

Table 2-1
Agricultural Wages as % of Manufacturing Wages
U. S. and California
(Period Average)

Period	United States	California
1948 - 1950	54%	59%
1951 - 1955	51%	53%
1956 - 1960	46%	48%
1961 - 1965	45%	46%
1966 - 1970	49%	50%
1971 - 1975	47%	50%

Source: Sue E. Hayes, "Farm and Nonfarm Wages and Fringe Benefits, 1948-1977" in Technological Change, Farm Mechanization, and Agricultural Employment. University of California, Division of Agricultural Sciences, Priced Publication 4085

While agricultural wage rates have increased in recent years, Table 2-1 shows that these wages still lag far behind those in manufacturing. More significant is the fact that this gap is now substantially greater than in the post-World War II period.

A third and equally significant indicator of the oversupply of agricultural workers can be found in the impact of increased national unemployment upon the size of the agricultural labor force. An excess of agricultural labor would be expected to be a "reserve pool" which is drained during periods of low national unemployment and then fills when unemployment is high. Hathaway and Perkins discovered that this is actually the case: in periods of low national unemployment there is a tendency toward a decrease in the number of persons entering the farm labor force, while in periods of high national unemployment there is an upsurge of entrants to agricultural work (4). The data supporting this conclusion are presented in Table 2-2 and involved tracking the employment history of a sample of workers over a four year period using Social Security records. This type of longitudinal study permits identification of employers and the type of business in which the employer is engaged.

Table 2-2
Mobility and Non-Farm Unemployment Rates, 1955-59

Mobility Period	Net % Change in Number of New Entrants to the Farm Labor Force	Non-Farm Unemployment Rate (%)
1955 - 1956	- 2.7	4.2
1956 - 1957	- 6.3	4.3
1957 - 1958	+ 1.7	6.3
1958 - 1959	- 1.8	5.5

Source: Dale E. Hathaway, "Occupational Mobility from the Farm Labor Force" in Farm Labor in the United States, C. E. Bishop, Ed. (Columbia University Press, 1968 printing)

From the data in Table 2-2 it can be seen that a 2% increase in the national unemployment rate is correlated with an 8% change in entrants to the farm labor force. As described by Hathaway (5), "These data indicate that there was an actual net inflow into the farm work force during the year of highest unemployment."

As analyzed by Hathaway, increased non-farm unemployment produces this effect because:

a) It reduces the rate of occupational mobility out of farm work;

b) It increases the rate of back movement from non-farm to farm jobs;

c) It increase the rate of new entrants into farm work as rural youth find non-farm opportunities limited.

While much attention has been focussed on occupational mobility out of farm work, these data indicate that the path is a two-way street and that decreased non-farm jobs in fact push workers back into the farm labor force.

Evidence of the oversupply of farm labor in California may also be found by examining the 1977 rates of unemployment in agricultural counties in the state (see Table 1-2, page 4). According to Mamer and Fuller,

> ". . . it appears that a serious unemployment problem exists during at least part of the year in the major agricultural counties (6)."

Evidence of the abundance of the labor supply for the agricultural sector is not found only in the rural areas, but may be found in the major urban centers of the U. S. as well. A survey of hard-core unemployed persons in Los Angeles found that half of their number were migrants from rural areas, and that about one-third were formerly employed as farm laborers (7). These data, together with that of Hathaway and Perkins, indicate that there exists a pool of persons who float from farm to non-farm jobs and back. They are viewed as "urban unemployed" or "rural unemployed" depending upon where they are located at the time when they are counted.

B. Characteristics of Farm Labor Supply

On a national basis there is abundant evidence that the demand for hired farm labor has declined in the post-World War II epoch. This evidence is recorded in the annual survey Hired Farm Working Force Report published by the U. S. D. A. (8). Based on interviews that seek to determine information regarding recent employment history, the national farm work force is known to have declined from 3,600,000 persons in 1962 to 2,600,000 in 1975. Less well known are the structural changes that have accompanied this decline.

Using this source of data, Bowles and Holt have shown that year-round full time farm work has declined and that, over the past dozen years, the proportion of hired farm labor that is performed by persons only temporarily in the labor force has increased (9). Bowles and Holt divided the farm labor force into three categories:

1) Hired Farm Work Only, persons in the labor force year round as hired farm workers;

2) Multiple Job Holders, persons in the labor force year-round, but who work for more than one employer (whether farm or non-farm) in the course of a year;

3) Temporary Workers, persons who do farm work for part of the year but who are not in the labor force for the balance of the year.

The latter category includes students and persons who identify themselves as homemakers.

The most recent national report, for 1975, contains data that may be summarized according to the categories of Bowles and Holt (see table 2-3).

According to these data, temporary workers comprise 54% of the hired farm work force. They perform 25.8% of all hired farm work and 57.9% of seasonal farm work. Seasonal farm work is taken to be the sum of the temporary worker and multiple job holder categories. Graphs showing the

Table 2-3
National Hired Farm Working Force of 1975

Chief Activity	Number of Workers (thousands)	Average Number of Days of Farm Work per Year	Total Person-Days of Work (millions)
Hired Farm Work Only	528	235	124
Multiple Job Holders	694	61	42.2
Primary Farm Work	131	157	20.6
Primary Own Farm	82	81	6.6
Primary Non-Farm Work	433	29	12.6
Primary Unemployed	48	(50)	2.4
Temporary Workers	1,416	41	57.9
Homemaker	231	43	9.3
Student	1,027	41	42.1
Other	158	37	5.8
Total	2,638		224.1

Source: Gene Rowe, Leslie Whitener Smith, The Hired Farm Working Force of 1975, U. S. D. A. Economic Research Service, Agricultural Economic Report No. 355.

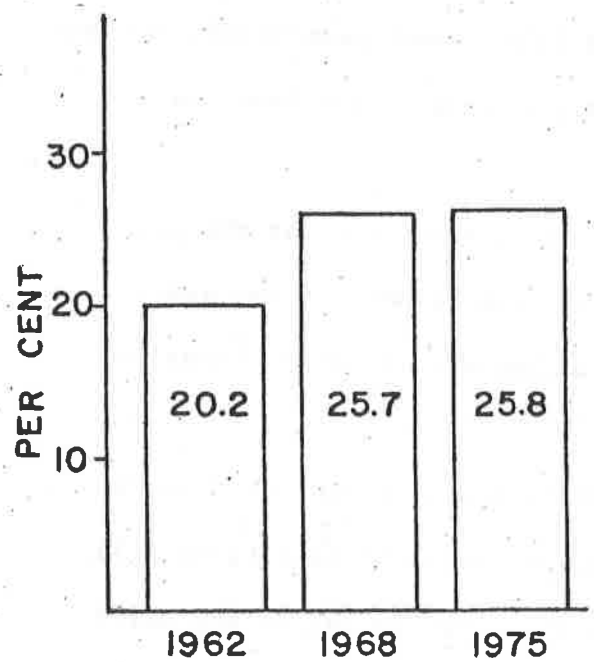

FIGURE 2-1

PER CENT OF ALL HIRED FARM WORK BY TEMPORARY WORKERS

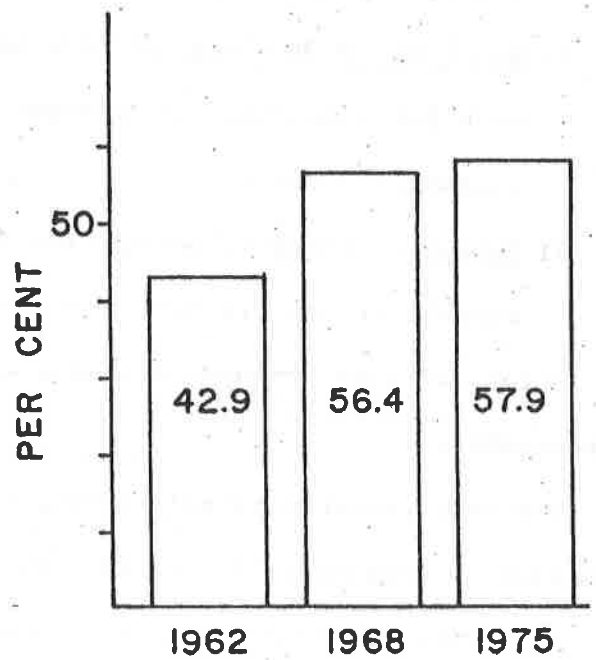

FIGURE 2-2

PER CENT OF SEASONAL HIRED FARM WORK BY TEMPORARY WORKERS trend of these data with time are presented in figures 2-1 and 2-2. The share of hired farm labor performed by year-round workers is declining. In 1975 these full-time workers performed 55.3% of the hired farm work. Twenty-five years earlier, workers in this category did 75% of the hired farm work (10).

The composition of the farm labor force has altered and the share of farm work performed by the different segments has significantly changed. More and more hired farm work is being done by temporary workers and less and less by full-time year-round employees.

1. California

These national trends are also reflected in data on California agricultural employment. The annualized average of agricultural employment has dropped from roughly 360,000 in 1950-55 to 290,000 in 1971-76 (see Figure 2-3). The largest decrease has been in the average number of farmers and

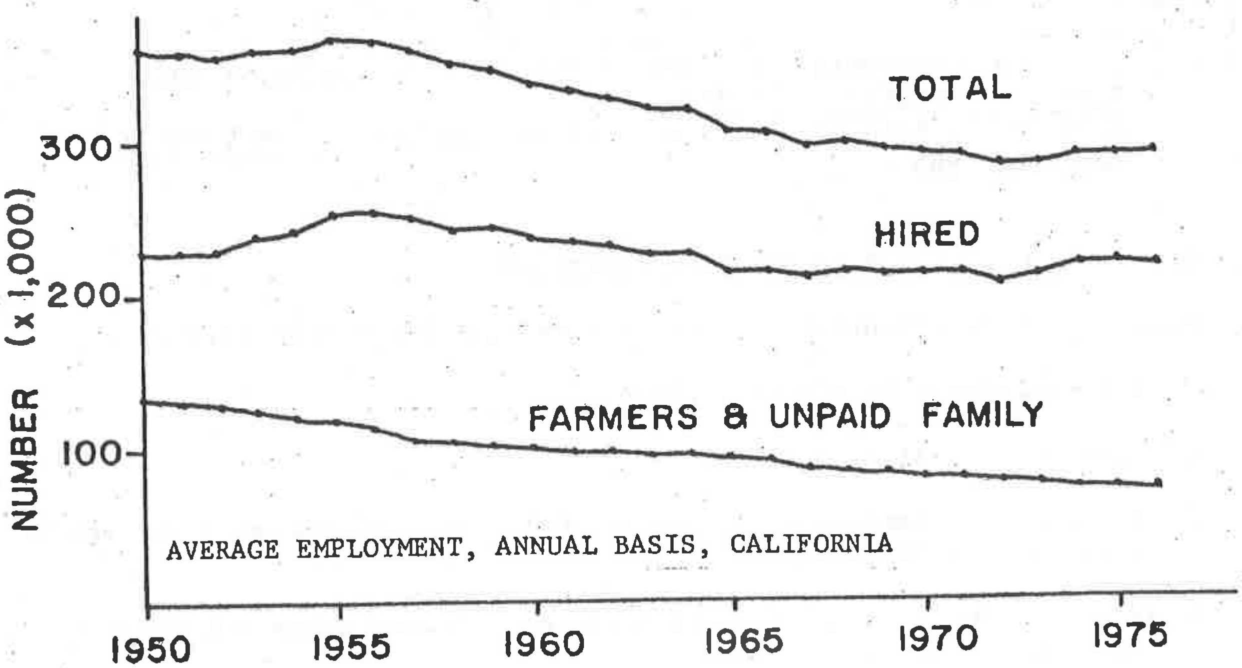

FIGURE 2-3

unpaid family members. In effect, farmers and unpaid family workers have been replaced by hired farm workers. The average employment of hired farm workers has decreased slightly as well.

The only statewide data that enable classification of hired farm workers according to the categories developed by Bowles and Holt are found in a study commissioned by the California Assembly Committee on Agriculture in 1965 (11). California had proportionately fewer year-round farm workers and more multiple job-holders than the nation as a whole in 1965 (see Table 2-4). The proportion of temporary workers was roughly the same.

Table 2-4
Structure of the Hired Farm Labor Force
United States and California, 1965

Chief Activity	California (Estimate)	United States
Persons Employed Year-Round	9.1%	20.2%
Multiple Job-Holders	36.0%	25.5%
Temporary Workers	55.0%	54.3%

Sources: California Assembly Committee on Agriculture, The California Farm Labor Force: A Profile
U. S. D. A. Economic Research Service, The Hired Farm Working Force of 1965

2. Sources of Data on California Farm Employment

There are three potential sources of data that break down California agricultural employment by county. These are:

1) Census of Population (12);

2) Agricultural Employment Estimates, California Employment Development Department (EDD) (13);

3) Quarterly Disability Insurance Reports, California Human Resources Development Department (14).

Table 2-5
California Farm Labor Employment
Hired Domestic Workers by County, April, 1970
Number of Workers

County	1970 Census of Population	Agricultural Employment Estimates (EDD)	Disability Insurance Reports (HRD)
Alameda	1,638	3,200	2,619
Butte	1,412	2,140	2,276
Contra Costa	814	1,320	1,490
Fresno	10,084	20,230	23,048
Imperial	2,865	5,950	8,741
Kern	9,563	18,930	17,515
Kings	2,372	3,930	3,307
Mendocino	397	360	622
Merced	3,828	4,200	7,259
Monterey	7,034	10,660	13,855
Orange	2,596	5,900	7,388
Placer	448	500	545
Sacramento	1,894	1,570	2,532
San Bernardino	3,440	5,530	4,587
San Diego	3,576	8,390	8,005
San Francisco	638	880	140
San Luis Obispo	1,542	1,880	1,996
San Mateo	637	1,670	1,732
Santa Barbara	2,776	5,230	5,382
Santa Clara	2,457	3,840	6,312
Santa Cruz	1,608	3,070	2,775
Shasta	423	490	488
Solano	916	1,670	2,106
Sonoma	1,840	3,300	3,035
Stanislaus	3,509	4,230	6,532
Tulare	10,883	21,000	19,014
Ventura	5,790	11,870	12,430
Yolo	1,428	2,490	3,365
Total (Reported Counties Only)	87,836	154,430	169,096

Sources: See notes (12); (13); and (14)

Farm employment for the month of April, 1970, according to these sources, is shown in Table 2-5. This period was chosen for purposes of comparison because it is the time when the Census of Population is conducted. The data show that the Census significantly underestimates farm employment. Systematic errors in the Census are well known to lead to inaccurate counts of minority populations. This would be expected to affect the count of farm workers in California.

Agricultural employment is estimated from data on production and worker productivity by the EDD. It is not a count of workers, but an estimate of labor demand. The Disability Insurance (DI) reports, on the other hand, are based on the number of workers on farm payrolls who earn at least $100. Considering the very different way in which these employment estimates are derived, there is actually rather close agreement between these two sources (within 10%, on the average). Unfortunately, DI records pertaining to agricultural employees are no longer reported on a seperate basis, and current employment cannot be analyzed in this manner. But the favorable comparison between EDD and DI data in Table 2-5 suggests that there will not be a very substantial error in the use of EDD data for county employment figures. For this reason, this study will use EDD data on hired farm workers in making county based analyses. Table 2-6 shows the most recent data.

The EDD Farm Labor Report gives a detailed representation of seasonal jobs which employ more than 100 workers within a single county at peak season. Jobs are described by crop and by activity, such as thinning, cultivating, harvesting, etc. Employment is also listed in more generalized categories such as "Miscellaneous Vegetables," "Tree Fruit," and "All Other Agriculture." This latter category accounted for 58.2% of the work

Table 2-6
Demand for California Farm Labor, By County
Total All Categories, All Other Agriculture
Peak Season 1978
(work weeks)

County	Peak Season Report Date	Labor Demand All Categories	Labor Demand "All Other Agriculture" Category
Alameda	Sept. 30	2,550	580
Butte	Sept. 16	5,140	3,520
Contra Costa	Sept. 30	1,700	740
Fresno	Sept. 16	62,920	25,390
Imperial	Jan. 28	11,970	4,590
Kern	Sept. 16	22,780	12,500
Kings	July 15	9,680	6,400
Mendocino	Aug. 12	1,770	570
Merced	Sept. 16	16,630	9,400
Monterey	Aug. 12	17,260	2,800
Orange	Sept. 16	6,100	2,300
Placer	Aug. 12	1,290	950
Sacramento	Aug. 12	5,490	3,690
San Benito	Sept. 2	4,770	1,600
San Bernardino	Sept. 30	7,720	6,570
San Diego	Sept. 30	11,530	4,980
San Luis Obispo	Sept. 30	2,400	1,350
San Mateo	Sept. 16	2,600	300
Santa Barbara	July 15	6,940	3,200
Santa Clara	Aug. 12	8,490	2,370
Santa Cruz	Sept. 30	6,240	1,810
Shasta	Sept. 30	1,050	1,050
Solano	Sept. 16	3,760	2,800
Sonoma	Sept. 16	7,520	4,750
Stanislaus	Sept. 16	13,420	7,300
Tulare	Sept. 30	31,530	19,250
Ventura	Aug. 12	18,860	8,730
Yolo	Sept. 16	7,360	4,700

Source: California Employment Development Department
Farm Labor Report 881-A, Report Date as Indicated

weeks of employment reported in 1977 (15). The accuracy of the Farm Labor Report is discussed in more detail in Chapter VI.

3. Women Farm Workers

According to the Census of Population of 1960 about 9% of California hired farm workers were female. By 1970, this proportion had increased to 16.5% (16). In large part this increased participation of women has been a result of technological change. Jobs requiring heavy, physical labor that have been traditionally held by men are being replaced by sorting or similar types of jobs that have been usually performed by female workers (17). This trend had been noticed by Friedland and Barton, and was an important motivating factor for a recent study of female California farm workers.

A seperate indicator of the increased participation of women in the hired farm work force of California was obtained in a detailed study of Yolo County workers employed in the processing tomato harvest. Thompson and Scheuring found that about 2/3 of the sorting workers on Yolo County tomato harvest machines in 1977 were women (18). A 1965 study of hand harvest tomato workers in Yolo County indicated that the vast majority were male (19). Thus one factor in the increasing role of women in the farm labor force is that the substitution of machines for hand labor creates some new jobs in which women as well as men are hired.

4. Ethnicity

The ethnic composition of hired farmworkers in California is not accurately known at present. Data from the 1965 study of hired farmworkers in the state as a whole indicate that about 45% were Mexican or Mexican-American (20). Since no comprehensive statewide study has been done since

Table 2-7

California Agricultural Workers, Per Cent Hispanic, by County, 1970

County	Number Workers	Per Cent Hispanic
Alameda	2,315	24.7
Butte	2,326	13.1
Contra Costa	1,341	22.3
Fresno	14,315	44.9
Imperial	3,664	60.1
Kern	11,242	43.4
Kings	3,332	44.8
Mendocino	745	9.4
Merced	5,829	37.2
Monterey	8,196	62.6
Orange	3,561	40.7
Placer	889	8.2
Sacramento	3,085	19.4
San Bernardino	4,975	32.6
San Diego	5,607	31.3
San Luis Obispo	2,437	29.6
San Mateo	1,027	19.9
Santa Barbara	3,618	47.2
Santa Clara	4,094	37.3
Stanislaus	5,838	25.9
Tulare	13,987	45.7
Ventura	6,756	67.0
Yolo	2,113	34.3

Source: U. S. Bureau of Census, 1970 Census of Population Manpower Package No. 2, Detailed Manpower Indicators Table 25 A, p. 75; Table 25C, p. 79 "Employed Population 16 Years Old and Over by Occupation, by Race and Ethnic Group"

that time, it is not possible to make current estimates regarding ethnicity.

The most recent source of data regarding county by county ethnic composition of the California hired farm work force is the 1970 Census of Population. These data are shown in Table 2-7. Since the Census systematically understates agricultural employment, these data on the proportion of Hispanic workers are expected to be seriously in error. It is likely that a large proportion of the hired farm workers not tabulated in the census are Hispanic. To see how serious the discrepancy may be, note that the Census of Population places the number of Fresno County agricultural workers at 14,315 in 1970. On the other hand, California EDD figures for peak season 1970 place the level of employment at 74,900 work-weeks. Thus, at peak season, there is indicated a discrepancy of 60,385 workers. Barton, et al, found the proportion of hired farm workers of Hispanic descent in Fresno County to be 90% at peak season 1977 (21). This would be possible only if virtually all of the farm workers missed in the Census count are Hispanic. While this is not impossible, on its face it is unlikely. At best, one could conclude that hired farm workers in Fresno County are in the range of 45% to 90% Hispanic.

There are a few recent studies of the ethnicity of workers in particular counties, or workers employed within a single crop within one county. All of these studies suggest that the proportion of persons of Hispanic descent among California farmworkers is actually much higher than the 1965 study indicated. (see Table 2-8).

Table 2-8
Per Cent Mexican and Mexican-American Farmworkers

County	Crop	Date	Per Cent
Imperial	All Crops	Jan. 1977	97%
Fresno	All Crops	Sept. 1977	90%
Yolo	Processing Tomatoes	Fall 1977	94%

Sources: Fresno and Imperial Counties--
California Commission on the Status of Women
Campesinas: Women Farmworkers in the California Labor Force
Yolo County--
Thompson and Scheuring
"The Impact of Mechanization Upon People and Communities"

It should be evident that these data suggest that a much higher proportion of California farm workers are of Hispanic descent than has been indicated in studies conducted in earlier periods. For purposes of comparison, a 1965 study of Yolo County processing tomato workers showed that 43% were Mexican or Mexican-American (22). This figure comes close to the 45% figure given in the statewide study of farm workers conducted in that same year. Based on these data and the data in Table 2-7, it is not unreasonable to suggest that at present substantially more than half of California hired farm workers are of Hispanic descent.

5. Local Workers or Migrants ?

While migrant farm workers have historically played a central role in California agriculture, current data suggests that the overwhelming majority of hired farm workers in the state are residents of the communities in which they work. Thus, Thompson and Scheuring find that 2/3 of Yolo County processing tomato harvest workers were local residents (23). The fact that 94% of these workers are also Hispanic might lead some observers to conclude that they are therefor migrant Mexican nationals, but this is not the case. The pattern of predominance of local residents in the hired farm work force has been found in a number of locally focussed studies. For example, a study of persons working in the Riverside County apricot harvest in 1963 showed that 76% of those employed only in agriculture during a fifteen month period centered at the time of harvest were local residents (24). The same study showed that 42% of those reporting non-agricultural as well as agricultural work in that period were local residents. A study of labor contractor employees in 1964 indicated that 50% of those employed in only agricultural work were local residents (25).

Other, more recent data independently supports the conclusion that a majority of hired California farm workers are employed in the area where they live. The 1977 study of women farm workers conducted by the California Commission on the Status of Women showed that about 57% of Fresno County farm workers lived in the immediate area. Again, Imperial County farm workers indicated that about 50% were permanent residents of Imperial County and another 30% were residents in the adjacent border areas (26). All available data supports the conclusion that the majority of hired farm workers in California work in the communities where they reside.

6. Multiple Job-Holders in the California Hired Farm Labor Force

Persons who are employed in agricultural as well as non-agricultural jobs comprised an estimated 36% of the California hired farm labor force in 1965. Studies of the employment histories of a sample of employees of labor contractors in 1964 and early 1965 suggest that between 30% and 42% of all such workers held both types of jobs at different points of time in that period (27). These data provide independent support for the 36% estimate of the statewide study. Unfortunately, there are no recent data bearing directly on this question. However, at least 25% of hired farm workers in Fresno and Imperial Counties in 1977 are members of families in which some members perform non-agricultural work (28).

C. Conclusion

The composition of the California hired farm labor force is shifting over time. The trends include:

a) increasing participation of women in the hired farm work force;

b) overall trend toward decreased employment;

c) increasing proportion of Hispanic workers;

d) increasing proportion of temporary workers in the hired farm labor force;

e) tendency for temporary workers to perform a large share of farm labor.

Most significant in terms of the needs of this study is the absence of recent comprehensive data on the structure of the California hired farm work force.

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CHAPTER III

HARVEST MECHANIZATION

Fruit and vegetable harvest mechanization involves more than the substitution of a machine for hand harvest workers. In order to harvest a crop by machine, almost every aspect of its production must be modified. In the past 25 years, adoption of harvest machinery has profoundly changed a number of agricultural industries in California.

The harvest of formerly labor intensive crops such as cotton and sugar beets has been mechanized. The "shake-catch" technology of tree shakers and catching frames has been perfected in the harvest of walnuts, almonds, and prunes, and is now in widespread use in the canning peach harvest. Pick-up machines are used to harvest nut and fig crops. A substantial portion of the wine grape crop is being harvested mechanically. Root and tuber crops such as carrots and potatoes are entirely mechanized, as are most vegetables grown for canning and freezing, including peas, snap beans, sweet corn, spinach, and tomatoes. Dehydrated onions, pickling cucumbers, and brining cherries are also machine picked.

Farm mechanization can be understood as an historical process. The purpose of this chapter is to describe this process in order to estimate its future impact on the farm labor force.. By comparing the mechanization of different commodities, certain common features are identified. Such an analysis must be used with caution, however, for no two agricultural industries are exactly alike.

The following discussion of pre-conditons to adoption of new technology, factors affecting the adoption rate, and social consequences of mechanization will rely on literature dealing with vegetable, fruit, and nut harvest mechanization in the United States since 1950. Mechanization of the cotton and sugar beet harvests will also be used as examples because they were labor intensive crops which were mechanized in California in this same period of time. Cotton mechanization is an important example because its history is especially well documented. J. H. Street's New Revolution in the Cotton Economy proposed some of the concepts used as a framework for this analysis.

A. Integrated Technology

In his work on cotton harvest mechanization, Street cites the "striking concurrence of technological achievements"-- a harvest machine, new methods of weed control, harvest time defoliation of the cotton plant, and improved ginning methods -- as being the principal factors in mechanization (1). To understand the process of farm mechanization, more than just farm machines must be examined. It is important to study the changes in production, in handling, and in the final product for two reasons. Mechanization often will not be feasible unless ancillary technologies are developed, and it is sometimes the economies realized at other levels of production which may propel mechanization of the harvest.

Not only must a machine be engineered to the crop, but the crop must be cultivated to fit the requirements of machine harvest. These cultural techniques may be classified into two broad generic categories-- the row crop technology (for the most part annual vegetable crops) and tree and vine technology (for the most part, perennial fruit and nut crops).

1. Row Crop Production Technology for Mechanical Harvest

Annual crops grown for mechanical harvest are almost always harvested "once-over." Although there have been extensive studies of multiple harvest machines for some crops, this type of machine is not in widespread commercial use in any row crop industry. With selective harvest, the remaining crop is damaged by the machine. This damage makes subsequent harvest uneconomical.

Since the entire plant is generally picked, every plant in a given field must mature at the same time. Row crop technology is directed towards achieving this uniform maturity in a large scale field. This technology is becoming capital intensive. It requires substantial inputs of petroleum products, and reduces the demand for early season farm work in weeding and thinning.

Precision listing (bed-shaping), fertilizer application, and seed placement are designed to give each plant in a field the same growing conditions. Mechanical cultivation and the use of herbicides are calculated to keep weeds from competing for nutrients, water, and air. Plant growth hormones are used to encourage uniform ripening, and to help set fruit.

According to Wayne D. Rasmussen, it was just such a package of production technology which transformed the processing tomato industry in California. The integrated technology consists of "effective machines, specially bred tomatoes, careful irrigation and fertilization and particular planting techniques (2)."

Precision cultural practices are use in many non-mechanized vegetable and melon crops. Uniform maturity can reduce the quantity of hand labor needed at harvest because a given field can be picked in fewer passes by the harvest crew.

Because it involves and annual crop with new seed being planted every year, row crop technology can readily include changing the attributes of the crop through breeding. The snap bean machine can harvest only bush varieties. Breeders have developed a variety with uniformly maturing pods borne well up from the ground in the central part of an erect plant (3).

Mechanization of the processing tomato harvest occured only with a specially adapted variety. A firm, crack-resistant tomato variety was bred on a vine with little foliage and a small determinate growth habit. The determinate habit means that all flowers set fruit within a short period of time, enabling the fruit to mature simultaneously (4).

The development of inexpensive cucumber hybrids with high yield, gynecious (female) flowering habit, and concentrated fruit set has made possible the mechanization of the pickling cucumber harvest (5). Hybrid varieties are a key part of high density, uniform stand production practices which have made vine-destructive harvest economically feasible.

2. Tree and Grapevine Production for Mechanical Harvest

Perennial fruit and nut crops, with a lifespan of 15 to 50 years, are planted infrequently. Thus genetic modification is more difficult than it is with an annual crop. Trees and vines can be adopted to the requirements of a harvest machine, however, through pruning, retraining, and orchard preparation.

Mechanical shakers are used to knock nuts and deciduous fruits from the tree. Reduction in the number of scaffold branches allows limb type shakers to operate with fewer hook-ups to the tree (6). Trunk shakers, which can shake the tree with a single hook-up, require that the primary scaffolds branch from the trunk of the tree at least 18" above ground level (7).

Durable crops such as walnuts, almonds, and figs may be shaken to an orchard floor which has been specially prepared to eliminate clods and rocks, then raked and picked up by machine. This preparation may require substantial changes in irrigation and tillage practices. It involves cultivation and herbicide use to eliminate weeds throughout the season. Prior to harvest, the land must be floated, dragged, leveled and/or rolled. The cost and difficulty of this preparation is dependent on soil type, and soil moisture content during preparation (8).

The more easily damaged deciduous fruits are shaken into catching frames. Low hanging scaffold branches of prune trees must be eliminated so that the frame can get under the tree (9). To harvest softer fruits such as peaches and apricots, more extensive tree working is required so that falling fruit will not impact on branches. To keep fruit from being borne above branches, the tree must be trained in a vase shape, eliminating limb over limb configurations (10).

Wine grapes must be retrellised so that the clusters of fruit are borne above the catching pan of the harvester, within reach of its striking bars (11).

Tree and vine restructuring can be costly. In some orchards the trees cannot be adapted to machine harvest; older vineyards sometimes cannot be machine picked.

3. Harvest Mechanization and Changes in Handling

Significant changes in produce handling have accompanied harvest mechanization. Fruits and vegetables are being transported to processors and packing sheds in ever larger containers. Hand pickers at one time placed prunes and tomatoes into 50 lb. capacity lug boxes. With mechanization, prunes are conveyed from the catching frame into 1200 lb. capacity pallet bins (12). The output of the first models of tomato harvesters was so great that they could fill 2 to 4 lug boxes a minute (13). Pallet bins and bulk tanks are used instead. One worker using a fork lift can handle much more of the crop in pallet bins than can a worker handling lug boxes (14). Handling labor has been further reduced by the substitution of 12½ ton capacity fiberglass tanks for pallet bins. The tomatoes are flumed from the tank, eliminating fork lift labor needed in pallet bin handling.

The labor savings of bulk container handling has facilitated the adoption of pallet bins in hand-harvested crops such as peaches, pears, brocolli, and cauliflower. Hand harvested grapes have been handled in gondolas rather than lug boxes at least since 1958 (15). The proven economies of large containers have virtually eliminated the use of field lugs in the fruit and vegetable harvest.

In some crops, mechanically harvested produce must be given special handling. This may be as simple as the priority treatment given machine harvested canning peaches in California (16). The fruit must be processed before machine induced damage becomes apparent.

The special handling may be more complicated, such as water tank handling of mechanically harvested tart cherries in Michigan. To minimize the development of post-harvest damage, the cherries are conveyed from the catching frame to 1,000 lb. pallet tanks filled with cold water. They are cooled below 60°F within a half hour after harvest at orchard side cooling pads (17).

Hand harvested onions are cured in sacks or windrows in a field. In Michigan, mechanically harvested onions are bulk cured in specially constructed bins (18). The transport of hand-harvested potatoes in field bags has been replaced with bulk truck transport of machine-harvested potatoes (19). The general trend has been to larger storage facilities and towards handling potatoes entirely in bulk up until the time they are to be put in consumer packages. The inclusion of dirt clods, rocks, and immature and machine damaged potatoes is a consequence of this special handling system (20).

4. Harvest Mechanization and Changes in Packing, Processing, and Product

Mechanically harvested produce generally includes more debris and culls than does hand harvested produce (21). Special procedures are required at the packing shed or processing plant to sort machine harvested commodities.

Machine picked sweet corn is delivered with more immature ears and trash, which must be graded out before the corn is packed. Costs are cut by handling the corn in bulk and packing it in a central facility (22).

Snap beans harvested by machine include more beans in clusters and more trash. Although New York state processors had to install special equipment to clean the mechanically harvested crop, they did not establish a differential in price between hand and machine picked beans (23). The processors owned harvest machinery in New York and Florida (24)(25).

Deliveries of shake-catch harvested cherries in Michigan included 2-15% fruit with stems attached. Processors have installed automatic destemming equipment and electronic sorters to process machine harvested fruit (26).

Several premium varieties of wine grapes machine harvested in California are being crushed in the vineyard. The field crushing reduces oxidation and aroma loss which occurs when these varieties are machine harvested and crushed at the winery (27).

Changes in the packing of fresh carrots contributed to the mechanization of the fresh market crop. Until the early 1950's carrots were usually sold bunched with their tops intact. Development of a poly-film bagger by the U. S. D. A. led to rapid conversion to prepackaged carrots. By leaving the tops in the field, shippers were able to fit more carrots into a rail car, and save on transportation charges. Store operators surveyed by the U. S. D. A. preferred to handle the prepackaged product, although consumers preferred bunched carrots to poly-bagged ones (28). Mechanical topping and digging of carrots in the field followed in the late 1960's in California and Texas (29)(30).

Harvest mechanization and new processing techniques in the fruit and vegetable industry have contributed to the trend away from hand picked, fresh products towards machine harvested processed ones (see Figures 3-1 and 3-2).

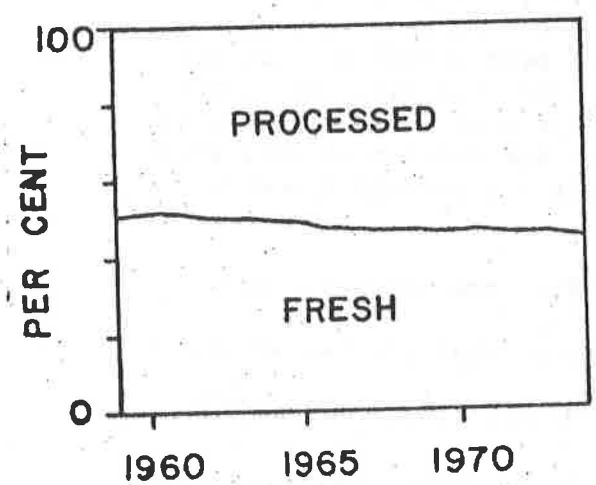

FIGURE 3-1

COMMERCIAL VEGETABLE SALES

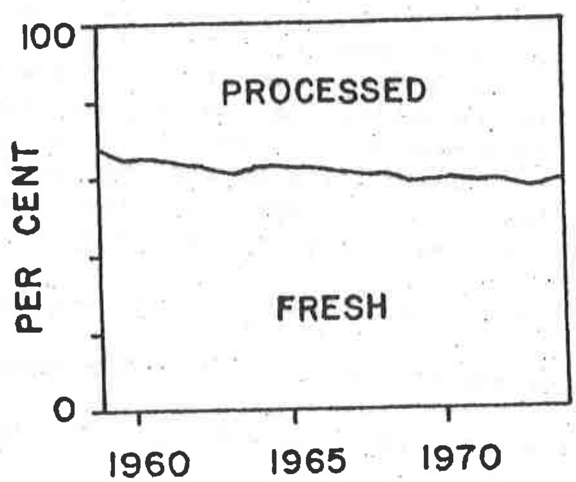

FIGURE 3-2

COMMERCIAL FRUIT SALES

"In some cases mechanization has been successful for the processed product and not the fresh market product," notes B. F. Cargill, the editor of the 1969 Michigan State University study of farm mechanization. "This has been one factor influencing an important trend in our fruit and vegetable industry -- the trend toward increased percentage of processed fruits and vegetables (31)."

The period which followed introduction of the snap bean harvester in New York state saw an increase in the price of fresh snap beans (which were hand harvested) and a decrease in the price of snap beans for processing. Per capita consumption of fresh snap beans declined while consumption of canned and frozen beans increased (32).

The development of flash freezing has had tremendous impact on the amount of labor required to produce vegetables. In 1959 Earle Gavett wrote:

> "This development, while not on the farm, had a terrific impact on the vegetable industry. Consider, for example, what has happened to the production of green peas. Prior to flash freezing in the processing plants and the widespread adoption of mechanical freezer space in consumer homes, the only way to get green peas that tasted and looked like fresh peas was to buy them in the pods. However, quick freezing of peas presents a product to the public that is very similar in color, quality, and flavor to garden fresh peas, and it requires less work for the housewife to prepare. The acreage of the fresh market portion of this crop has all but disappeared since 1939, while the acreage grown for freezing nearly quadrupled (33)."

In a similar fashion, the creation of other new products, onion powder and flakes, have allowed mechanization of that portion of the California onion crop which goes to the dehydrator (34).

A change in the final product may also be an inadvertant byproduct of mechanization technology. One example of this result is suggested by Claypool's observation that plant breeders, in selecting for traits that

that make a crop adaptable to machine harvest, may have to sacrifice quality traits (35). This illustrates the "degradation of product" which Braverman links with the mechanization of production in the U. S. (36).

Quality questions have been difficult for breeders trying to develop processing tomato varieties adapted to machine harvest. The determinate habit needed in a machine harvestable variety has been linked to low soluble solids content, an important quality defect to the processor (37). The small size of these varieties prohibits their being cored, as the larger hand harvested varieties were in the past (38). Small size has also been linked with low soluble solids (39).

Mechanization has also had an effect on the quality of snap beans. Strong flavor and firm meaty texture of snap beans are more characteristic of the pole varieties, which cannot be mechanically harvested. Only recently have bush varieties suited to machine harvest been bred with these traits (40)(41).

B. Substantial Cost Savings of Technology

With the trend to more highly mechanized operations, labor costs are a decreasing part of the production expenses of California fruit and vegetable producers (see Figures 3-3 and 3-4). Mechanization decreases labor's share of the value of production. Martin and Havlicek documented the decline in labor's share in the value of cotton production (42).

A substantial portion of the literature reviewed compares the cost of hand harvesting a given commodity to the costs of machine harvest. With infrequent exception, this literature reaffirms the concept described in the study of cotton mechanization by Street -- that technology is adopted

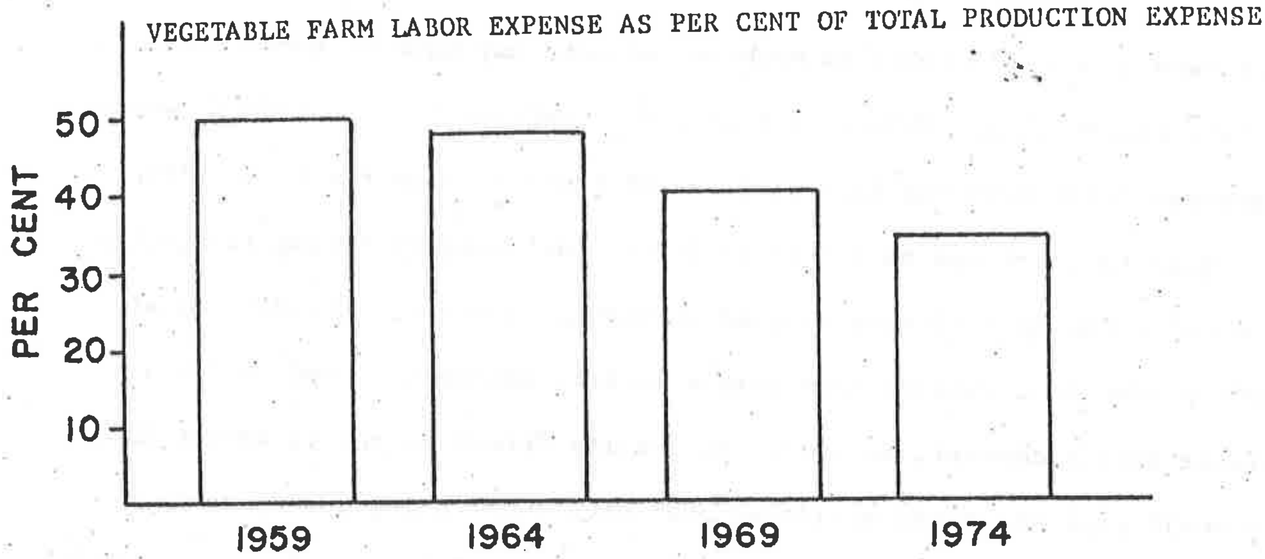

FIGURE 3-3

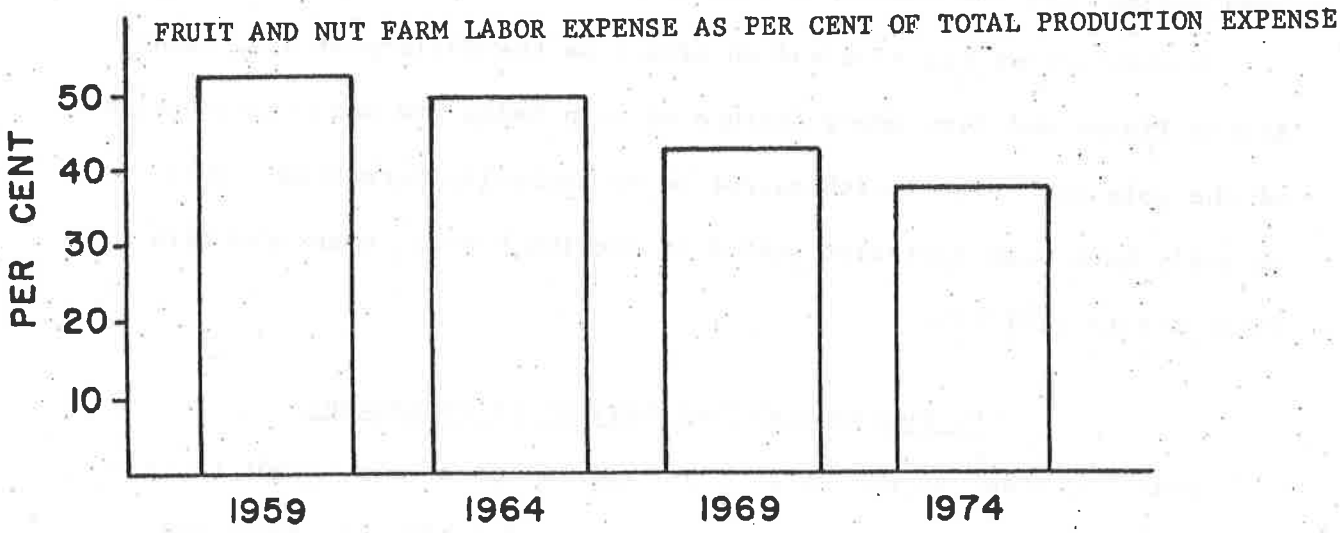

FIGURE 3-4

because it results in a substantial cost savings to the farm operator.

The cost savings of farm mechanization per unit quantity of production can be caculated by the cost savings equation:

$$S = V_L - (C_F + C_V + C_A + V_Q + V_Y)$$

where: S = cost savings

V_L = value of labor savings (cost of hand-harvest labor)

C_F = fixed costs of machine operation

C_V = variable costs of machine operation

C_A = cost of ancillary technology

V_Q = value of quality or grade loss caused by machine

V_Y = value of yield loss (the difference between the amount of crop left in the field by hand harvesters and the usually greater amount left by a harvest machine)

The cost savings equation is of concern to the farm operator deciding whether or not to adopt new harvest technology. For the technology to be cost saving, it must cost less than the hand-harvest labor it can displace. The cost savings, and the factors used to calculate it, are all calculated per unit of production. The savings may be expressed by any unit of production, such as ton, bale, acre, pound, etc.

The cost savings of the technology (S), is the cost of hand-harvest labor (V_L) less the cost of mechanical harvest ($C_F + C_V + C_A$) and the loss in value of the harvested product that occurs with mechanization ($V_Q + V_Y$).

Agricultural economic analysis has concentrated on calculating the "break-even point ." The analyst makes asumptions about the mechanized producers' costs and income, then calculates the size of harvest operation required to reduce fixed costs to the level where the value of labor savings can pay the costs of mechanization (i.e., $V_L = C_F + C_V + C_A + V_Q + V_Y$). Examples of break-even points are given in Table 3-1.

1. Value of Labor Savings

Harvest mechanization eliminates all hand harvest jobs, and replaces them with new ones. Mechanization saves the farm operator the costs of hand harvest. The absolute or dollar value of labor savings is dependent on the farm labor wage rate, and on the relative portion of production costs represented by hand-harvest labor costs. The value of labor savings will be much greater in commodities where hand-harvest labor is a great part of total production costs.

Table 3-1
Break-Even Point
Scale of Production Needed for Adoption of Machine Harvest to Pay Its Costs

Crop	Area	Year	Machine	Minimum Scale	Source
Green Peas	Washington	1967	Combine	900 tons	(44)
Snap Beans	Florida	1967	Two row harvester	160 acres	(45)
Potatoes	Idaho	1957	Two row harvester	6,000 cwt.	(46)
Carrots	Texas	1967	Tractor pulled harvester	32 acres	(47)
Walnuts	California	1951	Self-propelled pickup	25-30 acres	(48)
Wine Grapes	California	1970	Over the row harvester	160 acres	(49)

2. Costs of Mechanization

The costs incurred by the mechanized farm operator include costs of operating the harvest machine and the costs of new production practices and handling systems. The costs directly attributable to the harvest machine are both fixed and variable. Costs of operating the machine such as fuel, oil, maintenance and repair, and machine-harvest labor costs are all called variable costs, for they vary according to how much the machine is used. Increasing machine output is an important aspect of how producers try to minimize variable costs per unit of production (C_v). Output may be increased by multi-row operation, increases in per acre yields, and faster operating speeds.

The fixed cost of the machine is the price of purchase and the interest on financing the purchase. It can be paid as rent, a custom harvesting charge, or a loan payment. The fixed cost of the machine per unit of production (C_F) depends on the output of the machine for its lifetime. The total output of a machine increases (and fixed cost per unit of production decreases) as the machine is used on a larger scale operation, for more weeks each season, for more seasons in its productive life.

Agricultural equipment, especially harvest machinery, is used seasonally, for only a few weeks of the year. Although some shake-catch equipment can be used to harvest several different crops a year, most harvest machines have a very specialized application and the duration of their seasonal use cannot be expanded.

The useful life of a harvest machine is dependent on the durability of the machine, and on the fact that new technology may make it obsolete. "One may question whether depreciation (of the potato harvest machine) is due more to obsolescence or to use," wrote Davis in 1955 (50). Greene concurred that "obsolescence could make present machines depreciate very fast (51)." Similar concerns about obsolescence were noted for the green pea combine (52) and prune pick-up machine (53).

With little control over durability or obsolescence, the only option for the farm operator seeking to reduce fixed costs per unit of production is to use the machine on a large scale. Fixed costs are cut by increasing per acre yields, per hour output of the machine, and by increasing the seasonal output of the machine by using it on larger and larger scale plantings.

The costs of ancillary technology per unit of production (C_A) are not necessarily prominent in the cost savings equation. The initial outlay for some of the costs, such as special receiving and sorting equipment, is paid by packer or processor. The ancillary technology may reduce labor costs on its own. The precision culture of California canning tomatoes for machine harvest was a mechanized production practice that eliminated the hand transplanting of tomato seedlings, saving labor costs. Bulk handling of produce requires investment in bins, trailers, fork-lifts, and trucks, but it is highly labor saving.

New production technology can be a significant expense of mechanization. To convert a wine grape vineyard to machine harvest usually requires replacing trellis stakes and crossarms and raising trellis wires (54). Mechanized cherry growers must install cooling pads; nut farmers must pay the cost of orchard preparation; cucumber and tomato farmers must buy precision planters; cotton and potato farmers must purchase defoliation chemicals.

3. Impact of Harvest Mechanization on the Value of the Crop

Mechanical harvest is generally less precise and careful than hand harvest. Mechanical damage, and the inclusion of dirt and debris are common problems which make mechanically harvested crops less valuable than comparable quantities of hand harvested ones.

Impact damage and the inclusion of dirt occured with mechanization of the California tomato harvest (55). Broken and immature beans and trash are included with machine harvested snap beans (56)(57). When first introduced, cotton machines left some of the crop that hand pickers would have harvested. Machine picked cotton was of a lower grade and less value because of the tangled lint, high moisture content, green leaf stain, and inclusion of trash, oil, and grease in the load (58)(59).

Harvest machines often recover less of the crop than can hand-harvest workers. Several hand pickings allow most of the crop to be harvested at optimum maturity. Once-over harvest does not allow this selectivity, and yield is lost.

Shake-catch harvest of peaches, for example, results in substantial loss of immature and overmature fruit compared to hand harvest (60). Yield is also lost in machine harvest of snap beans (61) and cucumbers (62) for there is no opportunity for multiple pickings. Machine harvest can also damage fruit trees and vineyards, reducing yields.

Quality degradation and yield reduction are principal economic factors that impede adoption of new fruit and vegetable harvest technology, yet the value of labor savings of successful harvest technologies is so great that there is a net cost saving despite some reduction in the value of the crop.

C. Concentration of Production

The specific cultural requirements of crops grown for machine harvest can make mechanization adaptable only to certain growing areas. As a result, mechanization can cause a change in production districts.

Gavett associated shifts in processing vegetable production areas with mechanization of the green pea and sweet corn harvests. Sweet corn production shifted from the Northeast to the Lake States region, where large rectangular fields allowed rapid adoption of the 2-row cornpicker. Production of the green pea freezer crop concentrated in the Lake States and in the Pacific Northwest. Gavett reported that these areas had larger and more level fields than Eastern production areas, and were hence more amenable to adoption of labor saving technology.

The potato harvester must be used on lands that have a loose, friable soil. The machine was not adopted in New York, Pennsylvania, or Colorado because of their rocky and clod producing soils. Elliot noted a relation between increased acreage and mechanization. Despite a 4% decrease in U. S. potato acreage during the 1950's, production in the highly mechanized states of Minnesota, North Dakota, and Idaho increased 25% (63).

Mechanization of the tomato harvest has proceeded very slowly in the Eastern states because of a short growing season, summer rainfall, and unsuitable soil types (64). As a result, processing tomato production has become concentrated in California where there is a longer, dry growing season, and irrigated agriculture (see Table 3-2). The concentration has come about even though California canners must pay higher wages and more transportation costs than their Eastern competitors (65).

Table 3-2
California's Share of U. S. Processing Tomato Production

Years	California Share of U. S. Production (% of tons)
1953 - 57	54.9
1958 - 62	57.5
1963 - 67	61.8
1968 - 72	70.8
1973 - 77	83.0

Source: California Crop and Livestock Reporting Service
U. S. D. A.

Well drained, uniform soils in large, rectangular tracts are best adapted to growing tomatoes for mechanical harvest (66). These requirements have been responsible for the changing concentration of production among California tomato districts (67).

A similar intra-state shift in production was noted in the prune industry. Production declined in the coastal areas in favor of the Sacramento Valley and foothill areas. Prunes do not mature uniformly in the coastal districts, and are consequently difficult to shake-catch harvest. In the inland districts they mature uniformly and are harvested by machine (68).

How and Nyberg report a concentration of snap bean production in New York state and the Midwest, where machine harvesting had been introduced at an early date (70). They also noticed concentration of snap bean production within certain New York state areas (71).

D. Concentration of Farm Operations

The farm operator can realize the cost savings of harvest mechanization only if the harvest machine is used to harvest more than the minimum output defined by the "break-even point." The average scale of production of hand-harvest operators is often smaller than this minimum.

When harvest machines began to displace New York snap bean workers, only a small number of growers had the size of enterprise necessary to fully use one machine. The average non-mechanized farm surveyed by How and Nyberg had 47 acres of snap beans; the average mechanized farm produced 377 acres (72).

A study of California prune orchards in 1961, prior to the mechanization of the harvest in the coastal districts of California, found that less than 20% of the growers operated farms of 50 acres or more of prunes, the absolute minimum scale needed to utilize a harvest machine (73). Before the state's processing tomato harvest was mechanized in the late 1960's, the average grower raised 32 acres of canning tomatoes. A scale of 125 to 200 acres was recommended for profitable use of the harvest machine (74).

The producers who mechanize their harvest operations have lower production costs than hand-harvest producers. The small scale operator is at a competitive disadvantage, and, with time, is forced to mechanize or sell out. The small-scale operator may be able to mechanize without increasing the scale of farm operation. Machinery leasing, custom harvest work, cooperative equipment purchase, or processor ownership allow a machine to be used on a number of farms each season, on a scale large enough that cost savings can be realized.

Several authors have reported custom harvest operators mechanically harvesting small acreages of grapes, sugar beets, potatoes (75) and spinach (76). Farm operators lease harvest machines from snap bean (77) and sugar beet (78) processors. Without data showing the extent of custom hire and leasing practices, there is no way of knowing their impact on the trend toward large scale operations. Their existance suggests that the prevalence of small scale operators is not necessarily an impediment to adoption of harvest machinery which requires larger scale use to be cost saving.

Other data indicate that the average scale of farm operations prior to mechanization has little effect on the adoption of new harvest machinery. Mechanization is often cited as the cause for the demise of the small scale family farm, and is an important factor in the trend to larger scale farming (79). While other factors must be involved, mechanization is a primary element of that trend.

"Because of the large financial investment in machinery and equipment to grow and harvest the crop, the number of tomato growers has steadily decreased," wrote President of the California Tomato Growers Association, Jack Hayes, in 1973. "Just 10 years ago, there were more than 4,000 tomato growers in the state. By 1969, there were less than 1200, and in 1972, fewer than 600 growers remained in the business (80).

Mechanization can be correlated with increasing farm size (see Table 3-3 and 3-4).

Table 3-3
Mechanization and Scale of California Processing Tomato Farms

Year	Total Acreage in Processing Tomatoes	Number of Farms	Average No. of Acres per Farm of Processing Tomatoes	% of Processing Tomato Production Machine Harvested
1963	129,000	4,000	32.3	1.5
1969	154,000	1,200	128.3	99.5
1973	218,000	600	363.3	100.0
Sources	(86)	(87)		(88)

Table 3-4
Mechanization and Scale of U. S. Cotton Farms

Year	Total Acreage in Cotton	Number of Farms	Average No. of Acres per Farm of Cotton	% of Cotton Production Machine Harvested
1950	17,843,000	609,000	29.3	8
1959	14,618,000	242,000	60.4	43
1964	13,915,000	164,000	84.8	78

Sources: Robert G. Ainsworth "Causes and Effects of Declining Cotton Employment" Farm Labor Developments September-October 1967

U. S. D. A. Agricultural Statistics

The trend to large scale farms has been more pronounced in the vegetable farms than in fruit farms in California. The California vegetable industry has become very concentrated in the last 25 years. The number of vegetable farms has decreased from 4,779 in 1950 to 2,047 in 1974 (81)(82)(83). In this same period, the average size of a California vegetable farm increased from 152 to 533 acres (see Figure 3-5). While the average size of farm is

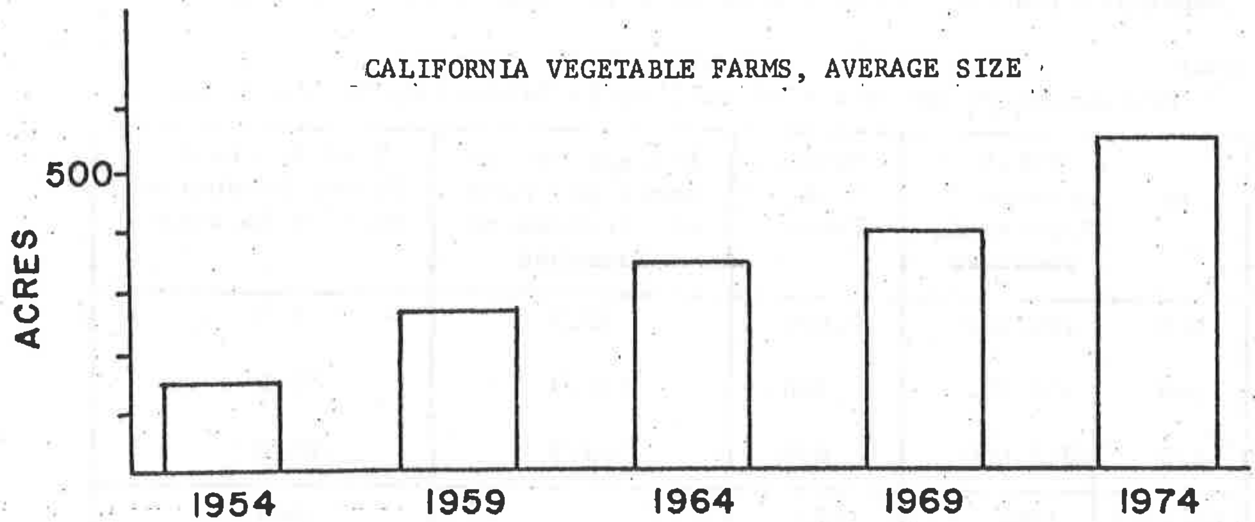

FIGURE 3-5

Table 3-5
Size Distribution of California Vegetable Farms
1974 Cropland Harvested

Size Class of Farms	Number of Farms in Size Class	% of Total Acreage in Size Class
1 - 49 acres	756	2.1
50 - 99 acres	176	1.4
100 - 199 acres	293	4.8
200 - 499 acres	336	12.9
500 - 999 acres	254	20.6
1,000 acres & over	233	58.0

Source: U. S. Bureau of Census 1974 Census of Agriculture Vol. 1 No. 5 California Table 33 an indicator of concentration, a more direct measure is shown in Table 3-5, which gives the size distribution of California vegetable farms. The table shows that the largest 233 farms harvest 58% of the cropland of all California vegetable farms.

Most cropland in vegetable farms is not owned by the farm operator. Approximately 70% of the land in vegetable farms in 1974 was leased (91).

In contrast to this, there are a large number of relatively small fruit and nut farms in California. The degree of concentration among these farms is much less evident that it is in the vegetable industry. There still is the trend towards fewer and larger farms.

The number of fruit and nut farms has dropped from 33,622 in 1950 to 22,286 in 1974, while the average size of fruit and nut farms increased from 66 acres to 113 acres (92). Both the rate of increase of the average size of fruit and nut farms, and the rate of decrease in the number of farms is significantly smaller than they are for Calfiornia vegetable farms.

The fruit and nut farms are also different in that they tend to be owner operated. Only 18% of the land in California fruit and nut farms in 1974 was leased.

E. Adoption of New Farm Technology

Technological change often involves more than the adoption of a single invention in a particular industry. It usually consists of adoption of a series of technological innovations, each of which is both cost and labor saving.

The advent of flash freezing in the processing industry led green pea growers to adopt the field-side vining station, then electric forks to feed the viners, and finally harvest combines (93).

The use of mechanical shakers in the prune harvest preceded adoption of catching frames and bulk handling in the Sacramento Valley (94). Adoption of mechanical shakers also preceded the use of pick-up machines and catching frames in the harvest of California almonds and walnuts.

Conversion to pallet bin handling occured simultaneously with the adoption of tomato harvest machines. Adoption of tank handling and electronic sorting then followed (see Figure 3-6).

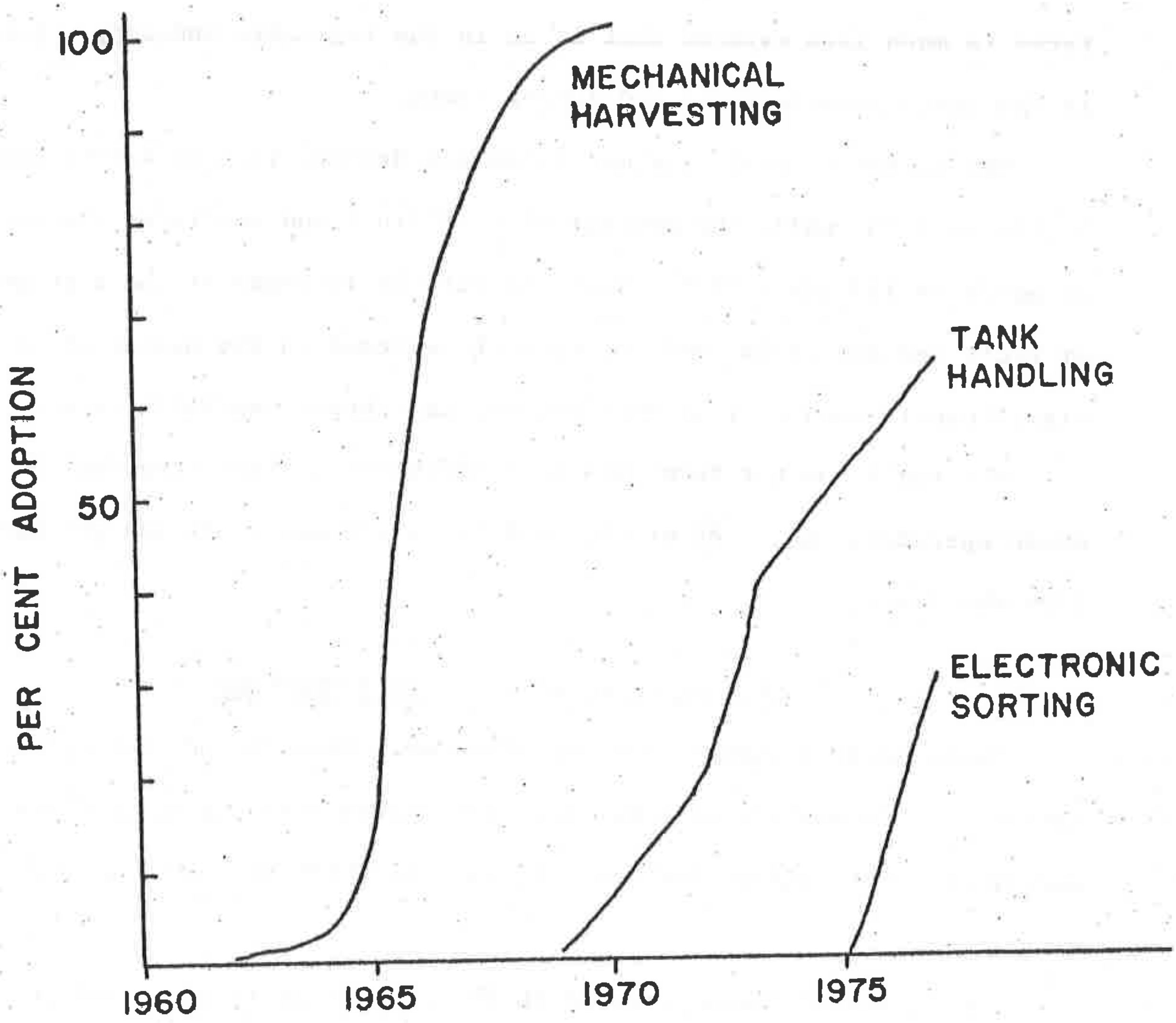

FIGURE 3-6

CALIFORNIA PROCESSING TOMATO FARMS, ADOPTION OF TECHNOLOGY

The general trend in farm technology has been towards higher capital cost and additional labor savings. It is a trend from tractor pulled harvest implements to self-propelled harvest machines, from the single row harvester to multiple row models. The term "harvest machinery" is generic. When discussing costs on labor displacing effects of harvest mechanization, this report will endeavor, wherever possible, to specify exactly which technology is involved.

Although the process of adopting new and often labor displacing technology is ongoing, it is during the period of harvest mechanization that most of the labor displacement occurs. By harvest mechanization, it is meant the substitution of a machine for the harvest workers' hands as the means to gather the crop. It is in this crucial phase, when farm operators adopt harvest machinery, that a large number of hand harvest jobs are eliminated, and a relatively few machine harvest jobs are created.

The adoption of harvest machinery at any given time can be described in terms of a percentage of total production (95). The change in adoption of "harvest machinery" in several areas has been graphed over time (see Figure 3-7). Harvest mechanization has occured in as few as two years for some crops, to as many as twenty years for others.

An average adoption rate can be calculated, and expressed as the average percent change in mechanization of production per year (see Table 3-6). This rate is change in adoption divided by years time, or the slope of the curves in Figure 3-7.

The adoption rate varies over time with the steepest slope (highest rate) at the adoption midpoint. The shape of the adoption curve varies from

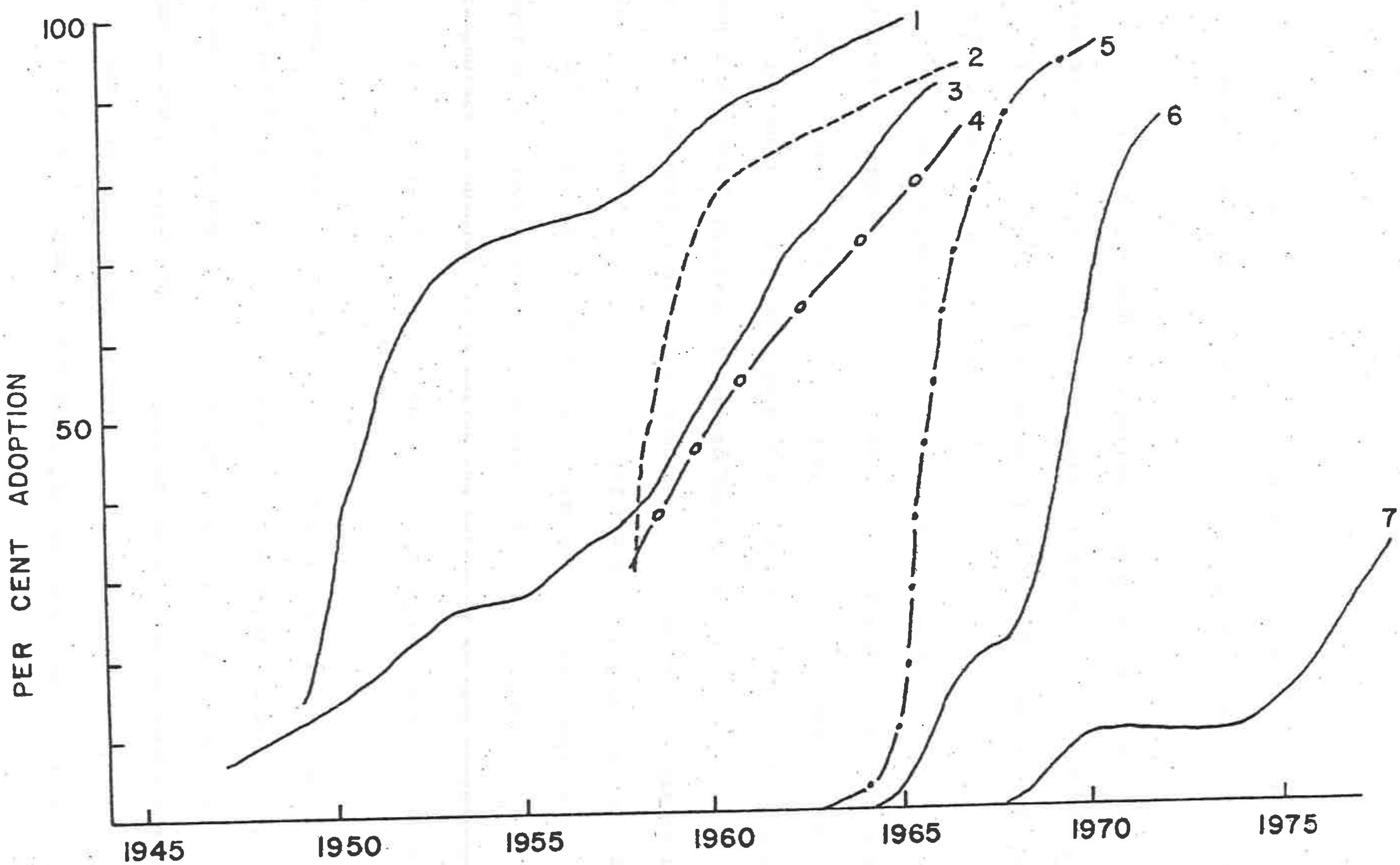

FIGURE 3-7

MECHANIZATION OF VARIOUS CROP HARVESTS

1 COTTON, CALIFORNIA 2 POTATOES, IDAHO 3 COTTON, UNITED STATES
4 POTATOES, UNITED STATES 5 PROCESSING TOMATOES, CALIFORNIA
6 PICKLING CUCUMBERS, MICHIGAN 7 CLINGSTONE PEACHES, CALIFORNIA

Table 3-6
Adoption Rates for Harvest Mechanization

Years Since Introduction	Portion of Production Machine Harvested	Average Adoption Rate (% per year)	Crop	Area	Sources
2 - 3	66%	22 - 33	Snap Beans	New York	(96,97)
5	95%	19.0	Processing Tomato	California	(98)
4	70%	17.5	Sugar Beet	California	(99)
7	90%	12.8	Pickling Cucumber	Michigan	(100)
7	80 - 90%	11.4-12.8	Prunes	Sacramento Valley, CA.	(101) (102)
14	100%	7.1	Sugar Beet	U. S.	(103)
15	90%	6.0	Cotton	California	(104)
20	90%	4.5	Cotton	U. S.	(105)
10	19%	1.9	Cling Peaches	California	(106)

sigmoid (California processing tomatoes) to much more irregular shapes which tend to have steeper slopes at mid-point, or the highest rate of adoption in the middle of the adoption period.

The rate varies among different crops, and among different areas producing the same crop as well. Since all production areas are not equally suited to harvest mechanization, the adoption of harvest machinery may proceed at a very rapid rate in one producing area, and at a much slower rate or not at all in other production areas.

With a dual adoption rate, the industry becomes dual sectored. The adoption period is one of competition between machine-harvest producers and hand-harvest producers. The rate of adoption of new technology depends on the economic viability of hand-harvest producers, and on the degree of cost savings that can be realized by mechanized producers. This is affected by the cost savings equation and by the ability of these producers to increase the scale of their operation.

Understanding these "adoptability factors" is of central importance in predicting the impact of harvest mechanization. While commercial application of new technology among several producers indicates that it is cost saving and integrated in the productive process, it is the adoptability factors which may allow a predictive estimate of the adoption rate.

Sociological studies of farm operators have sought educational and psychological explanations for the entrepreneur's decision to mechanize (107), (108). While these studies may explain which operators may mechanize, this report contends that the characteristics of indivual farmers have an insignificant impact on the rate of adoption of new technology in the California fruit and vegetable industry.

1. Expansion in Scale of Production

Conditions which allow producers to increase the scale of their operations such as a high demand for the commodity, or little competition from other production areas, favor a rapid rate of adoption. Conversely, the rate of adoption is slowed by conditions that limit expansion, such as over-production for demand, competition from low cost production areas, or government imposed production limitation.

Increased production accompanied mechanization of processing tomatoes in California. The market was expanding because of the increasing per capita demand for processed tomato products (109) and the adoption rate was rapid. Expansion of production has continued to the point where the industry has recently experienced several years of over-production and low prices. Rapid adoption of the snap bean harvester was also followed by increased production and low prices in New York state (110). Such price decreases compound the economic difficulties of the hand harvest sector.

A period of increased demand for cotton after World War II was cited by Street as a factor leading to mechanization (111). Ultimately, however, the market for cotton suffered from competition from low cost foreign producers and from the development of synthetic fibers. Producers could not expand production at all after acreage restrictions were set by the federal government beginning in 1951 (112). Acreage allotment was reported to have a "strong negative influence on the profitability of machine harvest (113)." These factors contributed to the slow adoption rate for cotton mechanization.

Rasmussen cites the changes in the sugar market caused by decreased competition from cane sugar producers during World War II, and the increased war-time demand as factors which favored harvest mechanization (114).

Declining domestic per capita demand for canned deciduous fruits, an export market which is declining due to competition from foreign producers, and supply control programs have prohibited producer expansion in California's cling peach industry. Productive orchard land declined 27.4% between 1969 and 1977. The adoption of shake-catch technology has proceeded at a very slow rate. Adoption was especially slow when the California state "green drop" program regulated production (1969-72).

Mechanical harvest of prunes has also proceeded slowly. Declining markets and production controls are factors which could explain this slow adoption rate.

2. Competitive Position of the Hand Harvest Sector

The adoption rate is also affected by the persistence of a hand-harvest sector in a mechanizing industry. Hand harvested producers may enjoy some special cost advantages over the mechanized producers in a given industry. Eastern processing tomato growers have been able to persevere in the face of low cost California competition because they are closer to market, and processing labor wages are lower than in California (115).

Table 3-7
Cost Savings of Harvest Mechanization as a Portion of Harvest Costs and Total Costs of Hand Harvested Producers

Crop	Area	Year	Technology	Cost Savings (S) as % of: Harvest Costs	Total Costs	Adoption Rate (% per year)	Sources
Carrots	Texas	1967	Pull Type Harvester	62.9	--	--	(116)
Snap Beans	New York	1957	Harvester	61.2	33.0	22 - 33	(117)
Sugar Beets	Calif.	1952	Two Row Harvester	56.8	--	17.5	(118)
Processing Tomatoes	Calif.	1965	Harvester	42.5	--	19.0	(119)
Cotton	Calif.	1949	Harvester	41.8	13.2	4.5	(120)
Potatoes	Idaho	1957	Two Row Harvester	38.6	--	--	(121)
Cling Peaches	Calif.	1973	Shake-Catch	33.0	7.1	1.9	(122)
Prunes	Napa Co. Calif.	1958	Pick-up Machine	25.0	--	--	(123)

Cost savings are based on the assumption that mechanized producers has average yield, operation costs, and sufficient scale for mechanized production. Adoption rates are from Table 3-6.

The operators of fruit and nut ranches may have already fully depreciated the costs of establishing their hand harvested vineyard or orchard, giving them a compensating cost advantage over newly established mechanized operations. This may explain, in part, the slow rates of adoption observed in the older producing areas of these crops.

Factors that increase the costs savings tend to put the hand harvest sector at a competitive disadvantage. If the cost savings are a great part of production costs, strong incentives exist for rapid adoption (see Table 3-7). The data suggest rapid adoption rate and great cost savings are roughly correlated.

The wage rate of hand harvest workers can affect the value of the labor savings. Rising wage rates may be a factor influencing the rate of adoption. This might be especially true in industries where a significant portion of production costs are harvest labor. With the exception of the influence of unionization (discussed in Chapter IV) the factors which affect rising wage rates are outside the scope of this study.

F. Conclusions

There are two concepts which describe the necessary preconditions to the adoption of new fruit and vegetable harvest technology. Integrated technology must be developed and proven before the harvest can be successfully mechanized. This new technology involves cultivating the crop so that it is adapted to machine harvest. It also involves new ways to handle and process the crop. Often these changes extend onto the table of the consumer.

The second concept is the substantial cost savings of technology. The harvest machine must save enough labor to pay for itself, for the direct costs of ancillary technology, and for any reduction in the value of the crop caused by mechanized harvest. Other costs of mechanization are borne by other segments of the industry, or by society as a whole.

The rate of adoption of new harvest technology is often quite rapid. California's processing tomato industry mechanized in about 5 years (124). Even the relatively slow adoption rate of cotton harvest mechanization proceeded at the historically rapid rate of 20 years (125)(126)(127).

A complicated series of factors affects the adoption rate in a particular locale. They include demand for the commodity, competition from other producing areas, controls on production, and the economic viability of the sector of the industry still using hand-harvest. The latter factor, the competitive position of hand-harvest producers, is dependent on the degree to which mechanization can cut costs, and on the cost and availability of hand-harvest labor.

There are social consequences characteristic of a mechanizing industry. Production often becomes concentrated in certain areas, and within those areas, among a few producers who have increased the scale of their farm operation. Mechanization leads to a decrease in the number of farm operators in an industry. It also results in a sharp decline in the employment of farm workers. This occurs first in areas which are being mechanized, and later in areas where production declines due to the non-competitive position of hand-harvest producers.

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80. Jack Hayes "California's Dynamic Tomato Industry Part I- Today" <u>American Vegetable Grower</u> March 1973

81. A vegetable farm is defined as a farm with farm product sales in excess of $2,500 per year, and deriving 50% or more of total sales from vegetables and melons.

82. U. S. Bureau of Census <u>1954 Census of Agriculture</u> Economic Area Table 4

83. U. S. Bureau of Census <u>1974 Census of Agriculture</u> Table 33

84. Ibid.

85. Ibid.

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88. William H. Friedland, Amy Barton "Tomato Technology" <u>Society</u> September/October 1976 Vol. 13, No. 6

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figure is different from percentage of total production if machine harvest had different per acre yields from hand harvest.

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110. How and Nyberg, op cit. page 2, 25

111. Street, op cit p. 83

112. Ainsworth, op cit. p. 29

113. Hedges and Hoover, op cit.

114. Rasmussen "Technological Changes in Sugar Beet Production" op cit p. 33

115. "California and the Tomato Market" <u>California Farmer</u> March 20, 1971

116. Sorenson op cit.

117. How and Nyberg, op cit.

118. Bailey, op cit

119. Phillip S. Parsons "Costs of Mechanical Tomato Harvesting Compared to Hand Harvesting" California University Agricultural Extension Service Publication AXT-224 (May 1966)

120. Hedges, 1950 op cit.

121. Jones, op cit.

122. Verner S. Grise, Stanley S. Johnson "An Economic Analysis of Cling Peach Production with Emphasis on Harvest Mechanization" U. S. Economic Research Service Agricultural Economics Report No. 240 (38 p. Washington, D. C., 1973)

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125. John R. Elliot "Cotton Harvest Mechanization Effect on Seasonal Hired Labor" U. S. Bureau of Employment Security (BES 209) (17 p. Washington D. C. 1962)

126. "Cotton Production and Mechanization" <u>Farm Labor Market Developments</u> July 1964 U. S. Dept. of Labor

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CHAPTER IV

THE IMPACT OF MECHANIZATION ON THE FARM LABOR FORCE

A. Impact on Farm Labor Demand

New harvest technology increases farm labor productivity. The operator of a cotton harvest machine can pick as much cotton in an hour's time as can a hand-harvest crew of 25 to 30 (1). With a two row machine operating at full capacity, the operator can produce as much as nearly 100 workers (2). On electronic sorter equipped tomato harvesters, the output per sorter worker is 4 tons per hour (3). An excellent hand picker could harvest only .24 tons per hour (4).

Harvest mechanization eliminates all hand-harvest jobs and replaces them with fewer jobs in the operation, maintenance, repair, and manufacture of harvest machines. The cost savings equation indicates why there are fewer jobs with harvest mechanization. For the cost savings to be realized, the cost of hand-harvest labor is greater than the total costs of mechanization. Only a small part of the costs of mechanization is the cost of labor to manufacture, operate, and maintain machines. Farm equipment manufacture can be geographically remote from the area where hand harvest workers have been displaced.

With the elimination of hand-harvest work, new machine harvest work is created. This work involves far fewer workers. It is of a different skill level, and is often performed in different production areas, by a different work force. The net effect on the farm labor market is a reduction in labor demand.

The net reduction in harvest labor demand per unit of production can be calculated by comparing the productivity of hand and machine harvest workers. It can be expressed as a percentage displacement of hand-harvest labor (5). Calculating this percentage is useful, for it isolates the impact of machinery on employment (see Table 4-1).

Table 4-1
Mechanization and Net Reduction in Harvest Labor Per Unit of Production Caused by a Change in Worker Productivity

Crop	Area	Year	Net Reduction in Demand	New Technology	Source
Carrots	Texas	1967	66-74%	Tractor pulled harvester	(6)
Cotton	Calif.	1949	92-93%	Self-propelled picker	(7,8)
Potatoes	U. S.	1959	50-66%	Two row towed combine	(9)
Processing Tomatoes	Calif.	1965	31-74%	Self-propelled harvester	(10)
Sugar beets	Calif.	1952	67-82%	One row hand sort harvester 2 row spike wheel harvester	(11)

Farm labor demand in California is estimated and recorded by the state Employment Development Department (formerly the Department of Employment) in its Farm Labor Report 881-A. While there are some reasons to question the precision of the Report's data, it is the only detailed historical source of data on California farm employment.

The simplest estimate of the relative importance of different harvests to farm labor employment is peak harvest employment, the maximum number of workers employed in the harvest at any given reporting week of the year. For many California crops, peak harvest does not occur simultaneously in every production district. In these crops, there may be many more individuals in the harvest labor force than workers employed at peak harvest. Peak harvest employment does not give any indication of the duration of harvest time work, which varies considerably among various fruit and vegetable crops.

With these cautions in mind, peak employment in the harvest of selected California crops has been graphed over time. Each graph represents a labor market substantially influenced by mechanization. In each graph, there is an identifiable period in which the peak harvest labor has declined (see Figures 4-1 through 4-8). A period of decline in labor demand was defined for a number of crops. Three year averages in peak harvest employment were calculated for the years prior to and directly following the indicated period of reduction, allowing a calculation of the change in average peak harvest work force (see Table 4-2).

Table 4-2
Periods of Reduction in California Farm Employment

Crop	Period of Reduction in Labor Demand	Net Reduction in Avg. Peak Labor Demand	% Change in Avg. Peak Labor Demand
Cotton (pick)	1949 - 66	86,510	-89.1
Tomatoes	1964 - 69	24,130	-49.7
Prunes	1957 - 67	17,237	-55.6
Apricots	1966 - 72	11,197	-50.4
Cotton (chop)	1963 - 70	9,620	-53.8
Walnuts	1958 - 67	7,134	-51.1
Potatoes	1959 - 68	5,833	-77.0
Snap Beans	1962 - 69	6,647	-87.5
Almonds	1961 - 66	4,980	-55.1
Hops	1958 - 68	2,657	-87.1
Carrots	1959 - 66	3,063	-79.9
Figs	1958 - 75	2,113	-67.4

COTTON, PEAK HARVEST EMPLOYMENT, CALIFORNIA

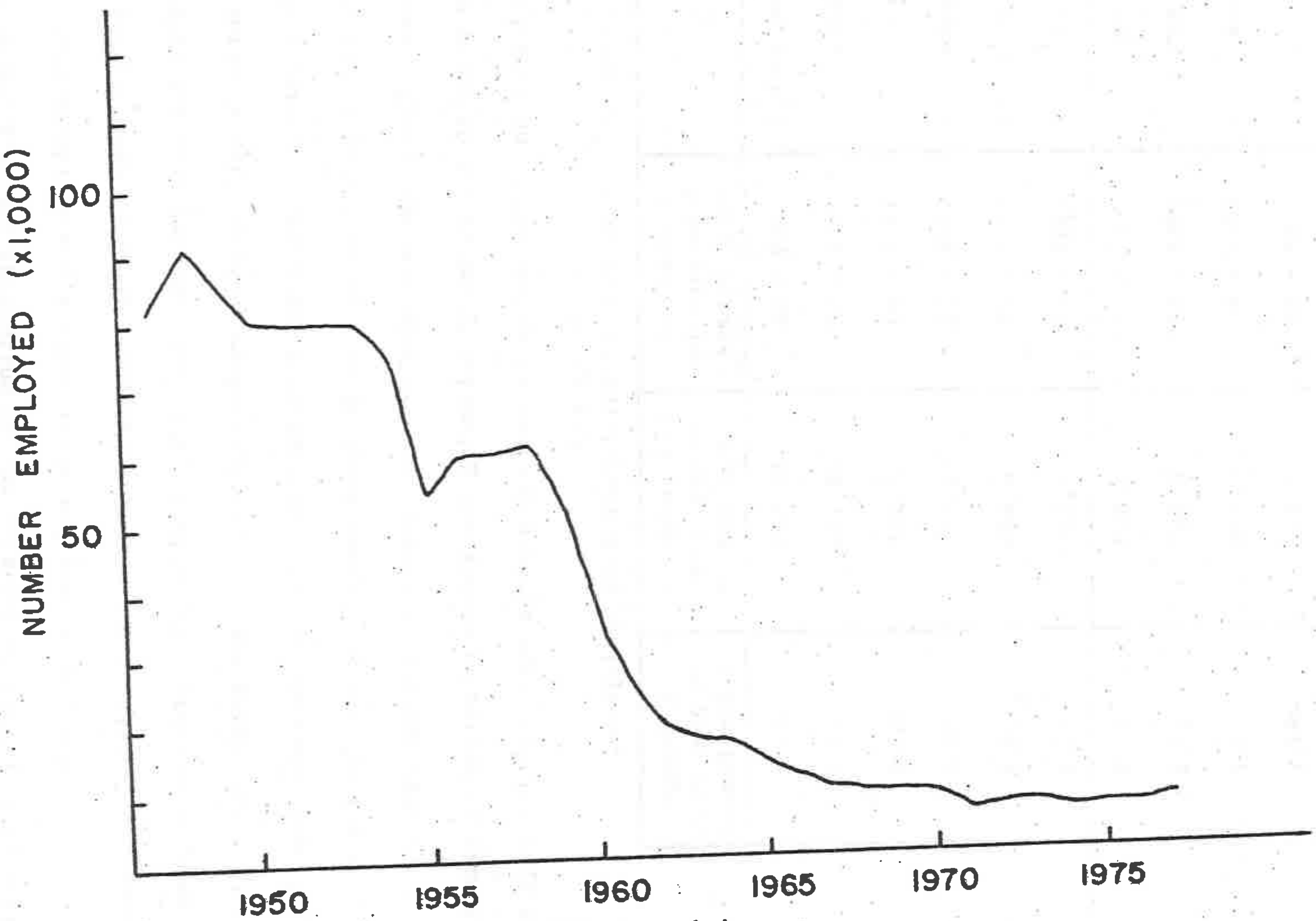

FIGURE 4-1

TOMATOES, PEAK HARVEST EMPLOYMENT
CALIFORNIA

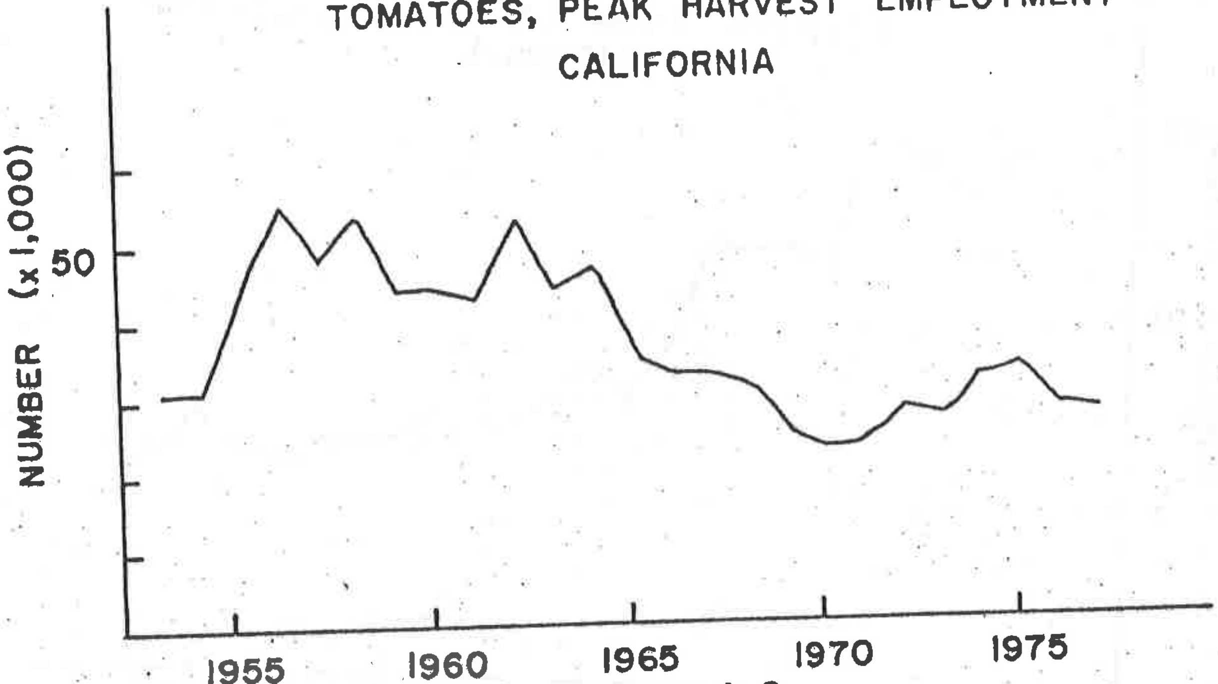

FIGURE 4-2

PRUNES, PEAK HARVEST EMPLOYMENT
CALIFORNIA

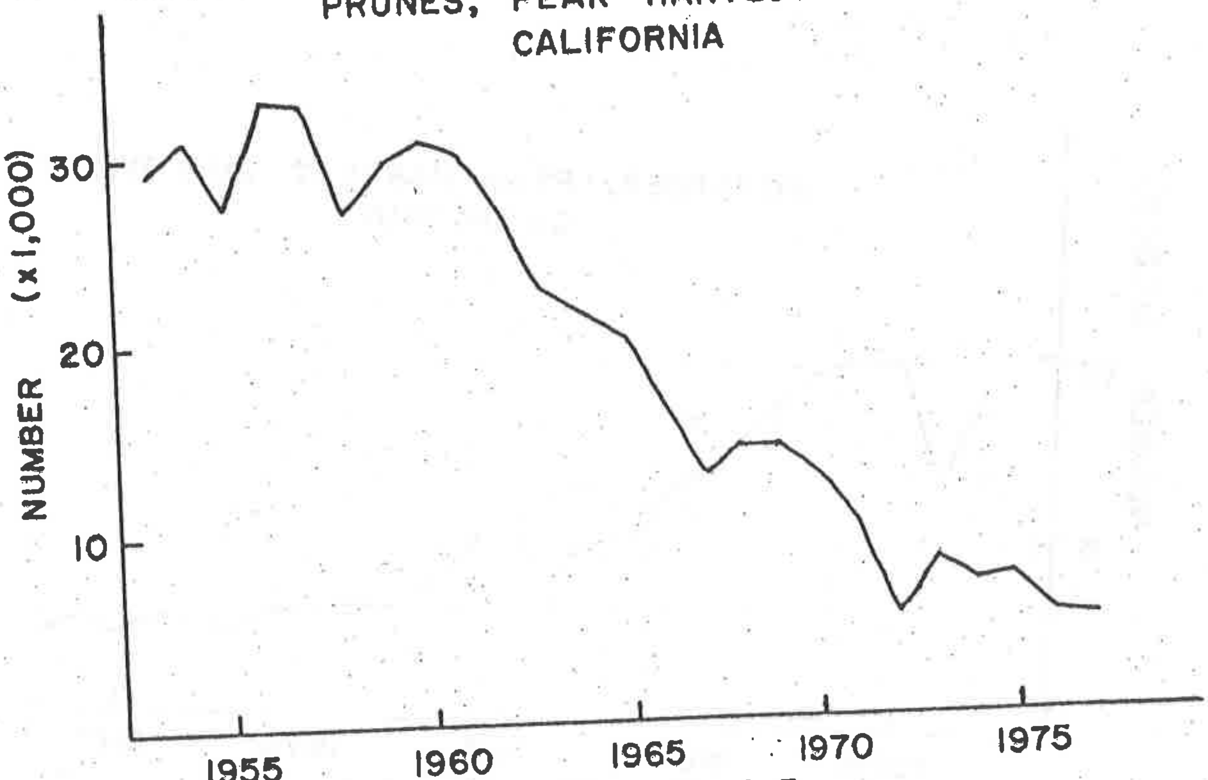

FIGURE 4-3

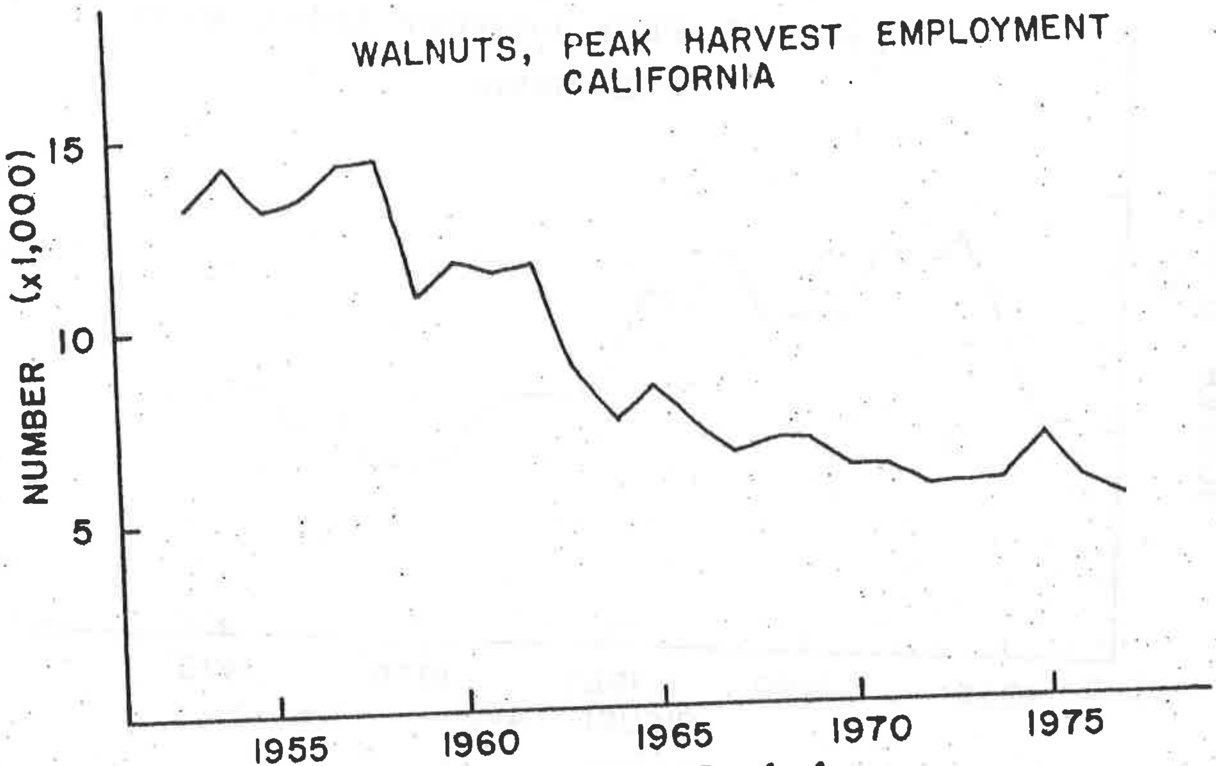

FIGURE 4-4

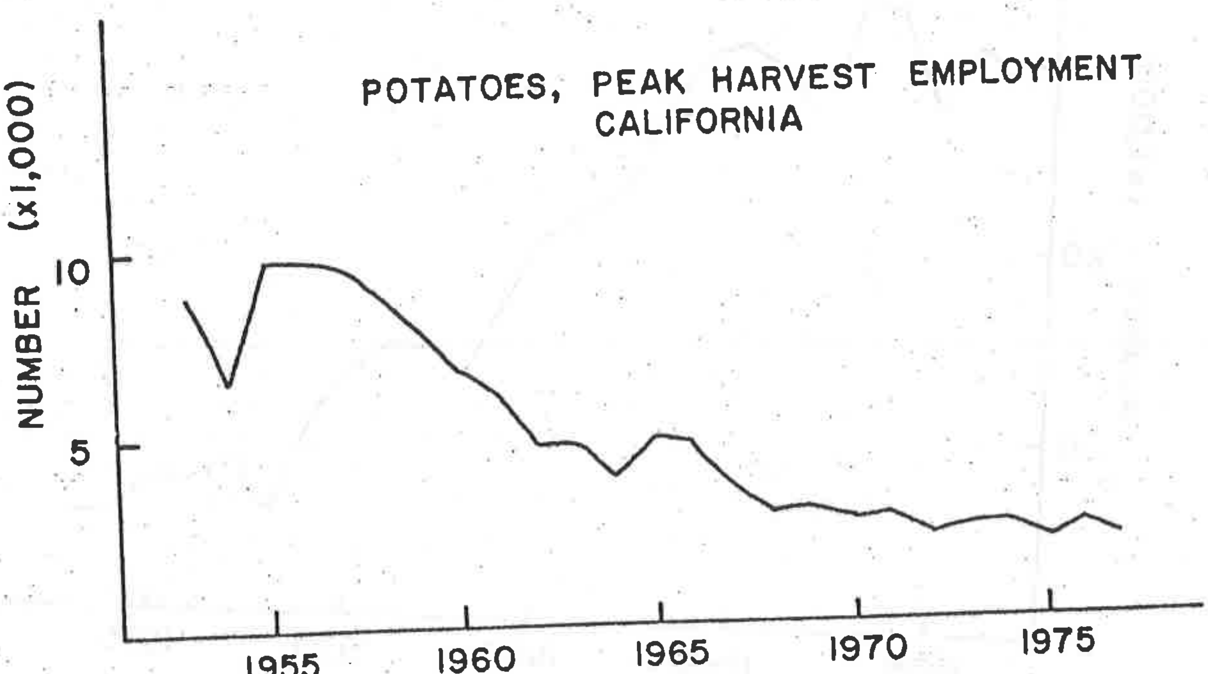

FIGURE 4-5

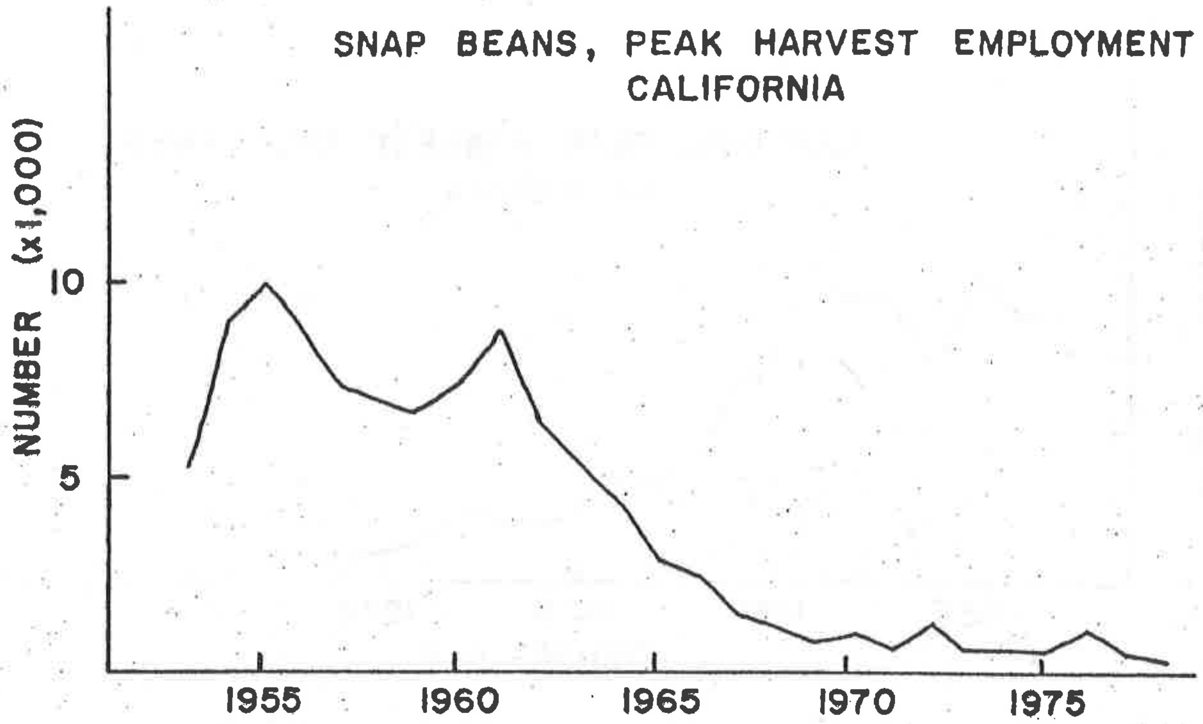

FIGURE 4-6

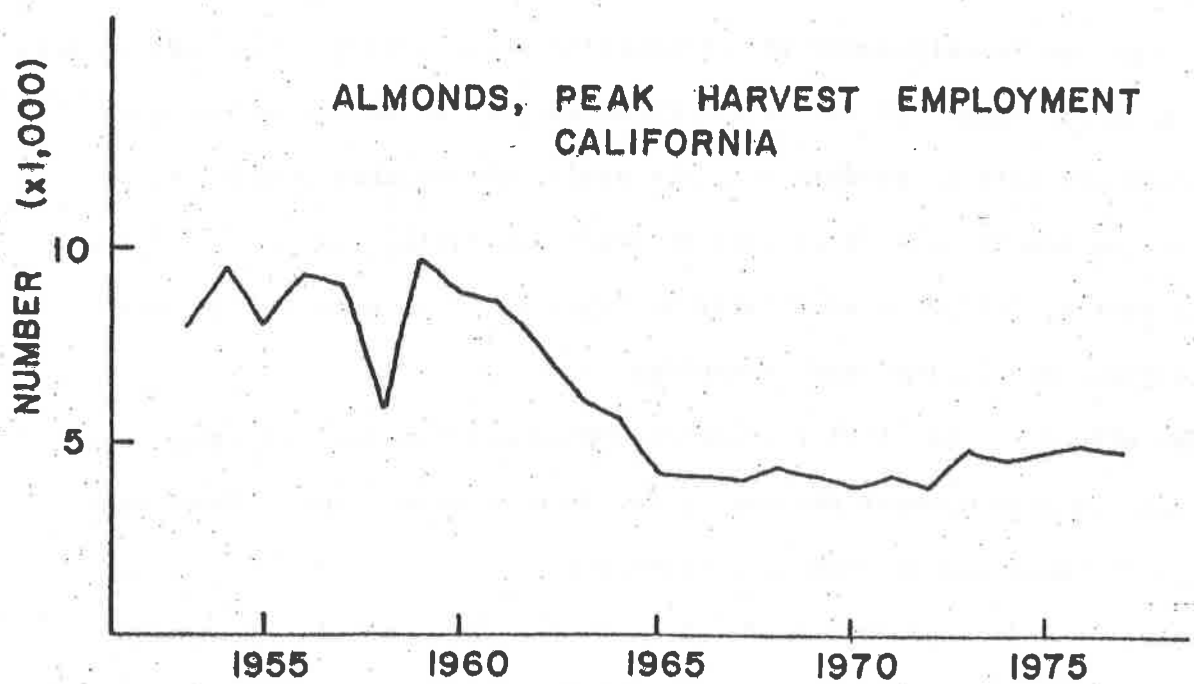

FIGURE 4-7

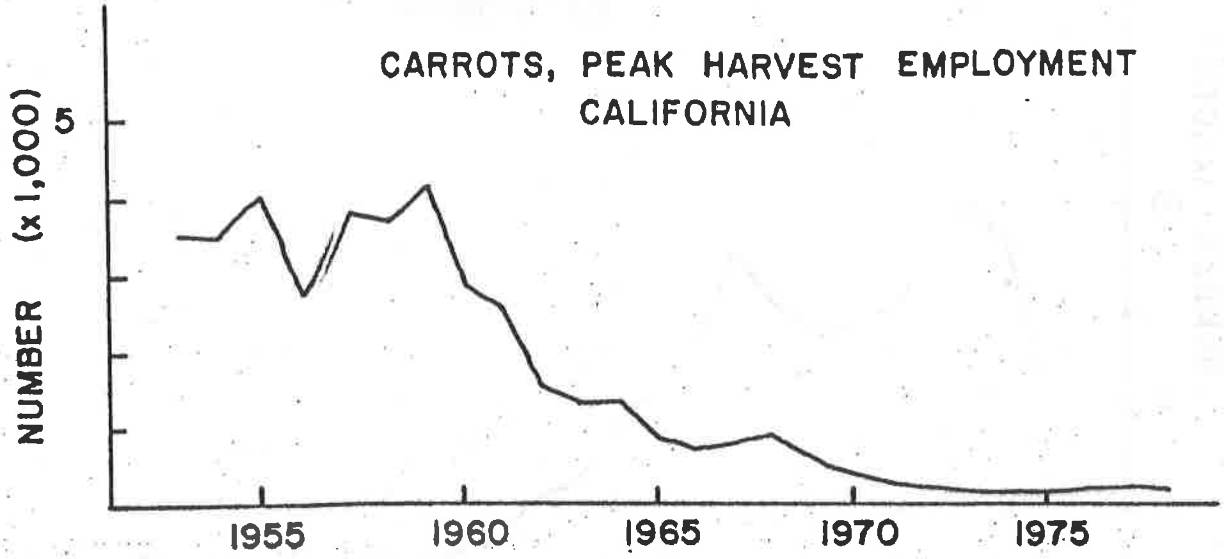

FIGURE 4-8

Part of the change in labor demand for the harvest of a given crop is attributable to the change in the number of acres of the crop harvested. This change can be calculated from production reports (12). The rest of the change in labor demand is due to all other factors which may affect peak employment per acre of production: the yield, the weather conditions at harvest, the concurrence of production among districts, the length of the harvest season, and the productivity of labor as it is affected by work organization, pay scales, and technology.

The effect of the other factors on employment can also be considered the change in peak harvest employment per acre of production. Three year averages in harvested acreage were calculated for the years prior to and following the indicated period of reduction in labor demand. Change in harvested acreage and change in peak harvest work force per acre harvested are given in Table 4-3.

Table 4-3
Factors Affecting Employment in Periods of Reduction in California Farm Employment

Crop	Period of Reduction in Labor Demand	% Change in Acreage Over Period	% Change in Peak Harvest Demand per Acre	Technology Adopted in Period
Cotton (pick)	1949 - 66	-17.5	-86.8	harvester
Tomatoes	1964 - 69	+12.7	-55.4	harvester for processing crop
Prunes	1957 - 67	+9.4	-59.4	shake-catch, pick-up machine
Apricots	1966 - 72	-20.3	-37.8	cutting machine in drying yards
Cotton (chop)	1963 - 70	-3.7	-52.0	herbicides and cultivators
Walnuts	1958 - 67	+18.7	-58.8	mechanical knock, catch, pick-up
Potatoes	1959 - 68	-17.4	-76.0	harvester
Snap Beans	1962 - 69	+28.3	-90.3	harvester
Almonds	1961 - 66	+41.3	-66.2	mechanical knock, catch, pick-up
Hops	1958 - 68	-73.8	-50.8	viner
Carrots	1959 - 66	+4.9	-80.8	topper-digger
Figs	1958 - 75	-34.1	-50.5	pick-up machine

The change in peak harvest workers demanded per acre may be interpreted as being a function of seasonal variations in weather, or of changing production practices. The effect of seasonal variations on net reduction in labor demand has been minimized in the table by the use of three-year averages for employment and production. The change in workers required per acre harvested tends to reflect only the change in production practices such as new varieties, more efficient organization of tasks, new handling systems, and harvest mechanization and other new technologies. As would be expected, the changes in production practices have had substantial impact on employment.

Increasing acreage has lessened somewhat the severity of employment decline caused by changing production practices in crops such as almonds, snap beans, walnuts, tomatoes, prunes, and carrots. Decreasing acreage has compounded the employment decline in cotton, apricots, potatoes, hops, and figs.

In the period of employment change for all of these crops except hops, the effect of changing production practices had far more impact than the changes in acreage. The declining acreage itself may reflect the impact of mechanization. California was slow to mechanize the potato harvest, and lost acreage to more mechanized states (13).

Declining production of a crop that is not mechanically harvested can come as a result of mechanization and technological change. The use of flash freezing, pea viners, and combines to produce frozen peas all but eliminated the market for fresh market peas (see Table 4-4).

Table 4-4
Average Acres of Green Peas Harvested

Period	For Fresh Market		For Processing		Total U.S. Production
	Calif.	U. S.	Calif.	U. S.	
1934 - 43	12,820	95,780	3,310	333,030	428,810
1944 - 53	10,379	24,806	7,914	429,276	454,082
1954 - 63	5,530	8,199	9,020	409,262	417,461
1964 - 73	2,000	2,125	9,180	417,262	419,387

Source: U. S. D. A.

An acre of fresh market peas requires 90 hours of labor to harvest, while processing peas require only 6.5 hours (14). The decline in California fresh market pea production reduced harvest labor requirements by approximately one million worker hours per year, while harvesting the increased processing pea acreage requires only an additional 40,000 worker hours per year.

B. Impact on Farm Labor Supply

Concurrent with the sudden sharp contractions in farm labor market demand come periods of labor surplus in specific farm labor markets. In times of low unemployment and rising wages, there is increased mobility of agricultural workers into the non-agricultural sector, and the possibility that workers displaced by new technology can find a job (15).

Yet harvest mechanization is more often associated with high levels of unemployment. The most dramatic example of this was the industrialization of Southern agriculture through adoption of tractors, cotton strippers and harvest machines, and the reductions in cotton acreage imposed by the federal government.

A labor surplus was created by the cotton allotment program before the adoption of harvest machines (16). Street found that in many cotton belt areas "total mechanization pushed its way in" despite a relatively abundant labor supply (17).

"The potential impact of adopting mechanical pickers is indicated by the fact that the smaller-sized picker can harvest an acre of cotton in six man hours compared to 74 man hours of hand labor," noted Dillingham and Sly.

"The tenant laborer is supporting more than 4 other family members. These figures make it possible to understand how the presence of a hundred mechanical pickers in a county could lead to the emigration of several hundred, and even thousands of persons (18)."

When harvesters were adopted in the 1950's, Elliot noted that peak employment in the U. S. cotton harvest dropped 250,000 workers, or 26%, between 1959 and 1961, with the greatest rate of displacement in the Far West. In this same time, the number of work-weeks of cotton harvest employment dropped from 7.6 to 5.4 million work-weeks, or 30% (19). The greater decline in work-weeks meant that the remaining cotton harvest workers worked 5% fewer work-weeks in a year.

Annual average employment of cotton workers declined 68% between 1960 and 1966, and was a dominating factor in the 18% decline in the employment of farm labor in the U. S. over that period (see Table 4-5).

Table 4-5
Annual Average Employment of Seasonal Hired Workers
Cotton and All Crops -- U. S. 1960 to 1966
(Thousands of Workers)

Year	All Other Crops	Cotton	Total All Crops	Cotton Employment as % of Total Employment
1960	550.5	212.1	762.6	28
1961	549.1	190.3	749.4	25
1962	549.4	157.5	706.9	22
1963	536.1	139.1	675.2	21
1964	576.0	129.3	705.3	18
1965	571.6	101.4	673.0	15
1966	553.7	68.5	622.2	11

Source: Ainsworth "Causes and Effects of Declining Cotton Employment" Farm Labor Developments Sept.-Oct. 1967

The mechanization of the harvest was strongly correlated with displacement of Negro tenant farmers (20). The cotton producing states of Arkansas, Mississippi, Alabama, and South Carolina had high rates of outmigration in the decade of the 1950's, which Ainsworth attributes to declining labor needs in cotton (21).

Despite increases in acreage, mechanization of the snap bean harvest eliminated 2,200 jobs in a 2 year period on mechanized farms surveyed by the New York State Department of Labor. While it was not discovered how much employment declined on hand harvested farms, the study reports that "there was a good deal of underemployment among the hand pickers during the bean season. Many more of them during 1958 were sharing the total harvest work with the mechanical bean picker and therefore, worked considerably fewer hours (22)."

A reduction in sugar beet cultivating labor demand, brought about by adoption of mono-germinating seed, displaced workers in Ohion in 1961. Migrant workers had to borrow money or get aid from relief agencies (23). In a two year period harvest mechanization eliminated 31% of the work in the Idaho potato harvest, 27% in Oregon, and 26% in North Dakota (24).

The adoption of electronic sorters on harvest machines was reported to have displaced 50% of the tomato harvest workers in Yolo County, California between 1975 and 1977 (25). The remaining workers were underemployed, working 20 hours a week instead of the customary 50 or 60.

Metzler surveyed farm workers in Kern and Stanislaus Counties in California, and assessed the impact of cotton and potato harvest mechanization, and the reduction in labor demand for cotton chopping. "Mechanization of cotton and potato operations is changing the migratory labor patterns over much of California," observed Metzler. "The major basis of the pattern in the past has been the prospect of from 5 to 6 months of work in the cotton fields followed by several months work in the deciduous fruit orchards. As the use of hand labor in the cotton fields is eliminated that pattern cannot continue, only the few workers who can obtain employment in pruning will be able to maintain themselves on a year round basis (26)."

Mechanization of the cotton harvest in Kern County eliminated 25,000 picking jobs between 1949 and 1969. It also resulted in the progressive curtailing of the work year for seasonal employees (27), and a shift in the peak season from early fall to late spring. The county changed from an area with seasonal inmigration of cotton pickers, to one with seasonal outmigration of its residents. Half of the outmigration occured during the cotton harvest, when cotton picking had provided income in the past (28). Officials of the Kern County Public Welfare Department stated that seasonal needs for public assistance mounted as displacement progressed (29).

The impact of cotton mechanization was also felt by workers in areas that did not grow cotton. More than 2/3 of the heads of households surveyed in Stanislaus County reported that they had worked in the cotton harvest in the past, but by 1962, few found any more work picking cotton (30). The survey showed that underemployment was prevalent among fruit and vegetable workers. Though 3/4 of the Stanislaus County domestic farm workers travelled to find seasonal work in other areas, they averaged only 129 days of work per year (31).

C. Impact on Work Place

Mechanization has other effects besides the displacement of most harvest time workers. Not only does the harvest labor market become smaller, but the character of work is transformed as well. Changes occur in the methods of pay, working conditions, and the tasks of the harvest worker.

Contrary to a popular notion that farm work is unskilled, hand-harvest workers often develop special skills and specialize in the harvest of a certain crop or group of crops(32). They are usually paid a piece rate (by the bucket, box, bin, etc.) which makes their wage proportional to their productivity (33).

Harvest machine operators are usually paid on an hourly basis, as are the sorter workers employed on tomato, potato, and peach harvesters. While it would be theoretically possible for these remaining harvest workers to enjoy increased wages, the oversupply of labor caused by displacement can cause a drop in their per-hour earnings (34).

The changes in the tasks in the harvest job can cause substantial changes in the character of the farm labor force. While hand-harvest of processing tomatoes required the lifting of 50 lb. lug boxes, there was no lifting required on the harvest machine. The elimination of the lifting requirment allowed women workers to work the harvest. According to Friedland and Barton, "the characteristics of the harvest labor force have changed drastically from male to female, from Mexican national to American, from migratory to settled (35)." Their observations are confirmed by comparison of surveys of Yolo County tomato workers in 1966 (36) and again in 1977 (37).

While the sorting work is less strenuous that hand-harvest work, the hazards of machine sorting on a potato harvester were reported to be more dangerous than hand work, according to Elliot. He relates a state agency report that "these people have to be alert to the dangers of the machines as there is always the chance of getting a finger, hand, or piece of clothing caught in chains, gears, lags, or belts (38).

The impact of mechanization on job safety was described by the California state Department of Industrial Relations in its 1966 report on agricultural job safety: "There has been an upward trend of injuries involving mechanical harvesters and pickers, reflecting the increased mechanization of the harvest. When farm machines are used in large numbers, the spector of serious injury is alway present. The table below compares the trend of mechanical harvesting equipment injuries with all lost-time agricultural injuries during the past 10 years (39)" (see Table 4-6).

Table 4-6
Lost Time Agricultural Work Injuries
California

Year	Total Injuries	Injuries Involving Harvest Machinery*
1956	16,672	221
1957	16,165	231
1958	15,841	243
1959	17,883	214
1960	17,121	219
1961	16,724	237
1962	16,104	253
1963	16,474	226
1964	16,022	255
1965	15,843	285
1966	15,325	318
% change 1956-66	-8.1%	+43.9%

Source: California. Dept. of Industrial Relations
Division of Labor Statistics

* includes harvesters, combines, diggers, and pickers

The fact that machine can be paced and controlled by a centralized decision maker is seen by Braverman as being as important to management as the fact that the machine increases labor productivity. Writes Braverman, "Machinery offers to management the opportunity to do by wholly mechanical means that which it had previously attempted to do by organizational and disciplinary means (40)."

A crucial aspect of this control is the role of farm mechanization in evading unionization. Migrant workers who harvested cucumbers were organized by the Obreros Unidos in Wisconsin in 1967. When they voted in favor of union representation at Libby, McNeil and Libby, the area's largest grower, the company announced its intention to mechanize its entire harvesting operation, and refused to negotiate any further with the union. The union filed an unfair labor practice, charging that there was no overwhelming economic justification for mechanization, that it was done only to evade unionization. The Wisconsin Employment Relations Commission disagreed, saying the decision was economic. The Commission allowed that Libby should have negotiated the mechanization issue before making its decision. As redress, Libby was to give preference to displaced workers when hiring machine harvest operators. Though the union had secured the right to represent Libby employees, the union's membership was eliminated by the mechanical harvester before the first contract was signed (41).

The United Farmworkers of America AFL-CIO (UFW) has been enjoying some recent successes in organizing California farmworkers. At a unionized wine grape ranch in California's central coast, a work stoppage was called to protest adoption of a mechanical harvester. A state mediator ruled that the

the company had not violated the mechanization clause of the labor contract by using the harvest machine (42).

Processing tomato workers in Yolo and San Joaquin Counties in Northern California went on strike in August of 1974. Since the enactment of the Agricultural Labor Relations Act, the UFW has been elected bargaining representative at a number of tomato farms. The adoption of electronic tomato sorters has eliminated much of the harvest time work in the processing tomato industry, and no collective bargaining agreements have been reached. A group of Stockton area tomato farmers came close to reaching an accord with the union, with mechanization the major unresolved issue. Despite a strike against one of the growers in the group in 1977, no contract was signed.

A strike and lockout at one fresh market tomato grower-shipper company in the Salinas Valley in 1977 resulted in a representational election. The workers voted in favor of the union. The next year, a majority of the harvest jobs had been eliminated by production cut backs and mechanization. The UFW filed an unfair labor practices charge with the Agricultural Labor Relations Board, alleging that the switch to mechanized harvest was not cost saving but a move to evade unionization.

Recent interviews with farm workers in Imperial and Fresno Counties in a study by the California Commission on the Status of Women give a clue as to worker perceptions of mechanization. Most of the farm workers who answered in Fresno felt that machines had affected the crops in which they work, while most Imperial respondents did not feel that machines had an impact. Many of those who felt there was impact indicated that they'd rather work without machines (43).

Notes.

1. John R. Elliot "Cotton Harvest Mechanization. Effect on Seasonal Hired Labor" U. S. Bureau of Employment Security BES 209 (Washington 1962 17 p.)

2. William H. Metzler "The Farm Worker in a Changing Agriculture: Part 1 in a series on Technological Change and Farm Labor Use, Kern County, California, 1961" California University. Giannini Foundation Research Report No. 277 (September 1964)

3. Mel Zobel "Machine Harvesting Cost Study" California Tomato Grower May 1978

4. Phillip S. Parsons "Costs of Mechanical Tomato Harvesting Compared to Hand Harvesting" California University Agricultural Extension Service AXT 224 May 1966

5. The next reduction of harvest labor demanded per union of production caused by a change in worker productivity (**R**) is calculated as follows:

$$R = \frac{P_h}{P_m} - 1$$

where P_h = productivity of hand-harvest workers in tons/hr.

P_m = productivity of machine harvest workers in tons/hr.

6. H. B. Sorenson, J. D. McNease, G. R. Power "Labor Requirements for Harvesting Texas Carrots" Texas Agricultural Experiment Station, College Station 1967 11 p. MP 826

7. W. R. Bailey, Trimble Hedges "Economics of mechanical cotton harvesting in the San Joaquin Valley 1949" California Agricultural Experiment Station. Giannini Mimeograph Report 111 (48 p., January 1951) Calif. A. E..S. Bulletin No. 743

8. John R. Elliot "Cotton Harvest Mechanization . . ." op cit

9. John R. Elliot "Potato Harvest Mechanization: Effect on Seasonal Hired Labor" U. S. Bureau of Employment Security BES R-204 (Washington 1961 21 p.)

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CHAPTER V

ADOPTION OF NEW HARVEST MACHINES

The process of harvest mechanization continues to displace hand-harvest workers. The purpose of this study is to identify the technologies which will have a major impact on the future farm labor force. Several criteria have been used to select technologies for the detailed study which makes up the bulk of this chapter.

Commodities were ranked according to the amount of employment they provide to California farm workers (see Table 5-1). Only those commodities that have harvest labor markets of 40,000 work-weeks or more were considered for study.

The historical analysis indicates that mechanization occurs only if it is cost saving and integrated into the production process. While the successful test of a prototype may indicate that cost savings are theoretically possible, this study regards commercial adoption of new technology as the only accurate guide to its feasibility. Reports on the mechanization of the commodities with large labor markets were analysed. Thirteen commodities were selected for study on the basis of meeting any one of three indicators of commercial feasibility:

1). Commerical adoption of new harvest machines in California (Apples, Apricots, Raisin Grapes, Wine Grapes, Olives, Peaches, and Processing Tomatoes).

2). If new harvest machines are not in use in California, then their commerical adoption in other states of the U. S. (Asparagus, Celery, Cucumbers, Cherries).

Table 5-1
Job Opportunities in California Fruit and Vegetable Harvest

Crop	Thousand of work-weeks of Harvest Employment
Strawberries	323.1
Grapes, Raisin	240.7
Tomatoes, Processing	215.5
Lettuce	215.5
Grapes, Wine	192.9
Oranges, Navel	155.6
Grapes, Table	143.0
Lemons	142.5
Tomatoes, Market	128.7
Oranges, Valencia	91.0
Celery	84.3
Asparagus	76.9
Plums	75.7
Apricots	58.4
Peaches, Clingstone	56.6
Broccoli	50.2
Olives	49.2
Onions, Bulb	48.3
Cherries	48.3
Pears	46.0
Cucumbers	44.0
Apples	40.7
Melons	40.5
Peppers	34.3
Avocadoes	31.8
Peaches, Freestone	30.4
Prunes	27.9
Potatoes	24.8
Nectarines	23.3
Onions, Green	22.0
Garlic	21.1
Cauliflower	14.0
Beans, Snap	11.6
Grapefruit	10.6
Bushberries	8.7

Source: California EDD Pre-Season Farm Labor Reports DE-3416
Estimate based on 1977 reports

3). If the new machines are for the harvest of a fresh market crop, then the complete mechanization of the portion of the California crop that is for processing (Fresh Market Tomatoes, Fresh Market Onions).

While mechanization of these 13 commodities represents a large part of the impact of new technology on farm employment, other technologies which are not discussed in the Chapter's detail will also have an impact. Continued adoption of new machines will eliminate employment of hand workers in a number of crops which are already substantially mechanized. These include shake-catch harvesters in prunes, mechanical shakers and pick-up machines in figs, snap bean harvesters, and cutting machines now in use in apricot and peach drying yards.

Conveyor belt harvest aids are in use in numerous crops. While they may increase productivity, their biggest impact is not in the displacement of hand-harvest workers, but in changing the character of hand-harvest work. Harvest aids make the work less skilled, and less strenuous. The worker, tied to the pace of the machine, is often paid on an hourly basis rather than a piece rate.

New labor displacing technology is being adopted in other phases of production besides the harvest. The focus of this study is on harvest mechanization because of its more sudden, concentrated impact on the farm labor market.

A. Wine Grapes

The harvest of California wine grapes is being mechanized. Some 500 machines (1) picked an estimated 30% of the 1978 harvest (2). Machine use is most common in the state's newly planted vineyards, and in the Thompson's

Seedless vineyards of the San Joaquin Valley (see Table 5-2).

Table 5-2
California Grape Acreage and Harvest Mechanization
By County

County	% of Prod. Mechanized 1977	Wine Grape Bearing Acreage 1976	Thompson's Seedless Bearing Acreage 1976	New Wine Grape Plantings 1968-76
Kern	40.0	35,065	19,497	34,326
San Joaquin	--	32,441	439	16,550
Fresno	31.8	30,528	135,550	24,944
Madera	45.6	25,159	27,664	21,154
Monterey	77.7	25,102	--	31,784
Stanislaus	--	19,144	3,588	11,665
Sonoma	14.5	17,993	--	31,784
Napa	1.4	17,198	--	15,286
Tulare	34.4	15,520	28,277	11,802
Merced	--	12,153	3,002	6,617
San Bernardino	--	9,387	--	9
Mendocino	--	7,556	--	4,197
Santa Barbara	--	5,205	--	5,855
San Benito	--	4,532	--	1,052
San Luis Obispo	--	3,093	--	3,837
Riverside	--	1,923	2,704	2,222
Kings	--	1,086	1,123	520

Sources: % production mechanized from Calif. EDD <u>Pre-Season Farm Labor Reports DE-3416</u>
acreage from California Crop and Livestock Reporting Service <u>California Grape Acreage 1976</u>

Developed by Cornell University, the grape harvest machine picks most of the New York state crop (3)(4). The harvester straddles a wire-trellised vineyard row. Mechanical beater rods made of a flexible material strike the cane, trellis and fruit, knocking the berries from the vine, where they fall onto a catching pan and roll onto a conveyor belt. The grapes are then conveyed over the adjacent row of vines and into an accompanying gondola or tank.

There are seven manufacturers of the harvest machine, with Upright Harvester Co. and the Chisolm-Ryder Co. predominant. The principle difference between models of picking machines is in the picking head, where the length, movement, and construction of the beater rods are suited to a particular grape variety and trellis.

A new harvester has recently been developed which does not use the "slapper-beater" principle, but instead shakes the vine to remove the grapes. Called the pulsator picking head, this new type harvester can pick many vineyards that a slapper-beater harvester cannot. The pulsator can harvest varieties which are heavily foliated, or bear their fruit on short spurs. Some varieties which can be harvested by the slapper-beater can be harvested by the pulsator with fewer leaves and less yield loss. The pulsator works at a faster rate, up to 50% faster than conventional machines. However, the first models have been subject to frequent breakdown (5)(6)(7).

Most of the grapes grown for the California crush are of varieties suited for machine harvest. 15.4% of the tonnage is of varieties suited only to the slapper-beater harvester, 6.0% is suited to the pulsator, and 54.7% is suited to both machines (see Table 5-3).

Change in Vineyard Structure

The grape harvester can operate only in vineyards which have been pruned with machine harvest in mind. Established vines which are cane or cordon pruned can be trained for machine harvest. The principle expense of this conversion is in replacing grape stakes and trellis wires. In most vineyards the costs of conversion are relatively modest (8).

Table 5-3
Adoptability of Calif. Grape Crop to Machine Harvest, by Area
% of Calif. Grape Tonnage Crushed in 1976 According to
Varietal Suitability to Machine Harvest Technology

Area	Varieties Suitable for Machine Harvest				Varieties Not Suited for Machine Harvest	Minor Varieties
	Slapper Beater Only	Pulsator Only	Both	Total Suitable		
Mendocino & Lake	52.7	1.6	27.1	81.4	14.3	4.3
Sonoma & Marin	45.5	0.8	36.9	83.2	14.9	1.9
Napa	41.3	5.6	39.0	85.9	9.4	4.7
No. Centr. Coast	39.5	6.1	24.5	70.1	17.3	12.6
So. Centr. Coast	35.6	9.3	32.5	77.4	16.8	5.8
Lodi Area	12.6	1.0	8.0	21.6	77.8	0.6
Modesto Area	19.9	10.8	50.5	81.2	17.8	1.0
Cent. San Joaquin	10.8	4.8	70.4	86.0	9.2	4.8
So. San Joaquin	12.9	8.4	54.8	76.1	18.5	5.4
Southern Calif.	51.5	1.7	3.3	56.5	35.2	8.3

Source on grape tonnage: Calif. Department of Food and Agriculture
Final Grape Crush Report 1976 Crop (Sacramento, March 10, 1977)

Different methods of training the vine are used with different harvest machines. The system needed for the pulsator harvester has not yet been perfected, but it involves raising vine height, and block pruning the vines so the growth is narrow enough to pass under the harvest machine. Head pruned vines may be harvested by the pulsator.

For the slapper-beater harvester, the important part of vineyard restructuring is pruning so that the fruit will be borne in the area which can be reached by the beater rods. This requires raising the vine height. The cross-arm width of a trellis may also have to be narrowed to accomodate the machine.

The vine and trellis stake must be close together to allow a tight seal of the leaves (or paddles) of the catching pan around the girth of the vine.

Old vines with gnarled, off-center trunks may have to be cut off, and new wood retrained, a process which requires three years before normal yield is re-established. End vines must be retrained so that the fruit is on the wire trellis, and not on the end post. In some vineyards, the end post must be shortened or replaced with a deadman anchor.

Whichever machine is used, the harvester cannot go over in-the-row obstructions such as standpipes and telephone poles. Vines must be pulled to allow a path for the machine to go around these obstacles.

The harvest machine breaks vineyard stakes. Old stakes must be replaced. New vineyards are being staked with hardwoods or steel. Sprinkler irrigation risers must also be protected with steel or wood. In the process of picking grapes, the mechanical harvester also strips the leaves off the vine, breaks canes, and occasionally stakes, trellis wires, and even irrigation risers and vines. As grape growers gain experience, this damage is limited by proper vineyard preparation and training of the harvester operator.

Some vineyards are planted with rows which are too narrow to accomodate the harvester, or they are planted on grades too steep for the machine. New harvester models can overcome these problems. While early models can work only on hills with less than an 8% side grade (9), newer machines have a leveling system which allows them to work on a 29% slope (10). A narrow model harvester is being manufactured and used where standard-sized harvesters cannot fit. It was developed for the European industry (11).

New engineering developments such as new materials for the beater rods, and a "floating" picking head are allowing older vineyards to be successfully harvested by machine (12).

Change in Handling Systems

Machine picked grapes can be loaded into the 1 to 3 ton field gondolas which are already used in the hand-harvest. A fork lift is used to put the gondolas on over-the-road trucks, or if the winery is a short distance away, the gondolas are unloaded at the winery.

With machine harvest, many growers are switching to larger (5 to 6 ton capacity) self-dumping gondolas. These gondolas tip their load into the tank of an over-the-road truck, eliminating the need for a fork lift and fork lift operator.

Machine harvest of wine grapes breaks up the grape cluster, and the grape skin. To avoid oxidation of the white wine grapes, and the resultant loss of flavor and browning of wine, various field crushing and juice handling systems have been introduced. Field crushing allows the use of closed tank systems and carbon dioxide blanketing to exclude oxygen from the must (unfermented grape juice). Field crushing has been in commercial use in California for as long as the harvest machine, since 1969 (13). There are three kinds of field crushing systems. Most of these special handling systems have been introduced by wineries for use with premium wine grape varieties.

1). On machine stemmer-crusher. The harvester includes a stemmer-crusher and tanks to hold the must. A tractor drawn nurse tank ferries the must from the holding tank to a waiting tank truck at field side. One problem with this system is that it makes the harvester heavy and unmaneuverable (14).

2). Seperate stemmer-crusher tank trailer unit. In this system, the harvester conveys the grapes to a seperate unit, which includes a stemmer-crusher and receiving tank pulled by a tractor. Two such units are required for each harvester. The tank may be either fork-lift loaded for a short haul to the winery, or the must may be pumped to a waiting tanker truck, which is more economical for a long haul (15).

3). Field side crushing. One large scale grape grower is using a large but mobile field side stemmer-crusher. The grapes are transported to the winery in a juice tank truck (16).

Cost Savings

While it is clear that harvest machinery substantially reduces labor costs, much less certain is how much total harvest costs are cut. Johnson and Grise found machine harvesting of Thompson's Seedless grapes to be slightly cost saving over hand-harvest. Their study does not include the cost of vineyard restructuring or the value of the yield loss in calculating the cost savings (17).

The harvester is economical only if it is used on more than 200 acres per season. Substantial economies can be achieved by double-shifts, or by using the harvester in the long rows of large scale vineyards. Small or irregular vineyards of short rows are not economically harvested by machine, for too much time is spend in maneuvering the machine in order to turn around.

Harvesters are being used in the non-harvest season as over-the-vine tractors which can spray agricultural chemicals or do rough pruning. These multiple uses allow the costs of the machine to be depreciated across other tasks, an important cost consideration for future economic studies. A mechanical harvester is being used as a pruning aid in Kern County, where it has reduced hand pruning labor requirements up to 43% (18).

The pulsator picking head was first used on a multi-row harvest machine in the San Joaquin Valley. Both two-row and four-row harvesters are in use. They can double or quadruple operator productivity, however, few present day vineyards are large and straight enough to accomodate a multi-row machine (19).

The cost savings of harvest mechanization is dependent on the value of the yield loss. With great yield loss, or a high value variety, it is still more economical to hand harvest.

Loss of quality has been a crucial aspect to winery acceptance of machine harvested grapes.

Yield Loss

Mechanization can reduce vineyard yield levels in four different ways. Improper training may cause the fruit to be borne out of the harvest zone, and missed by the machine. Yield loss occurs when old, gnarled vineyards prevent a proper seal of the collecting plates, causing the fruit to fall on the ground.

The principal sources of yield loss are the juicing and berry retention of certain varieties. Concord grapes (grown in New York) and Thompson's Seedless are picked with the least juicing loss. Vineyards in New York state have an average of 10% yield loss (20). Tests comparing the yields of machine and hand picked Thompson's Seedless grapes in Madera County indicate similar levels of loss (see Table 5-4). Thin-skinned varieties such as Burger, Zinfandel and Grenache suffer so much loss that they are more economically picked by hand.

Table 5-4
Yield Loss in the Harvest of Thompson's Seedless Grapes for the Winery

Percentage of Wine Grapes:	Hand Picked	Machine Picked
Left on Vine	0.9%	3.9%
Shattered (Left on Ground) or Juiced	3.6%	9.2%
Weighed in at Winery	95.5%	86.9%

Source: (21)

An additional source of yield loss is the uncalculated damage the harvester does to the vine vigor. Though seven years of mechanization reportedly caused no yield loss in New York vineyards (22), cane breakage, defoliation, and the loss of fruiting wood may be depressing yields in California vineyards according to studies in Madera County (23) and at the Kearney Field Station (24).

This loss seems to be cumulative, but can be reversed by hand picking the vine and allowing vigor to return.

Quality Loss

The impact of mechanization on quality has kept many California wineries from accepting machine harvested grapes. The machine incorporates "matter other than grape" (MOG) such as leaves, petioles, and canes into the load of grapes. It harvests a relatively higher proportion of secondary clusters than do hand harvesters, which means that machine harvested musts can be of a lower sugar content. The crushing and maceration caused by the harvester can lead to overextraction and oxidation, especially of the premium white wine grape varieties. A new quality problem is the contamination of grapes with oil and diesel fuel from the harvester (25).

The loss of quality is becoming less serious over time. Field crushing is providing a feasible means of reducing oxidation (26). A field press has been tested. It prevents the overextraction of white varieties that occurs when machine harvested grapes are being transported to the winery press (27)(28). The high cost of field crushing and pressing has limited their adoption, however. A simple means of reducing oxidation is now widely practiced. Meta-bisulfate is added to gondolas of machine harvested grapes.

Operators and manufacturers claim success in increasing the ability of the machines to remove leaves from fruit. MOG levels consistently below 1% are now attainable. Leaf trash can be kept out by operating the leaf fans at higher speed. This sacrifices yeild, as some berries are blown out with leaves. With experience, leaf inclusion seems to be of decreasing concern to the winemaker. Evaluations of wines with added leaf material revealed no effect on wine quality (29).

The pulsator harvesting system may have the greatest impact on quality, and on winery acceptance of machine harvested grapes. The pulsator does not beat leaves into the fruit as the slapper-beater harvester does. Instead, the berries are shaken from the vine, and MOG levels are very low.

The state's largest winemakers, Ernest and Julio Gallo, have refused to purchase grapes harvested by the slapper-beater machine (30). They will now accept pulsator harvested grapes (31). Gallo produces 100 million gallons of wine a year (32), about 30% of California wine production. Gallo's decision should have major impact on harvester adoption in California, especially in the Modesto area (Stanislaus and Merced Counties) where there is now little or no machine use.

Quality reduction is still a concern to North Coast wine producers, especially for premium varietals such as White Riesling and Pinot Chardonnay. The value of these varieties is so high that the extra yield of hand harvest more than pays for its higher cost. Despite these factors, harvest machines have even been adopted in the Napa Valley, where grape prices are highest in the state.

Increased Scale of Production

A boom in consumer demand for table wine caused growers to plant more than 200,000 acres of wine grapes between 1970 and 1975, causing California wine grape acreage to triple. 85% of these new plantings were of wine grape varieties which are suited to mechanical harvest. In Monterey County, and on the west side of the San Joaquin Valley, giant tracts of new, machine harvested vineyards have been established.

The surge in production of wine grapes has caused a decline in the relative importance of raisin and table grape varieties to the California grape crush (see Table 5-5).

Table 5-5
California Grape Crush, Tonnage by Variety Type as % of Total

3 Year Period	Wine Grape Varieties	Table Grape Varieties	Raisin Grape Varieties*
1975-77	58.9	10.3	30.8
1972-74	44.5	12.5	43.0
1969-71	33.7	15.5	50.8

* more than 90% Thompson's Seedless
Source: Calif. Crop & Livestock Reporting Service
Calif. Fruit and Nut Statistics 1965-77

Most commercial California grape farms (86.1%) are smaller than 100 acres. These farms include 39.7% of the state's vineyards (33). Though too small to justify a single harvest machine, many small scale growers are mechanizing by contracting with harvesting companies. By working for several growers, contract harvesters have been able to achieve economies of scale and use a single machine to harvest up to 500 acres of grapes in a single season (34)(35).

Viability of the Hand-Harvest Sector

The high demand for California wine raised the price for grapes to record levels. As the new plantings came into bearing, prices have fallen. An anticipated glut has not yet materialized.

Many producers will not be able to mechanize because their vineyards are too old, too small, on too steep a slope, or are of an unsuitable variety. As their vines grow older and yields decline, their vineyards will no longer be profitable to operate. If new plantings overproduce, low prices will accelerate the demise of those vineyards. Urbanization is causing vineyards to be pulled out in Napa, Alameda, Santa Clara, and San Bernardino Counties.

The age, lay-out, and variety of a vineyard affect its suitability for machine harvest. Most of the grapes grown for crushing in California have the potential to be machine harvested. About 20% of the state's grape crush is of varieties which cannot be machine harvested. Some of these vineyards, such as the Tokay grapes of the Lodi area; are quite old, and are gradually being taken from production. The varietal suitability varies from region to region (see Table 5-3).

The majority of the grapes grown for crushing (76.1%) is of varieties suited to machine harvest. Most of the state's acreage in these suitable varieties (73.5%) have been planted in the last 10 years. These vineyards have been planted with machine-harvest in mind. On the other hand, most Thompson's Seedless vineyards (91.7%) are more than 10 years old. Because the Thompson's Seedless vine is so well-suited to mechanization, even these old vines can be readily adapted to machine harvest.

The high proportion of suitable varieties in the Napa, Sonoma, and Mendocino areas is somewhat misleading, for many of the vineyards cannot be mechanized due to small scale and hillside terrain.

With time, vineyard plantings are shifting to mechanically harvestable varieties. 85.1% of the wine grape vineyards planted since 1967 have been varieties suited to mechanization. However, adoption of harvest machinery has proceeded at a slow rate. The major reasons for this slow rate are the High value of the lost yield, and the diseconomies of mechanizing small operations.

The pulsator harvester will allow the mechanization of varieties which formerly suffered too much yield loss and vine damage when harvested by the slapper-beater harvester. Wine grape harvesters should be adopted at an increasing rate. Adoption could continue until 70 to 80% of the state's vineyards are machine harvested. The last portion of the industry will be mechanized very slowly as hand harvested vineyards are removed from production. Hand harvesting may persist for a long time for vineyards producing premium grapes which cannot be mechanically picked. Varieties such as Zinfandel and Grenache continue to be heavily planted even though they cannot be machine harvested. If the price growers receive for these varieties remains high, at least this small part of the wine grape industry will continue to be hand picked.

Notes.

1. Approximately 600 harvest machines have been sold in California, according to a survey of manufacturers by Mark Epstein of the United Farmworkers of America in July, 1978. Assuming that the life span of a harvester is 5 years, the 100 harvesters in use in 1972 must now be fully depreciated, leaving 500 harvesters working in 1978.

2. Assumes 250 acres per harvester, and a harvest of 420,000 acres of grapes for crushing.

3. Ed Ralph "Experts evaluate machine performance in vineyards" Western Fruit Grower March 1971 p. 24

4. "Olmo talks mechanical harvest" California Grape Grower March 1973 p. 10

5. Harry Cline "Multi-row concept employed in California vineyards" California Grape Grower December 1977 p. 4

6. "Upright Update: A quarterly Upright Harvesters publication on mechanized viticulture" California and Western States Grape Grower January 1978, Insert

7. "'Shaking' grape off vine: new mechanical harvester" California and Western States Grape Grower January 1978 p. 7

8. "Art Seriman Likes Machine" California Grape Grower December 1970 p. 7

9. "Mechanical harvesting of grapes in Northern California" Redwood Rancher September 1972, p. 62

10. "Upright Update . . ." op cit.

11. "Specially designed grape harvesters go to France" Redwood Rancher September 1973 p. 37

12. Dan Weldon "Spotlight on grape harvesting: 70 year old vines mechanically picked" California Grape Grower September 1972 p. 10

13. "Capturing the fragrance for wine: Upright Harvesters work towards complete field crushing of grapes" Western Fruit Grower June 1972 p. 28

14. Eric P. Wente "Mechanical harvesting and field crushing: eight years of Wente experience" Wines and Vines February 1977 p. 21

15. Michael O'Brien "Closed and open transport and sampling of wine grapes" Transactions of the American Society of Agricultural Engineers 1977 p. 631

16. Benjamin Falk "California's largest: Tejon Ranch's field crusher" California Grape Grower February 1977 p. 6

17. Stanley S. Johnson "Mechanical harvesting of wine grapes" U. S. Economic Research Service, Agricultural Economics Report No. 385 (Washington, 1977 28 p.)

18. Falk, op cit.

19. Cline, op cit.

20. S. C. Mendall "An eastern view of mechanical picking" Wines and Vines February 1975 p. 24

21. "Watch Delivery Total" California Grape Grower December 1970 p. 6

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27. "Mechanical harvesting: Redwood Ranch and Vineyards takes to field pressing" Redwood Rancher Summer 1976 p. 24

28. "Unique Field Press" California and Western States Grape Grower January 1978 p. 2

29. A. C. Noble et al "Effect of leaf content and mechanical harvest on wine quality" American Journal of Enology and Viticulture Vol. 26, No. 3 1975, p. 158

30. "Mechanical harvesting showcased at Stanislaus Grape Day" California Grape Grower June 1976 p. 41

31. Jerry Seper "Tulare custom picker: future bright for mechanically harvested grapes" California Grape Grower July 1976 p. 6

32. "U. S. Wine Market: Estimate sales and market shares" The Blue Anchor August/September 1975

33. U. S. Bureau of Census 1974 Census of Agriculture Vol. 1 No. 5 California Table 25

34. "Tutunjians aim for harvesting record" California Grape Grower December 1973 page 25

35. "How one custom operator approaches harvesting" California Grape Grower September 1974 p. 6

B. Raisin Grapes

There has been minimal mechanization of California's raisin grape harvest. Less than one percent of the crop is harvested by machine and dried on continuous paper trays. A dried-on-vine (DOV) machine harvest system is more widely used in Australia.

Most California raisins are sun-dried. The grapes are hand harvested and spread to dry on 2 by 3 foot paper trays set out in the vineyard. The grapes are turned after 10 to 14 days, to facilitate uniform drying. The raisins are rolled into a "biscuit" or "cigarette" roll after another 6 to 10 days, and allowed to dry further. When the moisture content drops low enough, the raisins are dumped into "sweat" boxes, and then taken to a processing plant. Some of the crop is too moist to be packed, and must be further dried in a heated air tunnel.

A small part of the California crop is harvested and taken to a processor where the fresh fruit is washed and dipped in a hot caustic. The caustic disrupts the waxy cuticle, permitting rapid dehydration in an air tunnel. Many of the dipped raisins are also sulfured, to become the "golden bleached" raisin.

Raisin dipping is more common in other countries of the world. Olive oil and ash is used on grapes in Greece and Turkey. The Australian "sultana" raisin is either dipped or dried on the vine. Dried on the vine sultanas are machine harvested in Australia.

The DOV concept has been tried in California, so far without commercial success (1). The California system involves cutting the canes of the vine, and spraying the vineyard twice with a carbonate and methyl or ethyl oleate solution. The drying period is longer than the natural method because it is cooler on the vine than on the ground (2). The advantage of this system is that the vine canopy protects the raisin from early rains (3).

Two California growers have adopted the continuous tray harvest system developed in a joint research effort by the University of California, California State University at Fresno, and the U. S. D. A. The canes of the vine are cut 4 to 6 days prior to harvest. This pre-cutting reduces grape juicing at harvest (4). A standard slapper-beater type wine grape harvester is used to harvest the grapes. The single berries are spread in an even layer on a continuous roll of paper. The grapes dry in 10 to 12 days. A specially designed pick-up machine is used to brush the raisins from the paper tray and into a sweat-bin, where they are cured before being sent to the packing plant. This means the raisins are picked up sooner than are hand harvested raisins, which remain on the ground for 2 to 4 weeks, where they are vulnerable to damage from rain, insects, and rodents (5).

Changes in Production Practices

The vineyard structure requirements for machine harvest of raisin grapes are virtually the same as those for wine grapes. The Thompson's Seedless accounts for 94% of the acreage of California raisin variety grapes.

Thompson's Seedless vineyards are cane pruned, and can be machine harvested with few modifications.

The major change in production practices is the cane-cutting which must be done several days prior to harvest. Cane cutting must be done with continuous tray harvest so the cane loses enough moisture that the rachis (the berry's stem) shrivels. When the machine strikes the cluster, the berries are shattered from the vine with the captem intact, reducing juice damage (6). Cane cutting is also needed for the DOV method, to help dessicate the clusters.

The fruiting cane is hand cut between the trellis and the head of the vine. Even with a uniform trellising system, the cane severing is a difficult task requiring 5 hours of labor per acre of vineyard. Pneumatic pruning shears can increase worker productivity in this operation by 50% (7). The grape clusters on canes that are not cut will juice when harvested by the continuous tray method. Clusters on uncut canes do not completely dry in the DOV system.

Changes in Product and Handling

Mechanically harvested raisins produced on a continuous tray system are very similar to hand harvested raisins. DOV raisins are different from natural raisins. They are a greenish amber color, and more diverse in color and moisture content than natural raisins (8). The DOV fruit looks like confetti compared to the uniform blue-black color of natural raisins. Consumers prefer natural raisins to the DOV fruit, although a study of Michigan consumers indicates that this preference is not pronounced. Foreign buyers did not respond favorably to DOV fruit (9).

Adoption of a field side drying tunnel is a handling innovation that is occuring independent of harvest mechanization. The portable raisin dryer is used to lower the moisture content of field dried raisins to meet U. S. D. A. standards. The raisins are dried in pallet bins. This bulk handling saves a great deal of labor over the air tunnels used by processors, which require that raisins be spread on a tray. Five workers at a field side unit are reported to produce as much as a 22 member crew at an air tunnel dryer (10).

Cost Savings

An economic study by U. S. D. A. researchers in 1974 found the continuous tray harvest methods to be only slightly cost saving over hand-harvest. Total savings were estimated to be $26.16 an acre, or $11.63 a ton (11). This is a savings of only 10.6% of harvest costs. That study did not consider possible yield loss of machine harvest in calculating the cost savings. Cane cutting has been reported to reduce yields in Australian vineyards by 7 or 8% (12). Vine damage by the slapper-beater harvester may harm future fruiting spurs and decrease vine vigor and yield as well.

The DOV system was found not to be cost saving over hand-harvest and natural drying systems in the U. S. D. A. study (13). Researchers at California State University Fresno have reported a $34 an acre cost saving with this method, or a 17.2% saving in total harvest costs (14).

Both systems require substantial investment in machines. A harvester equipped with a spreader and trailer to lay the paper tray, as well as a pick-up machine, are used in the continuous tray system. An over-the-row spray rig and a harvest machine are required for the DOV system.

Factors Affecting the Rate of Adoption

The small cost savings of mechanization of the raisin harvest indicates that adoption of new technology will proceed at a slow rate. The small scale of most raisin producers will make mechanization impossible without use of the harvest system on contract or through cooperative ownership, or by consolidation of vineyards into larger farming units.

The California raisin district, centered in Fresno County, is also an area of widespread use of wine grape harvesters. It will be possible for the harvester to be used to harvest raisins in parts of the season, and then to harvest late maturing wine grape varieties the rest of the season. Should this alternate capacity be utilized, the increased output of the harvest machine would increase the cost savings of mechanization by reducing the fixed cost per unit of production.

Because of a disastrously small harvest in 1972, average annual raisin production dropped to its lowest level in more than 30 years (see Table 5-6).

Table 5-6
Average Annual U. S. Raisin Production*, Exports and Imports

Annual Average For Five Year Period:	Total Production (tons)	Domestic Exports (tons)	Imports (tons)
1930 - 34	197,800	58,600	758
1935 - 39	233,400	67,020	279
1940 - 44	269,000	83,540	51
1945 - 49	246,200	85,100	275
1950 - 54	217,400	66,540	77
1955 - 59	201,200	48,700	197
1960 - 64	222,200	61,080	349
1965 - 69	249,200	76,280	739
1970 - 75	191,000	57,280	1,801

*the entire commercial U. S. raisin crop is grown in California
Source: U. S. D. A. Agricultural Statistics 1946, 1956, 1966, 1976

California produces 25 to 40% of the world's raisin production (15). A substantial portion of the crop is sold for export.

Notes.

1. Carter Clary, Department of Viticulture, California State University Fresno, 1978 CIRS Interview

2. Henry E. Studer, Harold P. Olmo "Vine-drying of Thompson Seedless Grapes" Transactions of the American Society of Agricultural Engineers 1973 p. 944

3. Henry Studer, Dept. of Agricultural Engineering, University of California at Davis, 1978 CIRS Interview

4. Henry E. Studer, Harold P. Olmo "The severed cane techniqe and its application to mechanical harvesting of raisin grapes" Transactions of the American Society of Agricultural Engineers 1971 p. 38

5. Studer and Olmo "Vine-drying of Thompson Seedless Grapes" op cit.

6. Studer and Olmo "The severed cane technique . . . " op cit.

7. Henry E. Studer, Harold P. Olmo, Earl Rocca "Mechanical harvesting of raisin grapes . . . . an evaluation of methods for severing fruiting canes" California Agriculture March 1973 p. 10

8. Robert V. Enochian, et al "Production Costs and Consumer Acceptance of Dried on the Vine Raisins" Agricultural Economics Report No. 337 U. S. Economic Research Service 1976 p. 5

9. Ibid. p. 10, p. 20

10. Liz Luckett "portable raisin drier proves cheaper, faster" California Grape Grower April 1978 p. 10

11. Enochian, op cit. p. 6

12. Studer, 1978 CIRS Interview, op cit.

13. Enochian, op cit. p. 6

14. "Raisins-on-the-vine: 'Possible and Practical'" California Grape Grower September 1974

15. Enochian, op cit. p. 1

C. Clingstone Peaches

An increasing portion of the California canning peach crop is being mechanically harvested. Since 1968, tree shakers and catching frames have been displacing hand pickers (Table 5-7). Adoption of machine harvesting has been greatest in the counties with the greatest production. Mechanical harvesting has been reported in Stanislaus, Butte, Sutter, Yuba, and Merced counties (1).

Table 5-7
Percentage of Cling Peach Crop Tonnage Harvested by Machine

Year	% of Crop Machine Harvested	Source of Estimate
1966	0%	(2)
1968	2%	(3)
1969	7%	(4)
1970	10%	(2)
1973	11%	(5)
1975	12%	(6)
1976	16%	(7)
1977	22%	(7)
1978est.	30%	(7)

Shake and catch-frame technology for the canning peach harvest was thoroughly studied by University of California researchers during the 1960's (8). Peach harvesters can be categorized into two types: the two unit and the single unit machine.

A two unit harvester was designed by UC scientists. Two unit harvesters consist of two catching frames, each self-propelled with its own operator. The two frames work together, surrounding the tree. One unit includes the shaker arm, while the other unit has the conveying, grading, and bin filling equipment. The two unit harvester operates more rapidly than a one unit harvester because it moves straight down the row of trees. The Kilby machine is the most popular model. 58% of peach harvest machines were Kilby models, according to a survey by the California Canning Peach Association in 1975 (9).

Single unit harvesters have only one operator. The harvester must be driven towards the tree at an offset angle, then the shaker clamp is attached to the trunk. A catching frame shaped like an inverted umbrella then unfolds, and the tree is shaken. Two fruit conveyors, one at either side of the shaker, convey the fruit to the bin loader. After shaking, the umbrella-like catch frame is removed, and the machine backs away from the tree. A single unit harvester usually alternates between trees in adjacent rows (10)(11). The Adrian machine is the most popular. The 1975 survey found that 28% of the peach harvesters in use were Adrian machines (12). Orchard Machinery Company's "Catchall" harvester is also a single unit machine, and accounted for 8.3% of the harvesters in the 1975 survey. Single unit machines which can be driven straight down the row have been developed by Ro-lon and FMC, but as of 1975, they were not yet in widespread use (13).

Peach harvester engineering has concentrated on the crucial question of loading only full sized, fully colored and undamaged fruit. Sizing belts on the conveyor efficiently remove undersize fruit. The machine can be used as a scrapper to harvest orchards so full of undersized fruit that they cannot be hand picked (14).

Hand labor is required to sort out undercolored and injured fruit. The single unit harvester has a trailer type loading device with facilities for four sorters. The two unit harvester requires two or more hand grading workers (15). Electronic sorters that can assess the maturity of peaches by their color are being tested. The sorters could be used to replace hand graders on harvest machines (16)(17).

Other quality control features are included on harvesters to lessen impact damage. Decelerator strips or tubes above conveyor belts, and automatic bin filling equipment reduce fruit against fruit impact. Proper padding, wide slow conveyor belts, and little or no drop at transfer points are required to minimize the impact of fruit against the machine.

Changes in Production Practices

Peach trees are ordinarily thinned by hand in the spring. The hand thinner knocks some of the green fruit from the tree, so that the remaining fruit will develop to a large enough size to meet grade. The harvest machine has been used to shake the tree early in the season in order to reduce the amount of hand labor required to thin the crop (18). Labor costs were reduced by 25% at one ranch (19).

Research has been directed toward thinning the trees with chemical sprays. No compound has been perfected to the point where it will work consistently from year-to-year and variety-to-variety (20).

As the harvest machine has been designed to fit the peach tree, peach trees are being restructured to be suitable for shake catch harvest. Early studies revealed that fruit impact with lower branches of the tree was the principal source of damage in mechanical harvest. The goal of tree restructuring is to prune the tree so that no fruit is borne directly above another branch-- that is, no two branches are in the same vertical plane.

The ideal tree structure for mechanical harvest is a vase shape. Growers are advised to train young trees so that they are headed at 32", with three main scaffolds branching from the trunk, each 30" in length and branching into secondary scaffolds angled 30° from the vertical.

Approximately 41% of bearing California peach orchard acreage has been planted since 1968, when shake-catch harvesters were introduced. When 1977 plantings come into bearing in 1982, 2/3 or more of the orchards will have been planted since 1968 (see Table 5-8). These new trees are being trained with machine harvest in mind.

Table 5-8
California Clingstone Peach Tree Acreage Standing 1977

Bearing acreage planted since 1968	18,959
Bearing acreage planted before 1968	26,945
Total bearing acreage	45,904
Non-bearing acreage (planted since 1974)	9,103
Total acreage standing 1977	55,007

Source: California Crop and Livestock Reporting Service

Older trees may also be pruned for mechanical harvest. Trees trained with the modified leader (University of California) system, which predominates in the San Joaquin Valley, are more easily converted to mechanical harvest than trees trained according to versions of the Dahlgren system. The latter system, which is used in the Sacramento Valley, permits the tree to develop with more locations where limbs are directly above other limbs.

Tree restructuring involves elimination of low hanger wood and horizontal branches, and if necessary, reduction in the number of primary and secondary scaffolds (21)(22). Pruning results in yield loss proportional to the amount of fruiting surface removed. The restructured tree regains this loss in yield after one or two seasons (23).

Ultimately, almost all old trees can be modified for machine harvest, provided that the trunk is long enough for the shaker clamp to grasp (24). An estimated 90% of the state's cling peach orchards have the potential to be restructured for machine harvest (25).

Changes in Handling and Product

To maintain the quality of the canned product, mechanically harvested peaches must be handled and processed rapidly. Several canneries give preferential treatment to machine harvested loads, processing them immediately (26). As an increasing portion of the crop has become mechanized, however, there is too much machine harvested fruit for this special handling to be practical. Producers have turned to other methods to help maintain quality.

Growers are attempting to handle bins more quickly in the orchard, and to carry the bins only on trailers with springs (27). Quick handling of bins maintains fruit quality. When the receiving bins are not being provided rapidly enough for the output of the harvester, the harvest operator carries fruit on the catching frame instead of conveying it to an empty bin. Fruit is shaken onto fruit, resulting in high damage levels (28).

Quick handling of the fruit to the processor has been facilitated by the general trend of new canneries locating outside of urban areas, closer to the orchards. Fungicides have been used to limit post-harvest decay. Pre-harvest spraying of Benlate and post-harvest dipping of fruit in Benlate have been tested in this regard (29).

Although it has been proposed that machine harvested peaches be subject to special sorting at the cannery or at a central sorting facility, it is generally conceded that the sorting should be done on the harvester because it is less costly, and results in fewer bruised fruit (30)(31).

A portion of the canning peach crop is made into a concentrate juice. Concentrate production has evidently occured as a by-product of mechanization, because of the need to make use of peaches damaged in machine harvest.

Cost Savings

An economic study by the University of California in 1971 discussed the impact of yield loss, total yield, and harvest machine output on the economic feasibility of machine harvesting cling peaches. The yield lost due to machine inflicted damage has the greatest impact on whether or not mechanization is cost saving. Assuming 16 tons/acre yield, and 10% loss, machine cost would break even with hand-harvest costs if the machine was used to harvest 80 acres. Orchards greater than 80 acres would realize cost savings (32).

Hand-harvest accounts for only 16% of the total production costs (33). When yield loss exceeds 10%, the harvest costs saved by the machine are small when compared to the expense of the yield loss. The harvester is feasible only when low levels of yield loss are maintained. If the yield loss rises to 15% or more, hand harvest is always less expensive (34).

Alternative uses of the machine are enabling the depreciation of the machine's fixed costs in other farm jobs. Growers are using the machines for bulk thinning. By changing the sizing belt, peach harvest machines can be used to shake-catch harvest prunes, pecans, walnuts, almonds, olives, apricots, apples, cherries and plums (35). Olives, prunes, and nuts are

are common crops in the cling peach areas of the Sacramento Valley, while apricots, plums and nuts are common in the San Joaquin Valley peach areas. This additional use of the machine may figure strongly in the economy of its adoption.

Peach harvest machines have been operated at less than their potential output. The average machine harvested only 552 tons in the 1975 harvest, though the capacity of a single machine is 1750 tons per season. The state's 157 shake-catch machines picked 12% of the 1975 crop, although they had the capacity to harvest 38% of it (36). Each machine harvested approximately 40 acres, far below the break even point calculated in the U. C. study (37).

Yield and Quality Loss

Marketable peaches are lost or damaged in shake-catch harvest. Some fruits are not shaken from the tree, while others miss the catching frame and fall onto the ground.

The harvest machine can pick a tree once. Tests were conducted to see if selective shaking would permit a second machine picking. They revealed that the shaker cannot discriminate between ripe and unripe fruit, and that in any case, unripe fruit that remains on the tree is ruined by the first shaking (38). Where there is considerable variability in fruit maturity from tree to tree, the machine operator can harvest selectivly by shaking only the trees with a high proportion of mature fruit (39). This tree to tree selectivity makes the harvester less productive, however, as more time is spent moving the machine in the orchard.

Uneven ripening of peaches is not a problem in California. Many orchards are harvested with a single hand picking (40), although two and sometimes three pickings are done to increase the yield (41).

Proper tree restructuring contributes to uniform fruit maturity. The pruning of low hanger branches reduces the branches which bear late maturing fruit on the underside of the tree.

Although California peaches ripen uniformly, there is a very short period when a given tree can be harvested (42). If harvested too early, the machine picked fruit will be too green and will fail to meet color standards. If harvested too late, the fruit will be too soft, become damaged and fail to meet grade (43). Improper timing of the harvest can have devastating impact on yields.

Yields are depressed by loss of fruiting wood during tree restructuring. Older trees are affected by the shaking, and orchard life span may be shortened. A number of studies indicate that, in general, machine harvested peaches are of poorer quality than hand harvested ones (44). Some of the damage caused by machine harvest can be seen immediately after harvest. Curly noticed 5-10% fewer choice grade fruit at initial inspection.

Most machine harvest damage shows up after 24 hours (45) (see Table 5-9).

Table 5-9
Quality of Machine and Hand Harvested Fruit

	% of Choice Fruit	
	Hand Harvest	Machine Harvest
At Arrival at Processor	90%	85%
Within 24 Hours Holding	82%	68%

Source: (46)

Quality damage is expecially severe in the early and extra-early varieties of peaches, which are softer than late varieties at the same maturity (47)(48)(49). The extra early varieties show two to three times as much damage as the late varieties (50). The quality inspection conducted by the State of California is not able to assess all of the quality damage which becomes apparent in the canned product (51). Part of the canning peach crop, approximately 10%, is put in cold storage to be held until the cannery can process it. Mechanically harvested peaches which are held for any length of time show machine cuts and bruises. Only the highest quality machine picked fruit might be put in cold storage, and then only for a very short while, if at all. This inability to be held for processing puts a limit on deliveries of machine harvested fruit at peak season.

Factors Affecting the Rate of Adoption

The production of canned peaches in California has been declining (see Table 5-10). Both clingstone and freestone peaches are canned, with clingstones accounting for 94% of the California canning crop. The acreage of bearing clingstone peaches dropped from 63,770 acres in 1969 down to 46,320 acres in 1977.

The California canning peach industry is suffering from declining per capita consumption of canned fruit and from the loss of export markets to foreign competitors, including the Republic of South Africa.

The proportion of the California canning crop exported has fallen from a 14.3% average over 1962-65 to an average of 6.7% over 1974-76 (54).

Virtually the entire U. S. canning crop is grown in California. The decline in exports has occured particularly in the shipments of peaches to

Table 5-10
California Canned Peach Production in Tons

Period	Annual Avg. Production
1955 - 59	624,200
1960 - 64	781,680
1965 - 69	810,140
1970 - 74	675,120
1975 - 77	686,666

Source: California Crop and Livestock Reporting Service

Table 5-11
Exports of Canned Peaches
(000's of Pounds)

Year	From the Republic of South Africa	From the United States of America		
		Total Exports	Exports to Europe	Exports to the United Kingdom
1963	158,985	215,056	177,138	20,224
1964	154,710	236,595	192,800	13,450
1965	192,735	201,119	163,940	2,768
1966	209,160	229,094	180,802	3,795
1967	221,040	88,861	53,613	909
1968	204,345	114,887	64,593	175
1969	221,715	227,261	140,275	2,819
1970	212,850	168,151	117,780	1,801
1971	248,670	119,640	69,003	288
1972	246,240	111,353	54,291	498
1973	239,895	127,934	67,839	4,734
1974	274,725	96,615	32,895	765
1975	281,295	93,465	32,040	360

Source of South Africa data: State of South Africa: Economic Financial and Statistical Year-Book for the Republic of South Africa DeGama Publishers Pty. Ltd.(Johannesburg 1977)
Source of U. S. data: U. S. D. A. Agricultural Statistics

Europe and the United Kingdom, during the same time period that South African export of peaches has increased (see Table 5-11). The United Kingdom is the most important market for canned fruits and vegetables produced in South Africa.

The oversupply of canning peaches, and the restriction on production imposed by a cling peach marketing order have slowed the adoption of machine harvesters. Average size of clingstone peach farms in several counties is less than the 50 acre minimum needed to justify a harvest machine (see Table 5-12)(55).

Table 5-12
California Commerical Clingstone Peach Farms, Number and Average Size

County	Number of Farms	Acres of Clingstone Peaches	Average Number of Acres Per Farm
Butte	69	3,288	47.7
Fresno	115	2,656	23.1
Kern	5	1,244	248.8
Kings	41	1,414	34.5
Madera	4	770	192.5
Merced	128	8,272	64.6
San Joaquin	109	4,259	39.1
Stanislaus	433	18,849	43.5
Sutter	252	14,382	57.1
Tehama	3	701	233.7
Tulare	98	2,238	22.8
Yuba	72	7,320	101.7

Source: U. S. Bureau of Census <u>1974 Census of Agriculture</u> Vol. 1 Part 5 <u>California</u> Table 11 p. III-14

Processors still prefer hand harvested peaches to mechanically harvested ones, but producers are beginning to realize the quality potential endorsed by University of California scientists by machine harvesting fruit with no more damage than is found in the average hand harvested load.

Now that mechanization is underway, the machine harvested producer will be better able to survive continued overproduction and low prices.

Notes.

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3. "Words of wisdom on mechanical harvest" Cling Peach Quarterly 2:69 p. 9

4. "Then it went to the canners" Cling Peach Quarterly 3:69 p. 9

5. "Canners comment on mechanical harvesting" Cling Peach Quarterly 2:73 p. 5

6. "Mechanical harvesting increases" Cling Peach Quarterly 2:75 p. 17

7. Jim Laird, California Canning Peach Association, 1978 CIRS Interview

8. R. B. Fridley, P. A. Adrian, L. L. Claypool, A. D. Rizzi, S. J. Leonard "Mechanical harvesting of cling peaches" California Agricultural Experiment Station Bulletin 851 June 1971

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10. L. Van Heek "Mechanical harvesting of peaches in California" Fruit World and Market Grower May 1975 p. 19

11. Stanley S. Johnson, Verner Grise "Economics of harvest mechanization of cling peaches" California Agriculture March 1971 p. 8

12. "Mechanical harvesting increases" op cit.

13. L. Van Heek, op cit.

14. "Mechanical harvest: a report of the 1969 experience" Cling Peach Quarterly 3:69 p. 5

15. B. C. Horsefield, R. B. Fridley, L. L. Claypool Transactions of the American Society of Agricultural Engineers 1971 p. 1040

16. Rex L. Clark, P. S. Shackelford Jr. "Resonance and optical properties of peaches as related to flesh firmness" Transactions of the American Society of Agricultural Engineers 1973 p. 1140

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21. Clayton L Haws "'Coming of age,' is canner view of mechanical harvesting" Western Fruit Grower January 1970 pp. 16-17

22. Scott McRitchie "Canners and growers developing a uniform attitude about machine harvesting of clings" Western Fruit Grower January 1970 p. 14

23. Fridley et al, op cit. p. 10-11

24. Ibid.

25. Jim Laird, op cit.

26. "Canners comment on mechanical harvesting" op cit.

27. "Words of wisdom on mechanical harvest" op cit.

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30. Horsefield et al., op cit.

31. Scott McRitchie "Harvesting clings by machine for quality and efficiency" op cit.

32. Fridley et al., op cit.

33. Grise and Johnson, op cit.

34. Fridley et al., op cit.

35. "Mechanical harvesting increases" op cit.

36. "Mechanical harvesting increases" op cit.

37. Assumes the 1975 average yield of 14 tons per acre.

38. Fridley et al., op cit. pp. 20-21

39. Ibid. p. 22

40. L. Van Heek, op cit.

41. Fridley et al., op cit. p. 11

42. "Canners comment on mechanical harvesting" op cit.

43. Fridley et al., op cit. p. 43

44. Ibid.
Don Curlee, op cit.

45. Don Curlee, op cit.

46. "Then it went to the canners" op cit.

47. "Mechanical harvest: a report of the 1969 experience" op cit.

48. "Then it went to the canners" op cit.

49. Horsefield et al., op cit.

50. "Then it went to the canners" op cit.

51. Johnson and Grise, op cit.

52. Don Curlee, op cit.

53. Average for 1974-77

54. This represents an average of 232,750 thousand pounds exported out of an average of 1,636,150 thousand pounds of peaches canned over 1974-76. Calif. Crop and Livestock Reporting Service Exports of Agricultural Commodities Produced in California 1962-63, 63-64, 64-65, 1974-76; and California Fruit and Nut Statistics 1954-67, 1965-77

55. Fridley, op cit.

D. Apricots

Experiment use of shake-catch machines to harvest apricots was reported in San Benito County in 1959 and again in 1967 (1). An estimated 9.8% of California apricot tonnage was machine harvested in 1978 (2).

Peach harvest equipment, fitted with a different sizing belt, can be used to harvest apricots. The use of harvest machinery to pick apricots was reported only in Stanislaus and Merced Counties. These counties have the greatest cling peach acreage among the apricot producing areas. The adoption of shake-catch technology in the apricot harvest appears as a by-product of the mechanization of processing peaches. The changes in handling and production practices required to machine harvest peaches are very similar to the changes made in the canning peach industry.

Cost Savings

Mechanization of the apricot harvest is not as cost savings as mechanization of the cling peach harvest. Unlike peaches, apricots do not mature uniformly. Yield losses are consequently much higher. Apricots are also very soft and susceptible to damage.

The lack of uniform maturity of fruit in a ripening apricot orchard occurs among different trees in the same orchard, and even between fruit on the same tree. At optimum amturity, 80% of the fruit on a single tree is of proper maturity. The remainder is immature or overripe. As with peaches, the mature fruit cannot be shaken from the tree without removing or damaging immature fruit as well.

Considerable variation exists among trees within the orchard. If the entire orchard is harvested in one operation, much less than 80% of the fruit is recovered. The variability in maturity from tree to tree can be overcome by a system of selectively harvesting only the trees containing a high proportion of mature fruit. The harvester crew is preceded by a worker who selects the trees which are ready for harvest (3)(4). This selectivity is limited, however, by the economics of machine use. Tyler reports that an orchard can be harvested only twice in a 15 day, 10 hours per day harvest season without reducing the acreage capacity of the machine (5).

The lack of uniform maturity is responsible for a yield loss of approximately 20%. SADH was tested in Israel as a growth regulator, but the only maturity character which it enhanced was fruit color (6). In the U. S. growth regulators such as dimazide (Alar) and ethephon (Ethrel) are being used to encourage uniform maturity of peaches (7). If successful growth regulators are registered for use on California apricots, the value of the yield loss could be substantially reduced.

Mature apricots are softer than peaches, and therefore more susceptible to machine damage (8). Most of the damaged fruit suffers from flesh cuts, not bruises (9). Yield loss because of maturity defects and mechanical damage was analyzed in a study published in 1970 (see Table 5-13).

Factors Affecting Adoption

Although most California apricots are for canning, an increasing portion of the crop is being used dried, frozen, or fresh (see Table 5-14). The production of canning apricots, and total production of apricots have been declining (see Table 5-15). The declining market makes it difficult for a producer to increase production to more fully utilize the capacity of the harvest machine.

Table 5-13
Comparison of Yield Loss in Machine Harvested and Hand Harvested Apricots
% of Fruit Received by Processor by Maturity Defect and Degree of Damage

	Machine Harvest Bin Handling	Hand Harvest Bin Handling	Hand Harvest Box Handling
Maturity Defects			
Green	12.24	11.16	9.02
Over-ripe	7.33	5.02	5.04
Mechanical Damage:			
Severe	2.42	0.62	0.24
Moderate	4.73	1.68	0.47
Slight	7.75	5.00	3.76
Total Loss (Excepting Slight Mechanical Damage)	26.72	18.84	14.77
Total Loss in Delivered Load	34.47	23.48	18.53

Source: (10)

Table 5-14
Utilization of California Apricots % of Crop According to Use

Years	Fresh	Canned	Dried	Frozen
1970-71	7.2	68.4	19.9	4.5
1972-73	5.6	75.1	13.5	5.8
1974-75	5.0	70.2	17.3	7.5
1976-77	6.3	59.9	25.9	7.9

Source: California Crop and Livestock Reporting Service

Table 5-15
California Production of Canned Apricots
Annual Average, in Fresh Tons

	1970-71	1972-73	1974-75	1976-77
For Canning	214,100	208,800	184,500	157,000
Total	313,000	278,000	263,000	262,000

Source: California Crop and Livestock Reporting Service

The Brentwood and Winters districts ship apricots to fresh market. Harvest labor displacement will be the smallest in these districts, as the fresh crop cannot be mechanically harvested.

The small scale of many California apricot producers indicates that harvest mechanization will occur in conjunction with consolidation of farms, or contract or cooperative arrangements for harvester use (see Table 5-16).

Table 5-16
California Commercial Apricot Farms, Number and Average Size

County	Number of Farms	Acres of Apricots	Average Acres of Apricots per Farm
Contra Costa	55	1,546	28.1
Fresno	25	2,065	82.6
Merced	34	1,676	49.3
Riverside	7	392	56.0
San Benito	123	2,354	17.7
San Bernardino	9	218	24.2
San Joaquin	54	4,465	82.7
Santa Clara	113	1,992	17.6
Solano	91	1,913	21.0
Stanislaus	180	8,450	46.9
Yolo	22	1,453	66.0
other	114	1,310	11.5
Total	827	27,834	33.7

Source: U. S. Bureau of Census 1974 Census of Agriculture Vol. 1 Part 5 California Table 11 page III-19

Notes.

1. California Department of Employment. California Annual Farm Labor Report "Trends in Mechanization and Farming Methods" p. 12 1959; p. 8 1967

2. This is 13,925 machine harvested tons of 141,255 tons production as reported by California EDD in 1978 Pre-Season Farm Labor Reports DE-3416

3. B. C. Horsfield, R. B. Fridley, L. L. Claypool "Optimizing mechanical harvesting procedures for apricots of nonuniform maturity" Transactions of the American Society of Agricultural Engineers 1972 p. 878

4. R. B. Fridley, P. A. Adrian, L. L. Claypool, A. D. Rizzi, S. J. Leonard "Mechancial harvesting of cling peaches" California Agricultural Experiment Station Bulletin 851 June 1971

5. Ronald H. Tyler "Mechanical Harvesting Costs for Apricots" unpaged (Hollister 1968) University of California Cooperative Extension.

6. Sylvia Guelfat-Reich "Maturation and ripening of 'Canino' apricot as affected by combined sprays of succinic acid 2,2- dimethylhydrazide (SADH) and 2,4,5 tri-chlorophonoxyproprionic acid (2,4,5-TP). Journal of the American Society of Horticultural Science 1975 p. 517

7. L. Van Heek "Mechanical harvesting of peaches in California" Fruit World and Market Grower May 1975 p. 19

8. M. O'Brien, R. B. Fridley, L. L. Claypool "Food losses in harvest and handling systems for fruits and vegetables" Transactions of the American Society of Agricultural Engineers 1978 p. 386

9. Clayton L Haws "'Coming of age' is cannery view of mechanical harvesting" Western Fruit Grower January 1970 p. 16

10. Ibid.

E. Cherries

There are two species of cherry grown in the United States. Tart cherries (Prunus Cerasus) are grown principally in Michigan and the Great Lakes States. There is some additional acreage in the Pacific Northwest. Sweet cherries (Prunus Avium) are grown principally in Oregon, Washington, California and Michigan.

Tart cherries are generally frozen or canned. Only a very small portion of the crop is sent to the fresh market. Sweet cherries, on the other hand, are used primarily as a fresh market fruit. A large portion of the crop is brined. Some of the crop is canned (see Table 5-17).

Table 5-17
U. S. Utilization of Cherries*
Average Annual Production (Tons)

	1950-54	1955-59	1960-64	1965-69	1970-74
Sweet Cherries					
Fresh	36,346	31,682	34,513	38,887	61,602
Canned	16,163	16,168	14,462	14,097	15,324
Frozen	542	488	437	431	-0-
Brined	31,071	36,774	42,062	50,243	53,821
Total	84,122	85,112	91,474	103,659	130,747
Tart Cherries					
Fresh	7,675	6,228	5,498	4,443	3,910
Canned	70,627	62,041	64,335	49,387	41,665
Frozen	47,356	55,779	78,535	70,360	76,775
Brined	932	1,147	1,060	345	-0-
Total	126,590	125,195	149,428	124,535	122,350

*does not include on-farm use
Source: U. S. D. A. Agricultural Statistics 1972, 1976

More than 98% of the California cherry orchards are sweet varieties. About 2/3 of the California cherry crop is shipped fresh, to command high prices as the first deciduous fruit of the year in the U. S. fresh market. About 30% of the crop is brined. A small part of the crop (3%) is canned, principally in fruit cocktail (see Table 5-18).

Table 5-18
Utilization of California Sweet Cherries*
Average Annual Production (Tons)

	1950-54	1955-59	1960-64	1965-69	1970-74
Fresh	13,300	11,560	10,920	15,280	19,420
Frozen	60	-0-	-0-	-0-	-0-
Brined	8,420	9,520	9,640	8,400	8,628
Canned	6,020	6,120	3,760	2,740	1,032
Total	27,800	27,200	24,320	26,420	29,080

*excludes home use or unsold fruit
Source: California Crop and Livestock Reporting Service
Calif. Fruit and Nut Crops: Acreage Production Utilization and Value

Most of the U. S. tart cherry crop is shake-catch harvested. Mechanization occured first in Michigan where a joint research and development effort had been initiated by Michigan State University and the U. S. D. A. in 1956. These researchers developed harvest, handling, and processing equipment (2). By 1971, approximately 90% of Michigan's tart cherry crop was machine harvested (3).

Several factors limit shake-catch harvest of sweet cherries. Machine harvested cherries are bruised and stemless, and cannot be sent to the fresh market. Brining cherries must be harvested before full maturity, when they are still light enough in color to be bleached. Immature fruit is tightly attached, and difficult to shake from the tree (4). The large size of older sweet cherry trees also makes them difficult to machine harvest.

New production practices and handling methods have enabled mechanization of part of the sweet cherry crop for brining. In Michigan, where most sweet cherries are brined, an estimated 60% of the sweet cherry crop was machine harvested in 1971 (6). An estimated 5% of the California cherry crop was machine harvested in 1978 (7).

Change in Production Practices

Cherry trees are restructured for mechanical harvest in much the same way as other fruit trees. The number of scaffold branches is reduced to 3 or 4, low hanging branches are removed, and branches are pruned to permit easy attachment of the shaker clamp (8).

Pre-harvest sprays of ethephon are being used to insure uniform maturity and easy abscission of cherry fruits to be mechanically harvested. When ethephon is sprayed before machine harvest, yields of both sweet and sour cherry trees are increased (9). Ethephon cannot be used under California growing conditions because the ripening agent is phytotoxic to cherries. It causes gumming of the scaffold limbs as well as on the current season's growth (10).

Changes in Handling and Processing

Tart cherries are handled in pallet tanks of water. Field side hydrocooling maintains fruit quality (11). Stems are removed from 85-98% of the fruit during shake-catch harvest (12). The rest of the stems are removed at the processing plant, where orbiting belts carry the fruit past blades which remove the stems. The cherries are scanned by electronic sorters which cull defective fruit (13).

The quality of mechanically harvested sweet cherries for brining can be maintained at a high level if the fruit is brined immediately after harvest (14)(15). Even with immediate brining, the stemless machine harvested fruit cannot be used to make the cocktail pack of maraschino cherries. The pack, which is an important part of Oregon production, requires fruits with stems still attached (16). Most brined fruit is packed stemless in California.

Cost Savings

Fresh market cherries cannot be successfully harvested by machine. Sweet cherries for brining are harvested by machine in both the Pacific Northwest and in the Great Lakes States. Machine harvest of the California brining crop is limited. The cost savings of mechanization are not realized because of the high levels of yield loss. There is no ripening or loosening agent recommended for use in California.

Much of the California brining cherry crop is in old orchards of the Royal Ann variety. The trees are too large for successful shake-catch harvest, and cannot be restructured to adapt to the machine (17). The remainder of the California brining crop is Bing cherries. Most Bing cherry growers wish to sell their crop to the more lucrative fresh market. Brining is an occasional outlet for undersize fruit, and for when the fresh market is oversupplied.

Factors Affecting the Adoption Rate

Average annual production of California cherries increased 20% in the period 1970-74 from the period 1960-64. Expansion has been great in the fresh market production. While use of cherries for brining has fluctuated widely, average production has not changed appreciably. A sharply declining portion of the crop is canned (see Table 5-18).

Table 5-19
Average Size of Calif. Cherry Orchards (acres)

County	Number of Farms	Total Acres of Cherries per Farm	Average Acres of Orchard per Farm
Sweet Cherry Farms			
Contra Costa	19	304	16.0
Fresno	7	151	21.6
San Benito	10	335	33.5
San Joaquin	349	9,634	27.6
Santa Clara	79	1,189	15.0
Solano	16	136	8.5
Stanislaus	24	368	15.3
other	110	646	5.9
Total	614	12,763	20.8
Sour Cherry Farms	42	245	5.8

Source: U. S. Bureau of Census, 1974 Census of Agriculture

Current technology cannot successfully machine-harvest cherries for fresh market. Harvest mechanization of the processing crop can be adopted only on young sweet cherry orchards. If a cherry ripening and loosening agent were registered for use in California, mechanization of the harvest of new orchards would be cost effective.

At the current time, several factors limit new plantings of California sweet cherry orchards for the processing market. Cherry producers can double their returns by sale to the fresh market. There is strong competition from already mechanized production areas, and productions of California cherries for processing has been declining. New orchards will be planted, however, as Royal Ann orchards are pulled from production. Another factor that may have limited adoption to date is the small-scale of most California cherry farms (see Table 5-19).

Notes.

1. 12,763 acres out of 13,008 acres, or 98.1% are sweet cherries according to U. S. Bureau of Census 1974 Census of Agriculture Vol. 1, Part 5 California Table 11, p. III 15-16

2. Jordan H. Levin, H. D. Bruhn, Everett D. Markwardt p. 678 "Mechanical Harvesting and Handling of Cherries" in Fruit and Vegetable Harvest Mechanization: Technological Implications by B. F. Cargill, G. E. Rossmiller, Eds. (Michigan State Univ. 1969)

3. B. R. Tennes, J. H. Levin, B. F. Cargill "Tests on pallet tanks for the cherry industry" Transactions of the American Society of Agricultural Engineers 1975 p. 623

4. Levin et al, op cit., p. 679

5. Ibid., p. 672

6. Tennes, et al. op cit.

7. Warren Micke, University of California Pomology Extension 1978 CIRS Interview

8. R. Paul Larsen "Cultural Practices for Cherry Mechanization" in Fruit and Vegetable Harvest Mechanization: Technological Implications Cargill and Rossmiller, eds., op cit. pp. 687-697

9. "A better cherry harvest courtesty of ethephon" Western Fruit Grower May 1978 p. W-6

10. W. C. Micke, W. R. Schraeder, J. T. Yeager, E. J. Roncoroni "Chemical loosening of sweet cherries as a harvest aid" California Agriculture August 1975 p. 3

11. Michael O'Brien "Deciduous Tree Fruits-- Cherries: Introduction" in Cargill and Rossmiller, eds., op cit. pp. 675-76

12. Levin et al., op cit. p. 677

13. O'Brien, op cit. p. 675

14. Levin et al., op cit. p. 680

15. Robert T. Whittenberger, Robert L. LaBelle "Effects of Mechanization and Handling on Cherry Quality" in Cargill and Rossmiller, eds., op cit. p. 708

16. Levin, et al. op cit. p. 680
Larsen, op cit. p. 692

17. Micke, 1978 CIRS Interview, op cit.

F. Olives

Olives must be processed before they can be eaten. Most California olives, approximately 80% of the crop, are canned (1)(see Table 5-20). Olives for canning are picked at a pale green color, and turn black during processing (2). An average of 14% of the crop is chopped, minced, made into Spanish style green ripe olives, brined, or otherwise cured (3). Olives for oil account for 6% of the crop. The grower return on olive oil is less than half of the return on canning grade fruit. These olives are harvested late in the season, when the fruit has turned black on the tree. This harvest is principally a way to salvage small fruit.

California growers have harvested oil olives with shake-catch frames and shake with roll-out canvas for at least 10 years (4). An estimated 10-15% of the California olive crop was mechanically harvested in 1978. Mechanization of the canning crop began 4 years ago, and is limited to 8,000 acres of new olive orchards planted on the west side of the San Joaquin Valley (5).

Olive branches are thin and willow-like, and do not transmit the energy of the shaker to the fruit with much efficiency. To shake olives from a tree requires more shaking force than is required for deciduous fruits. The small mass of the fruit, their strong attachment to the tree, and the thin and willow-like branches of the tree all contribute to the difficulty in shaking olives for harvest (6).

Shake-catch frames designed for the prune harvest have been tried on olives, but they cannot shake the tree hard enough to remove all of the fruit. Specially designed long-stroke, high-impact shakers are being used to knock the olives from the tree. The fruit is then caught in a canvas catching frame and conveyed to a 4' x 4' field bin.

Orchard Machinery Co. is the principal manufacturer of the shake-catch olive harvester. Their "shock-wave shaker" can be adjusted so the machine can be used to harvest other fruit as well.

Change in Production Practices

A mature olive tree must be restructured for mechanical harvest. Restructuring is necessary so that the shaker can be easily attached to the limbs of the tree, and to provide clearance for a catching frame to fit under the tree. The tree is pruned so that the shaker vibration will be

Table 5-2
U. S. Olive Production and Imports

	Average for Five Year Period		
	1960-64	1965-69	1970-74
°Total U. S. Production (tons)	53,720	56,020	51,320
*Crushed for oil (tons)	7,000	4,074	3,420
Canned (tons)	36,940	41,606	39,960
+Other (tons)	9,780	10,340	7,940
Imports to the United States			
Edible olive oil (1,000 lbs.)	52,301	55,666	58,195
Olives in brine (1,000 gallons)	14,381	14,834	16,312
Dried (1,000 lbs.)	1,005	1,096	1,401

°U. S. Production is in California only
*About 40 gallons of oil are obtained from 1 ton of Calif. olives
+Includes Spanish, Greek and Sicilian styles, and chopped, minced, brined, and other cures.

Source: U. S. D. A. 1976 Agricultural Statistics

transmitted to the fruit.

Restructuring takes 3 to 4 years and causes a small, temporary reduction in yield. The tree is pruned so that there are four or five primary scaffold branches. These upright branches are selected so that the tree is vase shaped. Low hanging branches are removed so that the shaker clamp has access to the primary scaffolds. Long downward hanging secondary branches are removed because they do not transmit the shaking force. Since fruit on these branches are not harvested, the secondaries which do not transmit the shaker force can be identified after harvest, and be tagged for removal (7) (8). The loss of the fruiting wood of the willowy secondary branches can be offset by allowing the tree to grow taller. The goal of tree restructuring is to have the fruit borne on short twig like growth around the tops of the primary scaffolds. This restructuring makes the tree more difficult to hand harvest.

Young trees are pruned for mechanical harvest with the same goal of an upright vase shaped tree. The pruning must be done gradually, as substantial pruning will retard growth and delay development of the young tree (9).

Hartman estimates that approximately half of the state's olive growers are beginning to restructure their orchards for machine harvest (10).

Mechanization studies by University of California scientists have focused on the development of a chemical spray that would loosen the olives, enabling them to be easily shaken from the tree. A number of ethylene generating compounds were tested which succeeded in loosening fruit, but they caused leaves to drop as well (11). The average leaf remains on an olive tree for three years. The production of flowers (and ultimately of fruit) is reduced if more than 25% of the leaves are removed. Researchers in Israel discovered that by raising the pH of the formulation of one ethylene generating compound, ethephon, that fruit abscission could be obtained without excessive leaf drop (12). No loosening agent has yet be registered for use in California.

Changes in Handling

Olives are picked from the tree using ladders. Harvest workers pick into strapped-on picking buckets, which they empty into 35 to 40 lb. capacity field boxes. The picker is paid on the basis of the number of field boxes picked. A few growers use 1,200 lb. capacity bulk bins (13).

Machine picked olives are conveyed into bulk bins. Handling machine harvested olives in tanks of acetic acid or brine did not improve quality in one test (14). New studies are underway to asses the use of sulphur dioxide and ascorbic acid to prevent fruit darkening.

Cost Savings

Olive orchards require no thinning, and little pruning. Harvesting accounts for 50 to 70% of the total cost of olive production, and usually amounts to 35 to 45% of the grower's gross return (15). Harvest mechanization can eliminate most of this labor cost, and has the potential to substantially reduce total production costs.

The value of the yield loss caused by the machine is nearly as large as the cost savings. Yield loss is especially high in orchards which are not sufficiently modified for machine harvest, and in orchards of small fruited varieties. Even with optimistic assumptions about yield, the machine must harvest at least 75 acres before it can pay for itself (16).

Yield Loss

Yield is lost because fewer olives are shaken from the tree than can be harvested by hand workers, and because the harvester can damage the tree. Even with a well-trained orchard and a shaker designed for harvesting olives, 20% of the fruit can be left on the trees (17). In one study, the mechanical harvester shook an average of 85% of the fruit from the trees, compared to 95% picked by hand harvesters (18). Another study showed machine recovery to average almost 80%. The yield loss is not as serious for the larger olive varieties such as Sevillano. The larger mass of the fruit allows it to be more easily shaken from the tree.

Yield loss is much more significant for small fruited varieties such as Manzanillo and Mission. These varieties are predominant in California (see

Table 5-21). Manzanillo olives have been heavily planted since 1965. Ascalano olives are a large and more easily shaken variety, while Barouni is of an intermediate size.

Table 5-21
California Olive Acreage, By Variety
Acres Standing in 1977

Variety	Acres Planted 1965 or Earlier	Acres Planted Since 1965	Total Acres Standing
Manzanillo	11,640	13,568	25,208
Mission	4,995	54	5,049
Sevillano	8,046	2,511	10,557
Ascolano	904	367	1,271
Barouni	394	38	432
Other varieties	110	153	253
All Varieties	26,089	16,681	42,770

Source: California Crop and Livestock Reporting Service
California Fruit and Nut Acreage 1977 p. 15

If an abscission compound is registered for commercial use by government regulatory agencies, growers could use it to shake a much greater proportion of fruit from the tree, which would result in a substantial increase in the cost savings of mechanizing the harvest.

Yield is also depressed to a certain extent by machine damage to the trees. Mechanical shaking can break limbs and shaker clamp injuries can provide sites of entry for the bacteria which causes olive knot. These problems can be minimized by proper harvester operation, tree restructuring, and chemical sprays.

Loss of Quality

Olives are damaged in shake-catch harvest. The fruit impacts against foliage, branches, and catching surfaces. Some of the fruit suffers skin breaks or bruises. The most prevalent injurty is less severe, consisting of superficial scars which are readily apparent on green ripe olives. When processed black ripe, however, the scarring is completely obliterated (20).

Despite studies which show that there is little difference between black-ripe olives which have been hand picked and those that have been shake-catch harvested, processors are still reluctant to accept machine harvested fruit.

<u>Factors Affecting the Adoption Rate</u>

For a period of 25 years the total bearing acreage of California olives remained fairly constant, between 27,000 and 29,000 acres. There were some shifts in production areas, with Riverside, Sacramento and Butte Counties suffering declining acreage, and Glenn, Tehama and Tulare Counties enjoying increasing acreage.

Table 5-22
Average Number of Acres in Olives on Calif. Olive Farms, By County 1974

County	Acres of Olives	Number of Farms	Average Number of Acres of Olives per Farm
Butte	2,834	72	39.4
Fresno	1,627	44	37.0
Glenn	1,641	70	23.4
Kern	5,941	8	742.6
Kings	1,358	4	339.5
Madera	1,492	12	124.3
Tehama	3,689	174	21.2
Tulare	13,100	476	27.5
Other Counties	1,693	63	36.2
All Counties	33,375	923	26.9

Source: U. S. Bureau of Census <u>1974 Census of Agriculture</u> Vol. 1, Part 5, <u>California</u> page III-20 Table 11

A sudden jump in olive prices in the late 1960's spurred the planting of more than 11,000 acres of new olives between 1968 and 1971. As it takes 7 years for olive trees to come into full bearing, these orchards are only now coming into production.

Most California olive farms are very small scale. Statewide, the average farm had 36.2 acres of olives. The new plantings, however, are on a much larger scale, as evidenced by average sizes of 742 and 339 acres in Kern and Kings Counties (respectively)(see Table 5-22). In these two counties virtually all of the orchards have been planted in the last 10 years. By 1980, newly planted orchards will account for an estimated 1/3 of California olive production. It is in these new large scale orchards that the harvest machine is being used.

The market for the expanding California production is limited by the increasing importation of olives and olive products from overseas. Twelve other countries produce more olives and oil than the U. S. California produces the entire U. S. crop, which was 0.6% of the 1971-73 world production (21). All but a fraction of the brined olives and oil olives consumed in the U. S. are imported (see Table 5-20).

With this foreign competition and increasing domestic production looms the possibility of overproduction and low prices. Low prices will hasten adoption for they will lower the value of the yield loss, and make it difficult for hand-harvest producers to persevere. The only compensating competitive advantage of the hand-harvest producers is their ability to harvest green-ripe olives when machine harvested producers cannot.

The most significant factors affecting the degree of cost savings is use of the machine on a sufficiently large scale, and the problems of yield loss. Both the small scale of most producers, and the erratic yields of olive orchards make it difficult to consistently harvest enough fruit for the full capacity of the machine to be used.

Registration of an economically feasible abscission agent for olives will solve much of the yield loss problem, and give machine-harvest producers a sharp competitive advantage.

Notes.

1. 1975-77 average according to California Crop and Livestock Reporting Service California Fruit and Nut Statistics 1965-77

2. R. B. Fridley, H. T. Hartmann, J. J. Mehlschau, P. Chen, J. Whisler p.3 "Olive harvest mechanization in California" California Agricultural Experiment Station Bulletin 855 (November 1971)

3. Ibid.

4. R. B. Fridley, P. A. Adrian "Mechanization and Cultural Practices in Olive Production" in Fruit and Vegetable Harvest Mechanization: Technological Implications B. F. Cargill, G. E. Rossmiller, Eds. (Michigan State University 1969).

5. Hudson T. Hartmann, Pomology Dept., University of California at Davis 1978 CIRS Interview

6. R. B. Fridley, et al. "Olive harvest mechanization in Calif." op cit. p. 4

7. R. B. Fridley, J. J. Mehlschau, H. T. Hartmann, S. H. Logan "Mechanical Harvesting of Olives" Transactions of the American Society of Agricultural Engineers 1973 p. 58

8. "Olives: can they be machine harvested?" California Farmer November 6, 1976 p. 8

9. Fridley, op cit. "Mechanical Harvesting of Olives"

10. Hartmann, 1978 CIRS Interview, op cit.

11. H. T. Hartmann, W. Reed, J. E. Whisler, K. W. Opitz "Mechanical harvesting of olives" California Agriculture June 1975

12. Hartmann, 1978 CIRS Interview, op cit.

13. Fridley, op cit. "Olive Harvest Mechanization in California"

14. Fridley, op cit. "Mechanical Harvesting of Olives" p. 60

15. Fridley, op cit. "Olive Harvest Mechanization in California" p. 3

16. Fridley, op cit. "Mechanical Harvesting of Olives"

17. Fridley, op cit. "Olive Harvest Mechanization in California" p. 24

18. Fridley, op cit. "Mechanical Harvesting of Olives" p. 61

19. Hartmann, op cit. "Mechanical Harvesting of Olives"

20. Fridley, op cit. "Olive Harvest Mechanization in California: p. 9

21. H. T. Hartmann, K. W. Opitz p. 4
"Olive Production in California" California University Division of Agricultural Sciences Leaflet 2474 (Revised April 1977)

G. Apples

Only a small portion of the U. S. apple crop is shake-catch harvested. Mechanically harvested fruit show too many bruises for the fresh market, and can only be used for processing. Machine use has been reported in New York, Michigan, Pennsylvania, Virginia, West Virginia, Maryland, and Calif. (1)(2).

A low profile harvester is the most widely adopted type of machine. The two unit shake-catch harvester has three tiers of foam deceleration strips. The fruit falls through the decelerators onto four transverse conveyors, which carry the apples to a long side conveyor. They are then conveyed into a pallet bin (3). The basic harvester design was developed at Cornell University, and manufactured commercially in New York state (4). This type of machine is no longer manufactured in New York (5). However, a U. S. D. A. researcher has recently tested a similar low profile transfer conveyor harvester in Washington state (6).

Modified cherry harvesters are harvesting apples in Michigan (7). A California manufacturer has introduced a roll-out air cushion harvester (8). About 2% of the New York state crop was machine harvested in 1968 (9). By 1978, only 1% of the crop was shake-catch harvested (10).

Some California apples for crushing (juice, wine, and vinegar) are being machine harvested. Machine harvested fruit accounted for an estimated 1% of the 1978 crop (11).

There has been extensive research and development of apple harvest machinery. Engineers have developed harvesters that dislodge the fruit with air blasts (12)(13)(14), machines with multi-level catching frames (15), and vibrating tines (16), over-the-row harvesters (17), and a machine that surrounds the tree and fills its canopy with plastic spheres to cushion the fall of fruit (18)(19). Despite these ingenious innovations, apple harvest machines either cause too much damage to the fruit, or they are too expensive to be cost saving.

Change in Production Practices

Much of the fruit which is damaged in shake-catch harvest is injured in its fall through the tree before it reaches the catching frame. Even with a perfect catching frame, the characteristic structure of the apple tree is ill-suited for mechanization.

Most of the fruiting branches are above other branches. When shaken, fruit is bruised as it impacts on lower branches. Restructuring a tree by removing lower branches reduces some of this damage, and gives under-tree clearance for the harvest machine (20). Damage from fruit hitting major branches can be reduced by padding major limbs with plastic foam, but this is economically impractical (21).

Apple trees trained with the central leader system have a spindle bush, or Christmas tree like habit. Fruit is borne in the same vertical plane. When the tree is shake harvested, this vertical stacking results in fruit on fruit impact on the catching frame, and serious bruise loss. Trees can be pruned away from a central leader system and towards an open center habit. This lowers the average height of fruiting wood, and distributes the fruit more horizontally.

The conversion of McIntosh trees in New York state caused no loss in yield, but there was still substantial bruise damage when restructured trees were shake-catch harvested (22)(23).

Tree restructuring and limb padding are only partially successful in reducing bruising in the machine harvest of apples because much of the damage is caused by branches that surround the ripening fruit (24).

Smaller trees can be machine harvested with less bruise damage to fruit (25). New apple trees are being planted at closer spacing on dwarf rootstocks. The short, high-density orchards have a number of economic advantages. The trees bear earlier than standard trees. The orchards are higher yielding and more uniformly maturing than standard ones, and the fruit is easier to harvest by hand as well as by machine. Short tree stature allows hand-harvest workers to work without ladders. Because workers' feet remain on the ground, productivity has increased by 50% (26)(27).

Growth regulators have been tested to regulate apple ripening. Ethephon is used to promote fruit abscission, reducing the shaking force needed to mechanically harvest apples. SADH has been used to increase the firmness of fruit, making them more resistant to bruising (28)(29)(30)(31).

<u>Changes in Handling and Product</u>

Mechanically harvested apples must be used soon after harvest. In New York, they are used to make sauce and slicer apples at cannery and freezer.

Off-grade fruit is crushed for juice (32). In California, machine harvested fruit is crushed.

At peak harvest, much of the processing crop is put into cold storage to be processed later in the season. Experiments with post-harvest dipping of apples in Benomyl indicate that the fungicide might successfully allow a 2 to 4 month storage of machine harvested fruit (33)(34).

Cost Savings

Michigan State University researchers analysed the effects of machine induced impacts and product price on the potential cost savings of apple harvest mechanization (35). They found that low prices and high yields would make mechanization more economic under conditions prevailing in Michigan. Modified cherry harvesters and moderately priced catching frames are more feasible than the more expensive low-profile machine, which is practical only in large scale, high yield orchards. With a skilled operator and an orchard modified for mechanical harvest, the harvest machine can operate at a rate fast enough to be economic.

Harvest loss was found to be "a highly significant factor in the feasibility of the apple harvesting system." Assuming that the harvester is moderately priced ($20,000) and that there is a higher than average per acre yield (400 bu./acre), there must be less than a 10% machine yield loss for mechanical harvest to offer a cost saving. Even in extremely high yielding orchards, machine yield loss can be no more than 20% if mechanization is to be cost saving (36).

Shake-catch tests of McIntosh apples by scientists at Cornell University indicate that while special pruning and dwarf stature reduce mechanical bruising of the fruit, damage can be reduced under typical conditions to a level of 25% (37). Tests with a low-profile harvester in Washington showed 14% cullage for Red Delicious (38).

Excess cullage has been the principal reason for the cut back in shake-catch harvest of processing apples in New York. The price received by apple growers is based in part on the amount of damage in the load. Processors have been reluctant to take any machine harvested apples (39).

Factors Affecting the Rate of Adoption

Apples are grown in 34 states in the U. S. Washington, New York, Michigan, and Pennsylvania are leaders in fresh market production, while Washington, New York, Michigan, and California are the top processing states. California is the fourth largest apple producing state in the U. S. Although there have been significant yearly variations in total California apple production, the annual average of production has not changed very much over the last 20 years (see Table 5-23). With stable production, there is little opportunity for producers to expand their scale of operation.

Table 5-23
Production and Utilization of Calif. Apples, Average Annual Production*(tons)

Utilization	1955-59	1960-64	1965-69	1970-74
Fresh Market	61,780	66,590	71,580	61,000
Canned	50,580	61,960	61,510	69,160
Crushed	28,970	40,950	47,390	74,280
Frozen	27,910	28,310	25,700	+
Dried (On Fresh Basis)	49,856	42,190	46,320	31,560
Total	219,096	242,000	252,500	236,000

*does not include on farm use +in this period included with canned
Source: Calif. Crop and Livestock Reporting Service
Calif. Fruit and Nut Statistics

There are, however, two trends which favor harvest mechanization. An increasing portion of the California crop is being crushed. Quality requirements of loads to be crushed are not as stringent as they are for canning and freezing. 43.5% of the 1976 California apple crop was crushed.

The other trend is the planting of dwarf and semi-dwarf orchards, which accounted for 19.7% of California apple acreage in 1974 (40). Even though they are not yet harvested by machine, orchards planted on dwarf and semi-dwarf rootstocks decrease harvest labor requirments for they are easier to harvest by hand.

Notes.

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H. Processing Tomatoes

The harvest of California processing tomatoes has been mechanized since 1969. The machine cuts the entire tomato vine, then shakes the specially bred fruit from the vine and onto conveyor belts, where dirt, vines, and green or overmature fruit are sorted out. The desirable fruit is conveyed to a bin for hauling to the cannery.

A second generation of tomato harvest machine technology is now being adopted, reducing the demand for harvest labor even further. High capacity harvesters with photoelectric sorting systems are eliminating the need for sorter workers, while tank handling has reduced handling labor.

The electronic devices automatically discard green fruit and dirt clods from the conveyor belt, displacing up to 75% of the hand sorting workers. Ten to twelve channels of infrared lamps and photoelectric cells evaluate fruit as it passes over a drop in the conveyor belt. When a green fruit is detected by the electric eye in a channel, the electronic message is relayed by a solid state circuit to trip a pneumatic plunger, and the fruit is rejected. Though each channel has its own independent sensory and reject mechanism, all of the channels use the same electronic circuit. The multiplexing electronics permit elimination of redundant circuits, and are an important feature, for they keep down the cost of a sorter. Hand sorting workers are still needed to remove vines, and overripe, sunburned, or moldy fruit.

The first commercial use of this type of sorter was in 1975, when 12 electronic sorting equipped harvesters were put into operation (1). By the next year, and estimated 240 of California's tomato harvest machines were equipped for electronic sorting (2). By 1977, some 500 machines equipped for electronic sorting were in operation (3).

The widespread adoption of sorters was facilitated by the development of rugged, easily adjusted solid state electronics, and the new high-capacity harvesters. With broader belts and faster operating speed, these machines make it possible to use expensive electronic equipment on a large enough volume that fixed costs are reduced, and the sorters are cost saving. The new model harvesters also have more vigorous shaking mechanisms. Even without electronic sorting, these machines can increase sorter worker productivity.

Old model harvesters are quickly made obsolete by new technology. The first models of the harvester had a lifespan of 3 years (4). A 1977 survey found 60% of the harvesters in operation were less than 5 years old (5). This rapid obsolescence is translated into a correspondingly rapid rate of adoption of electronic sorting and high capacity harvesters in the tomato industry.

Change in Production Practices

A whole new production system was developed to grow tomatoes for mechanical harvest. This technology has been designed to produce high yields of uniform maturing, damage resistant fruit and cut down on sorting labor. Herbicides and precision listing and planting have made it possible for growers to provide a nearly uniform environment for all tomato vines in the field. Early and uniform fruit maturity can be aided by spray application of ethephon (2-chloroethanephosphonic acid)(6). Tomatoes ripened early by ethephon contain lower levels of soluble solids than unsprayed tomatoes (7). The spray breaks down into ethylene, a gas produced at low rates by tomatoes that encourages fruit ripening.

The most critical change in production practices was the development of a durable, small vine variety that set all of its fruit simultaneously (determinate habit). The first successful mechanically harvestable variety was VF-145, the result of a 20 year breeding program at the University of California at Davis (8). VF-145 was not, however, durable enough for machine harvest. About 25% of the fruit was delivered to the cannery with impact cracks (9).

New varieties of tomatoes have been developed with fruit which are pear shaped, elongated, or blocky. Studies showed these shapes more resistant to impact damage (10)(11). The blocky shaped (or square-round) tomato has proven the most resistant to the damage caused by bulk-handling. The square-round varieties have also proven difficult to shake from the vine. This has been one of the reasons that new model harvesters have been equipped with a more vigorous shaking mechanism. Square-round varieties now account for 40-50% of California canning tomato production. The first square-round variety was UC-134, introduced in 1970 (12).

In 1977, the University of California introduced UC-82, a variety that is square-round, firm fleshed, and has a better vine canopy to protect the fruit from sunburn (13). The ability of the vine to "store" ripe fruit means that more fruit can reach maturity before the ripest fruit burn in the sun. This means there are both fewer green as well as fewer overripe fruit to be sorted out at harvest time, displacing a certain amount of labor needed on the harvest machine. About 15% of the 1978 crop was planted to UC-82 (14).

Changes in Handling, Processing, and Product

With the advent of the harvest machine, tomatoes could no longer be handled in 50 lb. lugs. Instead the 900 lb. capacity pallet bin was used to handle the fruit. The empty bins are set on a trailer which is pulled by a tractor down the row with the harvester. When full, the bins are loaded by forklift onto an over-the-road truck.

The pallet bin has been supplanted by the 12-ton capacity tank mounted on a standard over-the-road tandem axle trailer. A larger tractor is needed to haul the tanks through the field, but this bulk handling eliminates the need for fork-lift operators on farm, inspection station, and cannery (15). Adoption of bulk handling has proceeded rapidly (see Table 5-24).

Table 5-24
Adoption of Tank Handling of Calif. Processing Tomatoes

Year	% of Production Handled in Tanks	Source
1969	1%	(17)
1972	20%	(18)
1973	40%	(19)
1977	More than 60%	(20)

The tomatoes are flushed out of the tanks with chlorinated water (16). The problem with tank handling is that the tomatoes are dumped directly into water flushed receiving systems, and must be processed immediately (21). Bins, on the other hand, may be unloaded and stored at the cannery, giving the canner the capacity to accept a surge in tomato deliveries.

Several new California canneries are "partial processing" canning tomatoes. The tomatoes are graded, chopped, and boiled to a paste, then handled in large cans, 55 gallon drums, or refrigerated tank cars (22). The concentrated product is then shipped to eastern processors where it is canned or added to other food products (24).

Cost Savings

Mechanical harvesters can pick the California canning tomato crop at substantially less cost than can hand pickers (25). The second generation of technology is, in turn, cost savings as compared with the original harvester, variety, and handling system. The value of the labor savings, and the cost savings for the new technologies were estimated by Mel Zobel in 1977 (see Table 5-25).

Tank handling requires large, high horsepower tractors, equipment which

Table 5-25
Processing Tomato Harvest Costs

Harvest System	Harvest Labor Cost ($ per ton)	Total Harvest Cost ($ per ton)
Electronic sorting-- Bulk tank handling	3.39	10.02
Manual sorting-- Bulk tank handling	5.92	10.74
Manual sorting-- Pallet bin handling	7.01	12.22

Source: (26)

is economical only on large acreages. The new generation of tomato harvesters require larger and larger scales to realize potential economies (see Table 5-26).

Table 5-26
Average Output of California Tomato Harvest Machines in Acres and Tons

	1961	1965	1969	1977
Tons/Hour	3.7	6.8	11.6	22.1
Tons/Season	1000	2537	3276	5052
Acres/Day	2.2	3.1	3.9	6.2
Acres/Season	80.0	122.0	133.0	220.0

Source: (27)

Photo-electric sorting equipment adds $40,000 - $50,000 to the cost of a tomato harvester. Many growers are using this type of sorter in two shifts, with floodlights making night harvest possible. Double shifts are needed so that the high costs of the electronic units are borne by a large enough production volume to be economical (28)(29). Cannery imposed quotas, necessitated in part by the lack of surge handling of tank loads, have often prevented the full utilization of electronic equipment.

There have been a number of problems with the quality of California machine harvested tomatoes. None of these quality factors have significantly detracted from the overall cost savings of tomato technology.

All determinate varieties are low in soluble solids. The new square-round UC-82 is especially low (30). Ethephon spray also decreases soluble solids. This represents a yield loss to processors, for some tomato products are sold on the basis of the soluble solids content. Research is underway to breed tomato varieties with more sugars.

Though firmer fruited varieties are being planted, mechanical damage to tomatoes remains a problem. The increased speed of the high capacity harvester causes greater mechanical damage (31). The conveyor drop in the electronic sorter causes more damage (32). Tank handling causes greater damage to tomatoes than bin handling (33). 3 - 8% of the total load by weight is lost as juice (34). Soluble solids and pectin are lost as a result (35).

The tomato harvester picks up dirt as well as tomatoes. Michael O'Brien estimates that tomato loads contain on the average 0.5% dirt (36). It has been estimated that dirt and trash removal cost the California processing tomato industry $75 million in 1975 (37).

Factors Affecting the Rate of Adoption

With mechanization of the harvest, processing tomato production has become concentrated in California, and among a small number of farm operators located in a few specialized districts (see Chapter III), accompanied by a consequent increase in the scale of California tomato ranches.

Only 30% of Eastern and Mid-western acreage was machine harvested as of 1975 (38). Frequent and prolonged summer rains in these areas make mechanization of the harvest difficult. The harvester cannot operate in wet fields, and there is mold damage to ripe tomatoes (39).

Decrease competition from eastern producers has not been the only factor enabling California tomato producers to expand acreage. Per-capita consumption of processed tomato products has been rising for at least the last 15 years (see Table 5-27).

Table 5-27
U. S. Per-Capita Consumption of Tomatoes and Tomato Products
Lbs. Consumed 1959-75

Year	Canned Tomato Products						Fresh Market Tomatoes
	Whole Tomatoes	Catsup & Chili Sauce	Paste and Sauce	Pulp and Puree	Tomato & Vegetable Juices+	Total	
1959	4.6	3.6	3.5	0.7	5.1	17.5	12.8
1960	4.6	3.8	3.8	0.7	4.7	17.6	12.6
1961	4.8	3.9	3.7	0.8	4.6	17.8	12.6
1962	4.6	4.1	3.9	0.8	4.7	18.1	12.7
1963	4.6	4.3	4.0	0.8	5.4	19.1	12.0
1964	4.5	4.6	3.9	0.8	4.5	18.3	12.2
1965	4.5	5.0	3.9	0.8	4.7	18.9	12.0
1966	4.6	4.8	4.2	1.0	4.4	19.0	12.4
1967	4.6	4.7	5.0	1.0	4.2	19.5	12.4
1968	4.9	9.8°		1.1	4.0	19.8	11.9
1969	4.9	10.1		1.0	4.1	20.0	11.7
1970	4.8	10.1		1.0	4.1	20.0	12.2
1971	4.9	9.9		1.0	3.9	19.7	11.4
1972	5.1	10.2		1.1	3.7	20.1	11.9
1973	5.8	11.3		1.1	3.3	21.5	12.6
1974	5.0	12.0		1.2	3.6	21.8	11.8
1975*	5.6	13.7		1.4	3.0	23.7	11.5

+ principally tomato juice *preliminary
° beginning in 1968 classified as "other concentrated products"
Source: U. S. D. A. Agricultural Statistics 1976 Tables 264, 266

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I. Fresh Market Tomatoes

Ever since the successful machine harvest of processing tomatoes, tests have been conducted to determine whether the fresh market crop could be picked by machine. From the first tests conducted in 1965, it was discovered that the machine would have to be specially padded to avoid bruising and scuffing the fruit, and that a special mechanically harvestable fresh tomato variety would be needed (1). New varieties such as Pakmor, Calmart, and Castlemart have been harvested by machines fitted with a washing system and padding. Cushioning materials have been put on shaker chains, cross conveyors, and other points where the fruit impacts with the machine. With each new test, engineers and horticulturalists have come closer to developing the suitable tomato variety, and the ideal design of machine (2)(3)(4)(5)(6)(7)(8)(9)(10). Harvest machines and tomato varieties have also been developed at the University of Florida (11)(12)(13)(14)(15)(16). A harvester has also been built at Clemson University, South Carolina (17). The first season-long commercial use of a fresh market tomato harvester occured during the 1978 season in the Salinas Valley. Though the cost savings are uncertain, the grower-shipper had converted its entire production to machine harvest, claiming success in marketing the fruit (18).

Changes in Production Practices

In most respects, production of fresh market tomatoes for mechanized harvest involves the same technology of uniform maturity used to produce the processing crop (19). The key part of the fresh market system is breeding a variety suited to machine harvest. The ideal characteristics of such a variety includes even maturity, a small vine, consumer appeal, and easy detachment from the stem (20).

The stem (pedicel) of the tomato is usually removed when the hand picker harvests the fruit. By contrast, when the machine shakes tomatoes from the vine the stem usually remains attached to the fruit. Stem bearing fruit conveyed to a trailer puncture other tomatoes. This is a serious source of damage. Undercutting the vines so that they wilt before harvest allows greater stem removal, but at risk of sun damage to the crop (21). The stems can be removed by sorter workers on the machines, but the machine must be operated at such slow speeds that the harvest system is no longer cost-saving.

The current focus of varietal development is to incorporate the "jointless" character into a commercially acceptable variety. When shaken by machine, the fruit detaches from the vine, leaving the jointless pedicels still attached to the vine. New varieties tested by the University of California in 1976 separated from the vine with 43% or more fruit still retaining their pedicels (see Table 5-28).

The jointless character is much more pronounced in the MH-1 fruit released by the University of Florida in 1971. Only 10-15% of the MH-1 fruit retain their stems (23). Quality of the MH-1 was reported to be as good or better than the prevailing Florida varieties (Walter and Homestead) (24)(25). The Salinas Valley tomato grower-shipper that harvested by machine

Table 5-28
Stem Retention in Machine Harvest of Tomato Varieties

Variety	Seed Company	% of Fruit Retaining Stems
Hybrid #9	Ferry Morse Seed Co.	82
Castle Hybrid 101	A. L. Castle Inc.	73
VFN 133	Goldsmith Seeds, Inc.	59
VFN 101	Goldsmith Seeds, Inc.	56
Castelmart	A. L. Castle Inc.	43

Source: (22).

in 1978 used an MH-1 type variety developed by the Petoseed Co., but it was reported to have a rough shoulder, a quality defect (26).

Velmar Davis estimates that a minimum of 10 years are needed to breed a new variety. Hanna's development of the processing variety VF-145 took 19 years, but considerable time was lost in developing the concept of what characteristics of a tomato variety could make it suitable for machine harvest (27). The characteristics needed for a machine harvestable fresh market tomato have been identified since 1968, when at least one breeding program was well underway (28).

Changes in Handling and Packing

Hand harvested tomatoes are placed into buckets, which are poured into a trailer. The trailers are tipped and the tomatoes roll into a chlorinated water bath at the packing house.

The Salinas Valley grower-shipper that used a mechanical harvester in 1978 handled the fruit in 12½ ton processing tomato tanks. The tomatoes were flumed from the tanks with cholorinated water, and then conveyed onto a highly automated packing line. While the mechanized packing line is not integral to mechanized harvest, it is quite labor saving on its own. Sizing, volume filling, and carton lidding were all done automatically.

The use of fungicides has been cited as an "absolute necessity" in packing machine harvested tomatoes for fresh market (29). The fungicide retards spoilage by organisms introduced with mechanical damage. Fungicide and wax sprays are already in widespread use in tomato packing sheds.

Cost Savings

The value of the labor saved in mechanical harvest is dependent on sorter worker productivity. Unless a jointless tomato variety is being harvested, productivity is very low. Jointed or partially jointed varieties must be sorted with a large number of workers destemming the tomatoes. The harvester output is limited, as machine pace must be slow enough for destemmers to handle the fruit. Test harvests with Castlemart in Merced County in 1976 required 12 sorter workers on a machine that harvested 3.8 tons per hour. This is only 3 times as productive as hand-harvest workers. Studer and Chen found this system more expensive than hand-harvest (30).

The 1978 harvest of MH-1 type tomatoes in the Salinas Valley required 15 sorter workers on a machine harvesting an estimated 10 tons per hour (31). While this would mean that the machine system is substantially cost saving (more than 50% of harvest costs), this estimate must be used with caution as there was no evaluation made of the fruit when it arrived at market.

Quality is an important consideration for the fresh market tomato industry. MacLeod, Kader, and Morris studies the changes in quality over the shipping and handling period. The part of the pack that was unmarketable in the "vine ripened" (actually picked pink) tomatoes increased from 11% at the shipping point to 17% at retail. There was 30% loss in a sample of fruit picked mature green (32). With such high levels of damage, retail receivers are unlikely to accept machine harvested fruit with even greater amounts of fruit injury.

In early mechanization trials dust and dirt in the machine harvested tomato pack shortened the shelf life of the fruit. Washing units installed on the harvester have been successful in eliminating this source of damage (33).

Post-harvest evaluation of mechanically picked mature green Castle 29 tomatoes showed an increase in the levels of unmarketable fruit over the hand-picked control. The total loss was only 7.8%, however, an amount considered to be low for many mature green operations (34). Fruit harvested at a stage more mature than green-ripe will suffer more quality damage. The machine can harvest mature-green fruit, and damage can be held to a commercially acceptable level.

Factors Affecting the Rate of Adoption

Though per capita consumption of fresh market tomatoes in the U. S. has declined since 1948, population growth has been large enough that the total market supplies continue to increase (35). Fresh market tomato acreage in the U. S. has declined, in part because of competition from tomatoes imported from Mexico.

California acreage remained fairly constant between 1948 and 1972. Edward Jesse noted shifts in the location of fresh market tomato acreage in California (see Table 5-29).

Table 5-29
Distribution of Fresh Market Tomato Acreage Among California Districts
1948-52 and 1968-72 Averages

District	1948-52	1968-72	% Change
Chula Vista-Oceanside	5,320	4,618	-14
Imperial Valley	4,020	2,240	-44
Oxnard	5,810	3,154	-46
Cutler-Orosi	3,380	2,860	-15
Gonzales-King City	2,140	4,190	+96
Merced	2,740	5,262	+92
No. San Joaquin Valley	4,510	8,720	+93
Other	2,540	636	-75
Total	30,460	31,680	+ 4

Source: (36)

He reported that:

> "Increased acreage in the mature green districts (Northern San Joaquin Valley, Merced and Gonzales-King City) and the corresponding drop in acreage in the vine-ripe districts (Cutler-Orosi, Oxnard and Chula Vista-Oceanside) are consistent with the national trend toward mature green production. Underlying this trend is better control of ripening through (ethylene) gassing and the inherently lower costs associated with mature green production and packing (37)."

Jesse noted that reduction in Imperial Valley acreage was caused by early season competition from Mexico and Florida.

Sensory evaluation in repeated trials has documented consumer preference for vine-ripened tomatoes over fruit harvested mature-green and ripened off-vine. Vine-ripe fruit are sweeter, contain more Vitamin C, and are perceived as more "tomato-like" (38). Opinion surveys have documented consumer dissatisfaction with the price and quality of fresh market tomatoes now available (39).

So far vine-ripe and pink tomatoes cannot be harvested by machine. The harvest of mature green tomatoes is more amenable to mechanization. If harvest machines are adopted, they will most likely be used in the mature green districts. The shift in acreage would be expected to continue to follow the trend identified by Jesse. The vine-ripe districts, if still hand harvested, would be at an even greater competitive disadvantage with mature green producers.

Notes.

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12. "'Sunshine' for fresh-market tomato harvest" American Vegetable Grower May 1971 p. 26

13. Chuck Woods "First tomato released for mechanical harvesting" Florida Grower and Rancher November 1971 p. 10

14. "Tomato semi-harvester offers a now solution" American Vegetable Grower March 1972 p. 60

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16. "Tomatoes: death of an old industry and birth of a new one" Flordia Grower and Rancher 7-8/1972

17. C. E. Hood, B. K. Webb, Y. Alper, E. T. Sims Jr., R. A. Jobes "A new fresh market tomato handling system" Transactions of the ASAE 1975 p. 1021

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31. 1978 CIRS Survey

32. Richard F. MacLeod, Adel A. Kader, Leonard L. Morris "Damage to fresh tomatoes can be reduced" California Agriculture December 1976, p. 10

33. "Industry Shows Renewed Interest in Machine Harvesting Fresh Tomatoes" Western Grower and Shipper October 1977 pp. 6-7

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J. Asparagus

Only a small portion of the asparagus crop is mechanically harvested. Mechanization is limited to the processing crop. In California, about 1.2% of the total crop is harvested by machine (1). This asparagus is sent to the dehydrator for use in soups (2). In Michigan, Washington, and New Jersey about 40% of the crop is picked by machine and sent to processors (3).

In Michigan, machine harvested asparagus is sent to the freezer. The simple sled-box harvester is in widespread use in that state (4). It uses band saw blades or another sharp edge set in a shallow "v" on the harvester. By moving rapidly through the field, the tractor drawn sled-box blade snaps the spears off cleanly, and the forward motion causes them to accumulate at the back of the sled. Some systems include fork lift handling of the full sled-box.

More refined asparagus harvesters include a moving band saw blade to cut the spears, a fan which separates trash from the spears as they are blown into a collecting pan, conveyor belts that load the asparagus into an accompanying bin, and multi-row operation.

The horizontal blade cuts all of the spears in the bed. It is non-selective. It cannot discriminate between short and long spears, as can the hand-harvest worker. Because of this lack of selectivity, short spears are not permitted to develop, and approximately 54% of the yield is lost (5).

Engineers have developed a selective harvester with the goal of reducing this loss in yield. The harvester selects only the large spears. Despite highly developed sensing and cutting mechanisms, the selective harvesters are able to reduce yield loss to only 47%. One cause of the yield reduction is the injury to the short, unselected spears. The selective machine has higher operating costs than the non-selective harvester rendering it economically infeasible.

Changes in Production Practices

Asparagus is a perennial crop. Each spring the asparagus spears develop from buds that are on short rhizomes of the crown. The spears must be cut before they open to fern. By late spring, the harvest is over, and the plant is allowed to grow. The fern is mowed or burned in the fall, in preparation for the next spring's harvest.

Agronomists and engineers have identified several characteristics of an asparagus planting which would be ideally suited to non-selective harvest. These characteristics include:

1. Increase in plant population to give higher yields (6).
2. Delayed opening of heads so spears can grow taller before opening to fern (7).
3. Cycling of the production of spears from the crown of the plant. The goal of the cyclic growth is to produce the emergence of a flush of spears of similar height which all could be harvested at once by a non-selective cut. Two strategies have been suggested to achieve cyclic growth. One is to use growth regulators to eliminate the effect of apical dominance of growing spears (8). The other is breeding varieties with the cyclic character.

Higher planting density was used to facilitate machine harvest in Delaware. Crowns were spaced 6 to 8 inches apart, doubling the plant population (9). In California high density stands have high initial yields, but as the planting grows older, normal yields soon return. The high initial yields include many more spears, but they are smaller in size (10)(11).

Agricultural scientists have concentrated most of their efforts on breeding new asparagus varieties suited to machine harvest. One new variety, UC 157, has been bred at the University of California. Its development may contribute to the adoption of harvest machines. The variety has two characteristics which make it adaptable to machine harvest. University plant breeders estimate that the variety will yield 40 to 100% more per acre than current varieties (12). The variety also has a strong tendency to initiate clusters of 3 to 5 spears at a time. This is the cyclic production character (13). Production of spears in clusters precludes, however, the use of selective harvesters. Current models cannot recycle their selection mechanisms rapidly enough to cut the adjacent spears (14).

The rate of adoption of any new asparagus variety will be slow because asparagus is a perennial crop which has a productive life of 8 to 15 years. A new variety can be introduced only as older fields are retired from production, or with increased markets and hence increased production of the crop.

The rate of adoption of UC 157 is also limited by the difficulty in propogating the hybrid seed. Asparagus is a dioecious plant (male and female flowers are borne on seperate plants). The hybrid's parents must be propogated asexually, then the cross is made. Production of the hybrid seed have been limited to 1,200 pounds per year, not enough seed to keep up with orders. The University is filling only California orders until enough seed is available.

The seed is being sold at high cost, $50 per pound as compared to $10 a pound for ordinary varieties. Growers are sewing the seed in greenhouses, and then transplanting young plants to the field. While more expensive than direct seeding or planting asparagus crowns, this system permits the scarce seed to be used in planting a larger acreage. A pound of seed can establish 2½ acres of plants. At current production rate, no more than 3,000 acres a year can be planted to the new variety (there are 37,000 acres of aspragus in California). U. C. plant breeders hope to produce 3,000 pounds of seed a year by 1981, which would allow some 7,500 acres a year to be planted (15).

One problem of uncertain magnitude is that the new variety is not resistant to fusarium wilt. Fusarium infections could reduce or eliminate the expected yield increases. Plant breeders claim the variety is vigorous enough to outgrow the damage caused by the pathogens (16).

Changes in Handling

Hand harvested asparagus is loaded onto tractor drawn sleds, then taken to a field shed where it is washed and trimmed. If the asparagus is for processing, the spears are trimmed to a 7" length and stacked neatly into field lugs for transport to the cannery. Asparagus for fresh market is cut much longer, and trimmed twice to yield a 9" spear. The spears are size graded by hand and packed in the standard pyramid crate.

Machine harvested asparagus consists of spears of various lengths which are loaded ungraded and jumbled together in a pallet bin. For a cut spear product, such as frozen asparagus, few changes are needed to process the crop (17). In fact, the presence of short spears increases the percentage of tips in the product thereby increasing the quality of the pack (18).

Most California asparagus for processing consists of whole spears packed in a can. Machine harvested asparagus which is to be spear packed must be size graded, aligned, and oriented in the same direction. A use must also be found for the short spears.

If machine picked spears are flumed or conveyed past processing workers so that they can be reoriented by hand, the cost is 2 - 2½¢ per pound (19). This is a significant cost when compared to 8¢ per pound paid to hand-harvest workers. A number of inventions have been developed to solve the problem of grading and orienting machine harvested asparagus (20). The orienters all use a system based on the fact that the center of gravity of a spear is closer to the base than to the tip end.

The mechanical devices that align and orient the spears can be installed on the harvester itself, or in the processing plant (21). The mechanical systems can re-orient 80 - 85% of the spears. Stationary systems intended for use in the processing plant have received the most attention. One Northern California canner has already installed an orienting machine to align asparagus for a spear pack. This machine allows the hand harvested crop to be brought from shed to cannery in a 4' x 4' pallet bin instead of the customary field lug.

Despite the development of mechanical asparagus orienters, a high proportion of the crop harvested by a non-selective machine is too short for a spear pack. Only a small portion of California canned asparagus is a cut spear product.

Mears, Carpenter, and Stammer have developed a possible use for the short spears. They washed and graded the asparagus, and packaged it for the fresh market in paper trays overwrapped with clear plastic. Though a marketing study indicates consumer preference for the product (22) and an economic study shows the system might be cost efficient (23) the question of machine induced damage has not been satisfactorily answered.

Cost Savings

In each sweep of the selective machine through the field it selects only the tallest spears. The selective harvester must return every one or two days. The non-selective harvester cuts all of the spears and returns in 4 to 5 days to harvest the next flush of growth.

No matter which machine is used, most of the harvest labor is displaced. But because the selective machine must make many more trips through each field, it cannot harvest as much acreage in a single season. The costs of the machine per unit of production are too high for the selective machine to be practical. Kepner calculated the seasonal capacity of the harvest machines (see Table 5-30).

Table 5-30
Seasonal Capacity of Asparagus Harvest Machines

Machine		Capacity
Selective Harvester	1 row	33 acres
Selective Harvester	3 row	100 acres
Non-Selective Harvester	1 row	105 acres
Non-Selective Harvester	3 row	315 acres

Source: (24)

Calculated on a per acre basis, the selective harvester requires 5 times the labor, and has 3 or 4 times the overhead and operating cost of a non-selective harvester (25). The yield difference between the harvest machines is not large enough to justify the greater costs of the selective machine. The selective machines harvest about 53% of the marketable spears, while non-selective models can collect about 46% (26). In well managed fields the non-selective harvester is proving capable of yields nearly as high as the selective machine (27).

Whichever machine is used, the value of the yield loss in California fields remains so substantial that it remains more economical to harvest by hand. Yield is lost in non-selective machine harvest in a number of ways. There are fewer cuttings in a machine harvest, resulting in a doubling of the number of unmarketable spears because of opening heads. There is also some mechanical damage to the spears during harvest. The greatest yield loss occurs because the machine cuts spears before they are ready to harvest (28). Although the selective harvester does not cause this sort of yield loss, it does damage some of the unselected spears, and they are lost anyway.

The University of California asparagus breeders believe that a high yielding, cyclic producing variety will encourage mechanization through compensation for the loss of yield. No planting of the new UC 157 variety has yet been harvested by machine, so it is not known whether this variety will give mechanized producers a cost savings. Frank Takatori has observed that the new variety tends to produce a cyclic flush of growth only at the beginning of the season, and that the cyclic character is not very pronounced (29).

Another cost consideration is the fact that the high yielding variety will also increase the productivity of hand-harvest workers. Asparagus plantings of high yielding varieties may still be more economically harvested by hand, especially if workers are paid a lower piece rate for harvesting high yield plantings.

The loss of quality of machine harvested asparagus is a serious barrier to the mechanization of the fresh market crop.

Factors Affecting the Rate of Adoption

The adoption of new asparagus varieties is limited by the fact that hybrid seed production is a very slow process, and that, as a perennial, only a small part of asparagus production is planted anew each year.

Asparagus is a declining industry in California, and in the United States. U. S. production of both fresh market and processing asparagus is declining. In California, asparagus production for fresh market has not changed substantially. California now produces 75% of the fresh market crop in the U. S. (see Table 5-31).

Production of California processing asparagus has declined at a faster rate than total U. S. production. One cause of this declining production has been the loss of the European export market for white asparagus (see Table 5-32). White asparagus is a labor intensive crop. The spears are grown on a raised bed. At harvest they are cut 8" below the top of the bed, just as the spear breaks through the surface. A great number of selective hand harvests are required to pick the spears at exactly the right point, before the tip begins to turn green in the light. Mexico and Taiwan now produce a white asparagus crop.

Table 5-31
U. S. and California Asparagus Production
Annual Average Production for Five Year Periods

	1956-60	1961-65	1966-70	1971-75
Production in 1,000 Cwt.				
California				
Fresh Market	664	604	560	645
Processing	1,202	1,274	867	663
Total Production	1,866	1,878	1,427	1,308
United States				
Fresh Market	1,252	1,043	862	860
Processing	2,355	2,551	2,166	1,732
Total Production	3,607	3,594	3,028	2,592
California as % of U. S. Production				
Fresh Market	53.0	57.9	65.0	75.0
Processing	51.0	49.9	40.0	38.3
Total Production	51.7	52.2	47.1	50.5
% of California Production for Fresh Market	35.6	32.2	39.2	49.3

Sources: Calif. Crop and Livestock Reporting Service
California Vegetable Crops: Acreage, Production and Value
U. S. D. A. Agricultural Statistics

Table 5-32
Exports of Canned Asparagus, Calif. & U. S.

Year	California		United States	
	Quantity (1,000 lbs.)	Value ($1,000)	Quantity (1,000 lbs.)	Value ($1,000)
1962	58,000	12,700	64,107	14,077
1963	53,000	12,250	62,246	15,100
1964	51,700	12,300	61,745	15,571
1965	38,300	9,810	46,443	12,482
1974-75	1,368	514	*	1,892
1975-76	375	194	*	1,322

Source: Calif. Crop and Livestock Reporting Service Exports of Agricultural Commodities Produced in Calif., 1962-62, 1963-64, 1964-65, Fiscal Year 1975-76

* information not given

Table 5-33
Harvested Calif. Asparagus Acreage, By Counties
Annual Average for 2 Year Period

County	1955-56	1966-67	1971-72	1976-77
Contra Costa	10,020	4,305	1,640	1,290
Monterey	*	2,560	3,250	2,740
Yolo	2,245	1,800	1,310	820
San Joaquin	57,690	32,400	27,615	18,990
Imperial	280	1,955	3,705	3,840
Orange	475	395	1,245	1,180
Riverside	75	2,630	1,935	300
Other Counties	5,665	5,005	3,650	2,940
Total	76,450	51,050	44,350	32,100

Source: Calif. Crop and Livestock Reporting Service Calif. Vegetable Crops, Acreage, Production and Value

* less than 50 acres

California asparagus acreage has declined to less than half of what was harvested 20 years ago. Much of this change reflects the loss of the white asparagus market, but production of green canned asparagus has dropped as well. Freezer asparagus production has increased. Production has declined most in the Sacramento-San Joaquin Delta area, and the surrounding counties. This decline has been greatest in San Joaquin, Contra Costa, Yolo, Sacramento, and Solano Counties (see Table 5-33).

The decreasing production makes it less likely that there will be large scale plantings of the new asparagus variety for machine harvest. However, a Kern County farm operator is planning to seed 3,000 acres of UC 157 (30).

Notes.

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2. Brian Benson, Dept. of Vegetable Crops, University of California at Davis. 1978 CIRS Interview

3. Ann Amioka "UCD develops asparagus hybrid" Woodland-Davis Daily Democrat June 2, 1978 p. 7

4. "Streamlining asparagus production" American Vegetable Grower June 1974 p. 11

5. R. A. Kepner "Selective versus non-selective mechanical harvesting of green asparagus" Transactions of the ASAE 1971 p. 405

6. "Asparagus most profitable when harvested by hand" Western Grower and Shipper February 1970 p. 32

7. Kepner, op cit.

8. "Streamling asparagus production" op cit., p. 12

9. Amos Kirby "Harvesters for 1200 acres" American Vegetable Grower February 1970 p. 24

10. Benson, 1978 CIRS Interview, op cit.

11. Frank Takatori, Dept. of Plant Sciences, University of California at Riverside, 1978 CIRS Interview

12. Amioka, op cit.

13. B. Benson, F. Takatori "Meet UC 157" American Vegetable Grower May 1978 p. 8

14. Amioka, op cit.

15. Ibid.

16. Benson "Meet UC 157" op cit., p. 9

17. David R. Mears, Lih-Yen Shiao, Mark E. Singly "Simulation of a fresh market asparagus packing line" Transactions of the ASAE 1977 p. 189

18. "Streamlining asparagus production" op cit.

19. Gajendra Singh, Milo J. Moore, David R. Mears "Mechanical orientation of asparagus spears and related physical properties" Transactions of the ASAE 1971 p. 985

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21. Singh, op cit.

22. David R. Mears, Harold E. Carpenter, Richard W. Stammer "Sorting and packing machine-harvested asparagus for the fresh market" Transactions of the ASAE 1974 p. 876

23. Mears "Simulation of a fresh market asparagus packing line" op cit.

24. Kepner "Selective versus non-selective mechanical harvesting of green asparagus" op cit.

25. "Asparagus most profitable when harvested by hand" op cit.

26. Kepner, op cit.

27. Mears "Sorting and packing machine-harvested asparagus for the fresh market" op cit.

28. Kepner, op cit., p. 407

29. Takatori, 1978 CIRS Interview, op cit.

30. Benson, 1978 CIRS Interview, op cit.

K. Celery

A whole range of technological innovations have been used in attempting to reduce the labor required to harvest and pack celery. Conveyor belt harvest aids, mechanical cutters, various packing systems, mechanical trimming, and automatic weight sizing machines have been adopted for commercial use in the U. S. Most of these innovations have been tried and subsequently abandoned for the harvest of fresh market celery in California, where more than half of the U. S. crop is produced.

Celery is mechanically cut in Florida and Michigan, the second and third ranking states in celery production. The basic harvester is a tractor mounted machine which cuts the celery at or below ground level, and grasps the head with opposing elevator belts which lift it to a horizontal belt so that it may be conveyed into a trailer for hauling to the packing shed. More advanced models are self propelled, and may be capable of harvesting several rows at once.

The small part of the California celery crop which is used for processing is entirely cut by machine (1). The fresh market crop, however, is entirely hand cut. Most of it is packed in the field.

Changes in Production Practices

The cultural and physical characteristics of celery make it ideally suited for mechanical harvest. The crop grows to a uniform height, and it is hand harvested in a single cutting. This is possible because there is a market for a variety of sizes of celery heads. Other attributes which give celery the potential for machine harvest include the fact that stalks are cut at ground level, making it easy to position the cutting mechanism, and that the outer petioles (or stalks) which can be damaged by a mechanized system are stripped from the head before it is packed for market (2). There are evidently no special production practices required to grow a crop for mechanical harvest.

Changes in Cutting-Packing System

The celery harvest involves several operations. The celery is first topped by a tractor mounted blade which mows the entire field to 16" - 18" high (3). The crop is cut, the outer petioles trimmed off, and the heads are packed into a shipping crate. Packing may be done in the field, or in a packing shed.

Harvest aids have long been used to save the labor needed to load the celery that has been hand cut. Most harvest aids include long, waist-high conveyors which run perpendicular to the row. The harvest workers cut and trim the heads, and set them on the conveyor, which carries them to a bulk bin.

In an attempt to minimize the handling of celery even further, a "T" shaped arrangement of 3 conveyors was attached to a mobile packing house called a "mule train" (4). The mule train was used both in California and Florida and employed a crew of up to 45 workers (5). Though the handling of cut celery was mechanized on the mule train, it remained a labor intensive operation requiring workers to cut and strip the heads. One of the earliest mechanical celery cutters was a 10-row machine built by Boots and Son Co. (Belle Grade, Florida) for use with the mule train mobile packing house (6). The mule train is no longer used in California, and is being abandoned in Florida as well (7). The big machine is prone to break down, and worker time is lost as the machine turns from one row to the next (8).

Mechanical celery cutters are used with shed packing in Florida and Michigan. Single row, tractor mounted harvesters are manufactured by Roy M. Lane and Sons (Belle Grade, Florida) and Lakewood Mfg., Inc. (Holland, Michigan)(9)(10). These machines bulk load the crop for delivery to a stationary packing shed, where it is trimmed, washed, and packed for shipment (11).

Mechanical cutting and loading have also been used by California producers. A self-propelled, two-row harvester was developed by Poly-Ag Co. (Hayward, California). A single-row, self-propelled model built by the High-Gear Harvesting Co. (Guadalupe, California) has harvested celery for shed packing in several California districts, but it is no longer used to harvest the fresh market crop (12).

One crucial advantage of the mechanized producers in Florida and Michigan is that they are harvesting on organic muck soil, which does not adhere to the celery. California producers harvest on mineral soil, which sticks to the celery harvested by machine. Although the dirt can be washed from the load, it becomes costly to remove the dirt from the packing shed.

Additonal petioles are stripped from machine harvested celery, reducing yield and increasing the amount of waste celery which must be handled. Although the machine eliminates most of the cutting labor, this is but a portion of the harvest work. When machine harvested celery is sent to the shed, it arrives unoriented and tangled in a bulk load, so additional shed labor is required. These extra costs, and the inaccuracy of the harvest cutter component when the fields are wet have prevented mechanization of the California celery harvest.

At the close of the Bracero era, the California celery industry switched from field packing to packing in a shed. In the past five years, the trend has been reversed. Now most of the state's celery is once again packed in the field.

Hand cutters work ahead of a three-wheeled mobile packing platform called a "hump." Three cutters work with each platform, cutting, trimming, and stripping celery heads. Three packing workers segregate the heads piled in front of them by size, and pack them into crates or cartons in 3 to 5 different size packs. They push the wheelbarrow-like hump ahead as they work down the row. A lidding worker closes the pack, which is then loaded on a truck for delivery to the cooler (13)(14)(15).

Some of the heads are too small for the smallest pack. These are often put in field boxes for trimming and bagging as celery hearts. Most California celery is now field packed. Estimates of the part of the crop that was field packed in 1978 varied from 75% in Ventura County, where two or three packing sheds operate, to more than 90% in the Salinas Valley, where only celery hearts are packed in the shed (16)(17)(18).

Some 5% to 10% of the celery crop is machine cut for processing. The High-Gear Harvesting Co. mechanically harvests virtually all of California's processing crop on contract. The machines are set to cut the celery above the ground, causing the head to fall apart. The heart is dropped in the field. The heart is a defect with respect to the dehydrator because it turns grey when dried. Hearts cannot be fed through the slicing machines, and so they cannot be used for soup, juicing, or freezing either (19).

Mechanical harvesting of processing celery has a history of some 10 years, occuring "hand-in-glove" with the growth of the dehydrated celery industry. The product is used for soup mixes and other processed food items.

Cost Savings

Of the various harvest systems, each of which has been commercially tested in California, the system of hand cutting and field packing has proven to have the lowest cost. Additonal labor costs incurred in handling and packing machine harvest celery, the necessity of an expensive packing shed, and the loss of yield caused by machine damage to celery petioles, are all factors which reduce the potential cost savings of the mechanized system. Changing quality appears to have little or no effect on the degree of cost savings. With only a portion of the labor costs being saved (the cutting work), the mechanized system is not cost saving in California.

There is a net cost saving, however, in Florida and Michigan, principally because the extra costs of handling and washing machine harvested celery are not as great as they are in California.

Factors Affecting the Rate of Adoption

The celery industry has undergone rapid changes in harvest technology over the past 20 years. It has shown a predisposition towards rapid adoption of labor saving and cost reducing technology.

Celery production has become concentrated in Florida and California, which together produce more than 85% of the U. S. crop (see Table 5-34).

Table 5-34
Commerical Production of Celery, Acreage by States as a % of U. S. Production

State	1934-1943 Avg.	1953-1954 Avg.	1959-1963 Avg.	1969-1970 Avg.	1973-1974 Avg.
California	34.1	43.0	46.7	51.3	54.7
Florida	18.2	28.1	33.7	35.7	30.7
Michigan	16.1	9.0	6.8	5.9	7.1
New York	11.6	6.3	5.9	3.4	3.1
Washington	1.3	1.3	0.9	0.9	0.7
All Other States	18.7	12.3	6.0	2.8	3.7

Source: U. S. D. A. Agricultural Statistics

Within California, celery production is being concentrated in Ventura and Monterey Counties (see Table 5-35). Production in these two counties is dominated by several large grower-shipper firms such as Bud Antle, Inc., and Sun Harvest Inc., which maintain year-round operations in both production areas, harvesting the Salinas Valley crop from July to December, and harvesting the crop on the Oxnard plain from January to June.

Such large operations may inevitably adopt machine harvesting in

Table 5-35
California Celery, Annual Average Acreage Harvested, By County

County	1955-1956	1966-1967	1971-1972	1976-1977
Orange	1,875	1,470	1,165	1,265
San Diego	1,785	1,210	525	545
Ventura	1,280	4,275	6,655	8,990
Monterey	3,320	5,330	5,685	6,350
San Luis Obispo	1,370	1,570	1,535	1,235
Santa Barbara	1,300	1,050	1,330	1,420
Los Angeles	1,825	*	*	*
San Joaquin	1,700	*	*	*
Santa Clara	1,535	*	*	*
Other Counties	760	745	255	295
California total	16,750	15,650	17,150	20,100

Source: Calif. Crop and Livestock Reporting Service <u>California Vegetable Crops: Acreage, Production, and Value</u>

* production included in other counties

conjunction with highly mechanized packing sheds, such as are now being used in Floria. Machine cut celery is unloaded by dumping in a water bath. Mechanized trimming and automatic weight sizing of heads eliminates much of the trimming, stripping, and grading labor.

<u>Notes</u>.

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L. Cucumbers

Cucumbers for processing are mechanically harvested in Michigan. In 1974, approximately 25,000 acres or 90% of the state's pickle acreage was picked by various models of once-over harvesters. Only 9,500 acres were mechanically harvested that year in the rest of the United States (1). Machine harvest technology was developed at Michigan State University, where research began in 1957 (2).

Once-over harvest machines cut the entire cucumber vine from the ground, then seperate the fruit from the vine with rubber pinch rollers. Self-propelled and tractor mounted machines have been built by at least six manufacturers. The tractor mounted Wilde pickle harvester is the most popular (3)(4).

Researchers at North Carolina State University have developed a multiple pick harvester, one that is not vine-destructive. The harvester runs its long tapered "fingers" under the vines, then snaps the cucumbers off as the vine is drawn over a curved bar (5). The multi-pick machine has been commercially manufactured (6).

Once-over harvest machines have been used in California. An estimated 20% of the California pickle crop was mechanically harvested in 1967 (7). No new harvest machines have been sold since that time, and adoption remains at 20% of the crop (8).

Change in Production Practices

A new production technology of uniform fruit development has been created to make once-over harvest economically feasible. Precision planting provides a uniform environment for all of the vines in a single field. High density plantings of special varieties provide for a more uniform fruit set.

Hybrid cucumber varieties have been developed with dwarf and gynecious (all female flowered) characters (9). Since fruit develop from female flowers, gynecious plants produce a large number of fruits per plant. Seed suppliers blend in 10-15% monoecious (male and female flower) pollinator variety with gynecious seed (10). Bee hives must be set in the field during flowering to insure concentrated and complete pollination. Pollination must be complete within four to seven days for fruits to be uniform enough for once-over harvest (11).

The dwarf character is one of shortened internodes. Flower bearing axils are closer together on dwarf varieties, increasing the number of fruit produced in a given area of soil.

Dense plan populations are integral to the once-over production system. Growers plant and thin to attain a stand of 60,000 to 80,000 or more plants per acre (12)(13).

Growth regulators have been tested with the goal of concentrating fruit production. Ethephon, SADH, and maleic hydrazide inhibt growth and induce production of female flowers (14). Chlorflurenol sprays can increase the number of fruit per plant (15).

Changes in Handling and Product

California processing cucumbers have been handled in pallet bins. This is now changing. Both hand and machine harvested cucumbers are now being handled in bulk tanks mounted on standard over the road trailers, such as those now in widespread use in the processing tomato industry (16).

The once-over harvester recovers relatively few of the smaller sized fruit. Mechanization has encouraged production of large size Kosher dill pickles at the expense of small gherkin pickles. Researchers at Michigan State are developing a "small pickle" production technology. By planting gynecious varieties that set fruit without pollination (parthenocarpy) and spraying with Curbiset, researchers have reduced the fruit inhibition effect whereby early fruit inhibit the set of additional fruit. The resultant concentration of fruit set raises yields for once-over harvest, and may make production of "small pickles" for mechanical harvest economically feasible (17)(18)(19).

Cost Savings

A number of factors limit the cost savings of multiple pick harvest machines. The repeated harvest damages the vines, resulting in decreased yields with each subsequent picking. It also limits the acreage capacity of the machine, increasing the fixed costs per unit of production. The cucumber vines must be planted at a wide row spacing to accomodate the harvester, decreasing per acre yeilds (20). The most persistent problem, however, is the crown fruit, those cucumbers borne on axils within 12 - 15 cm. of the base of the plant. These fruit must be hand picked, so that they will not inhibit set of additional fruit on the vine (21)(22).

The high yield loss and high costs make multi-pick machine more expensive than hand harvest. A variety that does not set crown fruit might be harvested by a multi-pick machine at a cost savings as compared with hand-harvest (23).

Cucumbers are harvested long before the fruit is botanically mature. They are picked while the fruit are still small, immature, and rapidly growing. At harvest time, cucumbers can increase their weight by 40% in 24 hours. Processors buy pickling cucumbers on a price schedule that varies with fruit size, with small fruit being the most valuable. Hand harvested fields are picked several times, so that the fruit can be harvested while still small. Oversize fruit cannot be made into pickles. If left on the vine, they will prevent the set of any additional fruit.

Early studies showed that the value of yield loss is the most important factor in whether a cost savings could be realized in once-over harvest mechanization. Yield is reduced in a number of ways. Once-over harvest results in yield loss because some fruits are never allowed to develop while others become oversize. The harvest date is a compromise between the optimal harvest date for early and late developing fruit. Yield is also lost because the harvest machine recovers fewer smaller fruit than can hand pickers, while including more oversize cucumbers, decreasing the value of the load. Machine harvested loads contain more fruit with stems as well as more broken and smashed cucumbers (25).

With mechanization, the yield per acre for Michigan processing cucumbers declined. Average yields were 5.8 tons per acre in the five year period preceeding mechanization (1960-64). Mechanization began in 1965. By 1972, more than 90% of Michigan acreage was machine harvested. Average yield for the period 1970-74 was only 4.0 tons per acres (26). In more recent years, improvements in production practices have increased yields (27).

Yield losses in once-over harvest mechanization are relatively greater for California producers. Hand harvested cucumber plantings yield 15-20 tons per acre, while machine harvested fields yield only 4-5 tons per acre (28). The high levels of yield loss indicate that once-over harvest mechanization technology is not yet cost saving in California.

Factors Affecting the Rate of Adoption

Hand-harvest producers have been able to compete with mechanized producers of processing cucumbers. Mechanization of the cucumber harvest in Michigan has not yet reversed the long term decline in that state's share of

Table 5-36
Michigan Processing Cucumber Production as a % of U. S. Production

5 Year Period	Michigan % of U.S. Tonnage	5 Year Avg. Acreage
1955 - 1959	51.7	27.4
1960 - 1964	33.8	23.1
1965 - 1969	19.6	15.8
1970 - 1974	17.4	19.6

Source: U. S. D. A. Agricultural Statistics

U. S. pickle tonnage (see Table 5-36).

Hand harvest has remained competitive because of high yields and because small pickles cannot be machine harvested. Imports from Southern Europe, Northern Africa, and Central and South America account for an estimated 46% of U. S. small pickle consumption (29). Increasing imports may harm the competitive position of the hand-harvest sector.

New cucumber varieties with more concentrated fruit set and/or the development of cucumber growth regulators will increase the cost savings of once-over harvest and result in more widespread adoption of harvest machines.

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M. Onions

In order to bring the harvest to market onions must be undercut allowed to stand in the field for 5 to 10 days so that the tops may dry before they are cut. Hand harvest workers use shears to cut the tops and roots from the bulb, which is placed in a basket. The basket is emptied into a burlap sack, which is tied shut and allowed to cure in the field for another 5 to 10 days (1).

In Michigan, Colorado and Idaho, machines underdig, top, pick-up, and trim the crop. The onions are bulk cured and stored before being sent to market. The mechanization process began when growers loaded their mechanically topped crop with potato diggers (2)(3). Specially designed harvesters are now used. They can load the crop with less damage, and incorporate a pinch roll or rotary blade to trim the tops missed by the mower.

Long-day onion varieties are planted in these regions. These varieties, which are adapted to planting areas north of 36° latitude in the U. S., are seeded in early spring for late summer or fall harvest. The tops are dry when the onions are harvested. When properly cured, the crop may be stored for sale throughout the winter and into spring.

California and Texas raise onions for the early fresh market. These onions are medium and short-day varieties (grown in California and Texas respectively). Planted for spring and summer harvest, these varieties are not as adaptable to mechanical harvest as the long-day types. Growers try to harvest their crop early, for the premium early season market. Many onions are consequently harvested when the tops are still green, making them difficult to top mechanically. The green tops are bulky and succulent, and clog the mower with a mud made of onion juice and dirt. The short and medium-day onions are also more susceptible to machine damage than are the long-day varieties (4).

More than half of the California onion crop is sent to the dehydrator to be made into onion flakes and powder. Virtually all of this part of the crop is harvested by processor-owned machines. The onions are undercut several days before they are topped with a flail or rotary mower. They are then windrowed for a curing period. The windrow is picked up by a grading machine, which has approximately 10 sorting workers who pick out dirt clods and "seeder" onions (onions which have bolted to seed and are hence not suitable for dehydration). The crop is then trucked in bulk to the dehydration plant. The mowers used on the dehydrator crop are too rough for use on fresh market onions. They do an insufficient job of trimming the tops, which can be especially green as the grower tries to get the crop to an early market (5)(6)(7).

Grading machines have been used in the harvest of a portion of California's fresh market onion crop at least since 1951 (8). The onions are machine undercut and hand topped, then placed in windrows for curing. The windrows are picked up by the machine, which conveys the onions past sorting workers, who remove clods and culls, and on to stations where the crop is put into burlap sacks (9).

Engineers at Texas A & M and the University of California have developed prototype machines which can top, load, and trim the difficult to harvest early fresh market crop, but none are yet in commercial use. The new harvest system involves using a tractor pulled rod-weeder bar to undercut the onions. A tractor mounted rotary mower then tops the onions. Even with rubber fingers and lifting rods operating to lift lodged tops, this topping operation successfully trims only about half of the bulbs. Many tops which fall into the furrow are not lifted by the mower and are missed altogether (10).

A mobile or stationary bulb trimmer is the key part of the system, for it clips the tops and roots so that the onions are up to market standards. The bulb trimmer consists of a series of parallel rods, spaced about 1½ inches apart. The onions are rolled over the bed of these rods, beneath which a series of closely adjusted rotary blades clip roots and tops which project below the bed (11).

Tests of the harvest system on commerical plantings in the Imperial Valley, Lancaster, Edison, Bakersfield, Fresno, and Stockton show little impact on yield and quality, but the system remains in the prototype stage.

Texas researchers noted that working conditions on the harvest machine were "extremely poor," adding "workers had to stand on the moving machine and were exposed to an unpleasant environment caused by dust and onion juice (12)."

Changes in Production Practices and Handling

Onion harvest mechanization is facilitated by complete weed control through herbicide application and precision bed formation (13). Tops are more easily mowed if they are on weed free, precision formed beds.

The high output of harvest machines requires bulk handling and bulk curing. Bulk methods are in widespread use in the northern districts which produce long-day varieties. The onions are loaded into a truck, then transported to a curing shed, where air is forced through the bulbs to bring them to an even moisture content for storage through the winter.

In spring onion areas such as California, the specifics of bulk curing have not been commercially developed. Successful experiments have been conducted with forced air curing of onions in burlap bags set on pallets, and of onions in slatted date and potato bins, and in solid wood bins with slatted bottoms (14). Curing occurs within several days whether the onions are left outdoors or put in a shed with forced air ciculation.

Cost Savings

Hand harvest labor accounts for some 60% of the cost of producing fresh market onions (15). Williams and Franklin reported in 1971 that Idaho growers paid 70¢ per hundredweight for hand harvested onions which are handled and stored in sacks. Mechanization of the topping operation would save 15¢ a hundredweight, while bulk handling and curing would save approximately 35¢ a hundredweight. Fully mechanized producers in Midwestern production areas had reduced harvesting and storage costs to as low as 20¢ per hundredweight (16).

While mechanization has proven very cost saving in the long-day districts which produce storage varieties, yield and quality considerations have so far kept the spring production districts from mechanizing the fresh market crop. Machine harvest can damage the spring onions because they are low in solids, high in water content, and hence more easily damaged than long-day varieties (17). It is also more difficult to trim the tops and roots from spring onions than it is for long-day varieties. None of the harvest machines now in commercial manufacture are capable of trimming spring onions to the level demanded by the market.

Although it is not yet in commercial production, tests on the Texas A & M bulb trimmer and harvest system in California have shown that the machine can trim the tops off of more than 90% of the crop. This equalled or exceeded the results in several samplings of bulbs trimmed with hand shears (18). The machine is not as successful in trimming the roots off of the bulbs, because the roots offer less resistance to the cutting blades (19), but excessive roots are thought to be of no hindrance to the marketing of the crop (20).

In the California tests a small portion of the crop was damaged by the undercutting mechanism, and by the trimmer. No studies were done to see if there was any additional damage which might not be apparent until the crop is marketed.

Factors Affecting the Rate of Adoption

Should a commercially manufactured machine prove capable of harvesting spring varieties with little damage, harvest adoption should be rapid.

Burkner and Perkins project that the harvest system could be used optimally on 250 acres (21). The average California onion farmer planted

83 acres of onions in 1974 (22). In Imperial County, a principal production area, the average farmer planted 215 acres. As an annual crop with no production restrictions, onion plantings of individual farmers could easily be expanded to make full use of a harvest machine.

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CHAPTER VI

THE IMPACT OF NEW HARVEST MACHINES ON FARM LABOR

From the point of view of hand-harvest workers, the most important effect of adopting new fruit and vegetable harvest machinery is that it displaces labor. Mechanization eliminates hand-harvest jobs during the period of adoption. They are replaced with far fewer machine-harvest jobs. Machine-harvest work consists of new tasks of different skill, strenuousness, and safety. The work may be performed by a different work force in a different area. The majority of hand-harvest workers do not find work in the mechanized sector. Rising unemployment, and the concomitant increased incidence of crime, alcoholism, mental illness, heart disease, and suicide are the impacts felt by society as a whole (1).

One measure of the impact of new harvest machines on farm labor is the net displacement in harvest labor demand. Displacement represents the decline in demand over a given period, and can be expressed by a measure of employment such as work-weeks, or number of peak harvest workers. It must also be defined by a geographic area, a specified period of time, as caused by a particular technology. Displacement is the difference between employment at the beginning and end of the period:

$$D = E_f - E_i$$

$D =$ Net Displacement

$E_f =$ Final Employment

$E_i =$ Initial Employment

Two projections of farm labor displacement are constructed in this chapter. They project the displacement which is expected to follow adoption of the new harvest technologies discussed in Chapter V. Initial employment is regarded as the annual average employment for the period 1975 - 1977 (see Appendix A).

In the first projection, conservative assumptions are made about the adoption of these technologies, and estimates are constructed of the resulting impact on employment in the 5 years following the base period, that is, by 1982. This 5 year projection estimates the minimum impact of these technologies in the short term. In the second projection, less restrictive assumptions are made about adoption in order to estimate the maximum impact of these technologies during the 10 years following the base period, i. e., by 1987.

A. Estimates of Current Employment

Farm labor demand in California is estimated by the state's Employment Development Department (EDD) in its semi-monthly Farm Labor Report 881-A.

Demand is reported on a county-by-county basis. If more than 100 workers are employed in a single seasonal job in a given county, then the work is listed by crop and by activity. All other employment is classified as "all other agriculture." Employment is reported as the number of work-weeks of labor performed in the week preceeding the report date.

The data in this report are derived from production data and productivity estimates. The total number of work-weeks of harvest labor demanded in a year is derived from this information using the following relationship:

$$E = \frac{T}{PH}$$

E = Employment in the Harvest of the Commodity in in the Year (work-weeks)
T = Tons of Commodity Produced in the Year

P = Average Productivity of Harvest Workers (tons/work-hour)
H = Average Number of Hours of Employment per Work-Week

Production information used in preparing the report is obtained from statistics prepared by government agencies. An informal survey of farm advisors and growers is used to estimate productivity, and the hours of weekly employment.

When both machine and hand harvest workers are employed, this employment equation becomes compounded as follows:

$$E = \frac{(1 - A)T}{P_h H_h} + \frac{(A)T}{P_m H_m}$$

$$E = \begin{bmatrix} \text{Hand} \\ \text{Harvest} \\ \text{Employment} \end{bmatrix} + \begin{bmatrix} \text{Machine} \\ \text{Harvest} \\ \text{Employment} \end{bmatrix}$$

A = Portion of Crop Harvest by Machine

P_h = Productivity of Hand-Harvest Workers

P_m = Productivity of Machine-Harvest Workers

H_h = Hours of Weekly Employment of Hand-Harvest Workers

H_m = Hours of Weekly Employment of Machine-Harvest Workers

The total work-weeks of labor demand are then allocated to the appropriate time of year according to estimates of how much is produced in each week of the season. Data from only 24 of the 52 weeks of the year are recorded in the published Farm Labor Report 881-A.

Peak season labor demand is the largest number of work-weeks reported in any of those 24 reporting work-weeks. This sometimes underestimates the actual peak season employment, if it occurs between reporting weeks. Peak labor demand is in effect derived by the same formula and assumptions used to calculate total employment, except that " E " represents peak labor demand in work-weeks, and " T " represents the tons of commodity produced in the peak reporting week.

Peak season labor demand is sometimes regarded as a count of the maximum number of individual workers employed. This is an erroneous use of the 881-A Report, for it does not take into account turnover among farm employees.

The methodological flaws in the preparation of the 881-A Report are discussed in Appendix B. Despite these flaws, the report compared favorably with data from Disability Insurance reports (see Table 2-5, p. 15). The decision to rely on this report for information on current employment was simplified by the fact that it is the only statistical source on current California farm employment by crop, activity, and county.

B. Estimates of Labor Displacement

An estimate of future employment can be made with the same data used by the EDD to estimate current employment, i. e., tons of production, worker productivity in hand and machine-harvest, hours of weekly employment, and portion of the crop which is harvested by machine. The projections which follow are an estimate of the decline in farm employment which may be caused by adoption of new farm technology. The effects of other factors on employment are not included in the estimate.

Tons of production. Since the projection seeks to estimate only the effects of new technology on employment, production is assumed to remain constant over the period of displacement. Changing levels of production do, however, affect both employment, and the adoption of new farm technology. In some crops production will decline, and the effect will be to reduce hand-harvest employment and impede mechanization. Production decline might also come because of the inability of California producers to mechanize the harvest.

In other crops, production will increase, but this can also lead to more rapid adoption of new technology. The general trend has been for California farm production to increase. In this respect, the assumption of no change in the level of production may mean that the displacement projections are overestimates. However, the historical analysis of Chapter IV indicates that the change in productive acreage has a relatively minor effect on employment in labor markets undergoing mechanization (see Table 4-3, page 73).

This assumption also negates the impact of shifts in production districts which will make it difficult or impossible for hand-harvest workers to find machine-harvest work. In this respect, the assumption of no change in production makes the displacement projections underestimates.

Worker Productivity. Estimates of harvest labor productivity include all workers in the harvest crew, including supervisors as well as loading and hauling workers. Over time, the productivity of hand-harvest workers increases because of new production practices and increased yields. Machine-harvest worker productivity increases as mechanized technology is perfected, and the output of harvest machines increases. These increases are dependent on new technological discovery. Without any way to estimate these projected productivity increases, the productivity of hand-harvest and machine-harvest workers is assumed to remain unchanged over the displacement period. This assumption makes the projections of displacement underestimates.

In crops which are not yet machine harvested in California, machine-harvest worker productivity has been estimated from reports on machine use in other states, and from reports on tests of harvest machines in California.

Adoption of Harvest Machinery. Two sets of assumptions have been made regarding the adoption of new harvest technology in the 13 prioritized crops.

Because there are so many unknown factors involved in projecting future adoption of farm machinery, it is impossible to know exactly which technologies will be adopted, and when. By making conservative and less restrictive assumptions about adoption, however, this study will set a range of the anticipated impact of these technologies on employment.

The conservative assumption is that only those crops currently being mechanized in California will be mechanized in the five years following the base period used to calculate initial employment. Adoption of new harvest machinery in those crops is assumed to follow a sigmoid curve. Recent information on adoption levels has been used to project the levels of adoption in 1982 (see Table 6-1).

The less restrictive assumption is that new harvest technology which has proven commercially feasible anywhere in the U. S. will be adopted in California in the 10 years following the base period, i. e., by 1987. Adoption levels under this assumption are also given in Table 6-1.

It should be noted that for most of the 13 crops, new mechanization will occur only in the harvest of a particular segment of production, such as the fresh market or the processing crop.

<u>Calculation of Labor Displacement</u>. By definition, displacement is the difference between employment at the beginning and end of a defined period. The displacement caused by the mechanization of the 13 prioritized crops is estimated with the assumption that the tons of production (**T**), hours per work-week (**H**), and the productivity rates (P_h and P_m) remain unchanged over time. With these assumptions, displacement may be calculated from

Table 6-1
Adoption Projections and Productivity Estimates for New Fruit and Vegetable Harvest Technology

Crop	Technology	% of Calif. Production Harvested by New Technology			% Net Displacement of Harvest Labor
		Current Level of Adoption According to EDD	Adoption Under Conservative Assumptions 5 Years	Adoption Under Less Restrictive Assumptions 10 Years	
Grapes, Wine	Over the row harvester	26	58	76	- 90
Grapes, Raisin	Continuous tray system	0	0	100	- 83
Peaches, Clingstone	Shake-catch harvest	20	63	100	- 85
Apricots, Canning	Shake-catch harvest	15	40	100	- 90
Cherries, Brining	Shake-catch harvest	0	0	100	- 83
Olives	Shake-catch harvest	0	30	90	- 95
Apples, for Crushing	Shake-catch harvest	0	0	100	- 89
Tomatoes, Processing	High capacity harvester Electronic sorting	0.1	100	100	- 70
Tomatoes, Fresh Market	Once-over harvester	0	0	90	- 85
Asparagus, Processing	Non-selective harvester	1	1	100	- 92
Celery, Fresh Market	Mechanical cut and loading	0	0	100	- 90
Cucumbers, Pickling	Once-over harvester	0	0	100	- 92
Onions, Fresh Mkt. Bulb	Mechanical top, lift, trim	0	0	100	- 90

information on initial employment, adoption, and productivity as follows:

$$D = E_f - E_i$$

$$D = \left(\frac{(A_f)T}{P_m H} + \frac{(1 - A_f)T}{P_h H}\right) - \left(\frac{(A_i)T}{P_m H} + \frac{(1 - A_i)T}{P_h H}\right)$$

A_f = Final adoption (portion of crop machine harvested at end of period)

A_i = Initial adoption (portion of crop machine harvested at beginning of period)

which may also be expressed as:

$$D = \left(\frac{(1 - A_i)T}{P_h H}\right)\left(\frac{(A_f - A_i)}{(1 - A_i)}\right)\left(\frac{P_h}{P_m} - 1\right)$$

The first of the three factors in the final equation above is hand-harvest employment at the start of the displacement period, which can be derived from the EDD pre-season reports. The second factor may be calculated from the assumptions about adoption in Table 6-1. The third factor is the net displacement caused by increased productivity. This factor for the 13 crops and technologies is estimated in Table 6-1 as well.

The final equation may be further simplified if A_i=0, or if A_f=1. These simplifications are as follows:

1. If A_i=0, then $D = \frac{T}{P_h H}(A_f)\left(\frac{P_h}{P_m} - 1\right)$
2. If A_i=0, and A_f=1, then $D = \frac{T}{P_h H}\left(\frac{P_h}{P_m} - 1\right)$
3. If A_f=1, then $D = \frac{T(1 - A_i)}{P_h H}\left(\frac{P_h}{P_m} - 1\right)$

In the first and second of these simplified displacement equations, there is no machine-harvest employment, so it does not need to be calculated. Machine-harvest employment does need to be calculated if $A_i > 0$, so that hand-harvest employment may be derived for the first factor of the equation.

The range of labor displacement expected from the mechanization of the

13 prioritized fruit and vegetable crops is broken down by crop in Tables 6-2 and 6-3, and by county in Table 6-4.

The displacement projection indicates at least 38,126 peak harvest jobs will be eliminated by 1982, and that no more than 128,176 jobs will be eliminated by 1987. These peak harvest figures are not a count of individuals who will be displaced. Some farm workers will lose more than a single job. To regard these figures as a count of affected individuals would be to double count workers who harvest more than a single crop, and those who work in more than a single county.

Displacement can also be expressed in terms of work-weeks of employment. The mechanization of the 13 crops is likely to cause labor demand to decrease by at least 226,060 work-weeks by 1982, which is 1.51% of average annual California farm employment (for the years 1975-77). The reduction in labor demand is not likely to exceed 742,120 work-weeks by 1987, which is 4.97% of annual farm employment.

The duration of the harvest jobs that will be eliminated varies from a week or two, as in the cherry harvest, up to the six months that celery harvest work may last in a given county. On the average, each of the jobs is about 6 weeks long.

Although the reduction in farm labor demand is small for the state as a whole, it is anticipated that its impact will be concentrated in certain labor markets (see Tables 6-5 and 6-6). The expression of displacement as a percentage of average annual peak harvest labor demand is quite high. This is in part because of the double counting inherent in adding peak harvest jobs, and because fruit and vegetable harvest mechanization eliminates a

Table 6-2
Projection of Minimum Labor Displacement from
Calif. Fruit and Vegetable Harvest Mechanization 1978-82, By Crop

Crop	Peak Harvest Jobs	Work-Weeks
Tomatoes, Processing	19,890	144,620
Grapes, Wine	8,040	26,180
Peaches, Cling	5,700	37,280
Apricots, Canning	2,268	7,380
Olives	2,228	10,600
Total Displacement	38,126	226,060

Table 6-3
Projection of Maximum Labor Displacement from
Calif. Fruit and Vegetable Harvest Mechanization 1978-87, By Crop

Crop	Peak Harvest Jobs	Work-Weeks
Grapes, Raisin	38,903	167,290
Tomatoes, Processing	19,890	144,610
Grapes, Wine	12,955	41,990
Tomatoes, Fresh Market	12,235	95,060
Peaches, Cling	10,533	70,050
Apricots, Canning	9,062	30,430
Olives	6,350	30,780
Cucumbers, Pickling	4,628	32,030
Onions, Fresh Market Bulb	4,450	34,300
Cherries, Brining	2,501	8,810
Asparagus, Processing	2,336	24,440
Apples, Crushing	2,266	13,680
Celery, Fresh Market	2,067	48,650
Total Displacement	128,176	742,120

Table 6-4
Projection of Labor Displacement From Calif.
Fruit and Vegetable Harvest Mechanization, By County

County	Minimum Displacement 1978-1982		Maximum Displacement 1978-1987	
	Peak Harvest Jobs	Work-Weeks	Peak Harvest Jobs	Work-Weeks
Alameda	67	190	594	3,550
Butte	400	2,020	829	4,720
Colusa	431	3,720	431	3,720
Contra Costa	544	4,180	1,532	9,040
Fresno	7,441	55,730	44,825	226,420
Glenn	129	690	368	1,960
Imperial	93	550	1,192	8,030
Kern	1,761	9,440	4,474	32,540
Kings	822	4,070	2,726	8,580
Los Angeles	--	--	522	3,990
Madera	851	2,750	4,400	15,690
Mendocino	396	740	847	3,530
Merced	2,098	14,210	4,320	26,820
Monterey	--	--	1,754	22,240
Napa	652	1,890	842	2,430
Orange	333	1,980	806	8,690
Riverside	380	1,510	802	3,660
Sacramento	424	3,170	485	3,840
San Benito	1,388	6,510	2,295	12,090
San Bernardino	150	340	342	770
San Diego	--	--	2,387	35,230
San Joaquin	4,360	20,750	14,208	81,200
San Luis Obispo	--	--	81	1,560
Santa Barbara	--	--	119	2,780
Santa Clara	1,415	7,240	4,423	23,930
Santa Cruz	--	--	764	5,770
Solano	1,075	7,270	1,425	9,050
Sonoma	448	1,060	2,285	8,680
Stanislaus	5,162	27,430	10,234	50,920
Sutter	1,686	12,130	2,219	14,820
Tehama	181	790	464	1,910
Tulare	1,751	7,900	9,337	40,630
Ventura	396	2,650	2,093	35,150
Yolo	2,893	22,800	3,138	24,570
Yuba	399	2,350	613	3,610
Total, All Calif Counties	38,126	226,060	128,176	742,120

Table 6-5
Projection of Minimum Labor Displacement from Calif.
Fruit and Vegetable Harvest Mechanization 1978-82
for Selected Counties

As % of Average Annual Peak Season Farm Labor Demand in Base Period	
Stanislaus	34.3
Yolo	32.2
San Benito	30.9
Contra Costa	27.3
Solano	24.9
Sutter	22.3
San Joaquin	19.2
Napa	17.0
Contra Costa	16.4
Mendocino	16.2
As % of Average Annual Total Farm Labor Demand in Base Period	
Yolo	10.4
Contra Costa	7.5
Sutter	7.0
Stanislaus	5.4
San Benito	5.3
Solano	5.3
Colusa	4.5
Yuba	3.6
San Joaquin	2.8
Merced	2.8

large number of jobs that are of relatively short duration.

The estimate of displacement represents only part of the effect of new farm technology on California farm employment. It does represent most of the expected employment decline from the mechanization of the harvest of fruit and vegetable crops which employ more than 40,000 work-weeks of harvest labor. These labor markets accounted for an estimated 17.0% of California farm employment in 1977. Displacement in these large labor markets will also be caused by other technological changes in the fruit and vegetable harvest such as harvest aids, dwarf rootstocks for fruit trees, increased yields, more

Table 6-6
Projection of Maximum Labor Displacement from Calif.
Fruit and Vegetable Harvest Mechanization 1978-87
for Selected Counties

As % of Average Annual Peak Season Farm Labor Demand in Base Period	
Contra Costa	76.7
Stanislaus	68.0
San Joaquin	62.5
Fresno	56.0
San Benito	50.9
Santa Clara	47.5
Madera	44.3
Yolo	35.0
Mendocino	34.6
Solano	33.0
As % of Average Annual Total Farm Labor Demand in Base Period	
Contra Costa	16.2
Yolo	11.2
San Joaquin	10.9
Fresno	10.7
Stanislaus	10.0
San Benito	9.8
Sutter	8.6
Mendocino	7.2
Solano	6.6
San Diego	6.5

efficient organization of harvest tasks, and new handling systems. An unknown, additional quantity of displacement may be caused by the development and adoption of harvest technology in crops not prioritized for detailed study, i. e., those in which harvest mechanization has not yet been commercially adopted. Researchers at the land-grant colleges and the U. S. D. A. have done extensive work towards the mechanization of the harvest of these crops.

New technology will cause displacement in the remaining 83.0% of California farm work. Reduction of labor in the thinning, pruning, irrigation, and cultivation of California crops will occur as labor saving technology continues to be adopted in these operations. Displacement will also occur with the mechanization of fruit and vegetable crops with labor markets smaller than 40,000 work-weeks.

Kumar, Chancellor, and Garrett projected changes in labor demand for a number of California crops (2). While there are serious questions about their methodology (3), it is interesting that they project that new technology in field crop production will have a significant impact on employment. Assuming no change in acreage and yields, they project the greatest reduction in labor demand in the period 1976-81 will be in the production of wine grapes, followed by cotton, processing tomatoes, and sugar beets.

The productivity of labor in livestock operations will also continue to increase as poultry ranches, milking parlors, and cattle feedlots grow larger and more automated.

Mamer has suggested that labor "stabilization" will have a large impact on employment (4). This stabilization process is a trend of fewer individuals performing the same amount of work by working for a greater number of days each season. It is brought about by seniority systems, and new labor management practices. Other data indicate that the trend is in the opposite direction, that temporary workers perform an increasing share of farm employment (see Figures 2-1 and 2-2). In the absence of any comparitive survey data, there is no accurate measure of this trend in California. Mamer asserts that labor stabilization may cause as much displacement of farm workers as new technology.

The impact of technological displacement of farm workers on rural

California employment will be compounded by the impact of technology on non-farm employment in California canneries and packing sheds. An example of this non-farm displacement is the decision by the Tri-Valley Growers cannery in Modesto to undertake a mechanization program that will eliminate 70% of the work in the cannery in 3 years, causing the displacement of 5,000 workers (5).

C. Conclusion

A displacement projection was made to estimate the impact of new fruit and vegetable harvest technologies on California farm employment. The projection anticipates a net reduction of at least 38,126 peak harvest jobs by 1982, but not more than 128,176 jobs by 1987. On the average, each of these jobs provides 6 weeks of employment. This displacement represents 1½% to 5% of California farm employment, and will be concentrated in certain counties.

The projection includes most of the displacement which may occur from the adoption of new machinery to harvest fruit and vegetable crops which employ more than 40,000 work-weeks of labor in California. This type of work accounted for 17% of California farm employment in 1977. Other technologies are expected to reduce the remaining 83% of California farm work.

Notes.

1. Michael Linfield "Agricultural Mechanization in California: The Social Costs of Mechanization, Displacement, and Unemployment" United Farmworkers of America AFL-CIO December 12, 1977 unpublished paper

2. Ramesh Kumar, William Chancellor, Roger Garrett "Estimates of the Impact of Agricultural Mechanization Developments on In-Field Labor Requirements for California Crops" in Technological Change, Farm Mechanization, and

Agricultural Employment California. University. Division of Agricultural Sciences. Priced Publication 4085 1978

3. Their projection purports to estimate future changes in demand for in field labor requirements for California crops. One basic problem with their projection is that it does not include the labor required in the production of a number of crops, including strawberries, valencia oranges, olives, cucumbers, melons, peppers, avocadoes, potatoes, snap beans, brussells sprouts, and sweet potatoes. These crops provided an estimated 664,400 work-weeks of harvest time employment for California farm workers in 1977.

4. John W. Mamer, Varden Fuller "Employment on California Farms" California Agriculture pp. 10-12 Vol. 32, No. 11 November 1978

5. Gerald Perry "High Labor Costs Seen as Threat to Cannery Jobs" Modesto Bee August 27, 1977

CHAPTER VII

POLICY RECOMMENDATIONS

As has been made clear in previous chapters there will be a continuation in the decline of annual average farm employment in California. The state's fruit and vegetable farms that will mechanize their harvest operations will lose as many as 128,000 employees by 1987. Because of the pattern of multiple job holding by some workers participating in the harvest of several crops, it is likely that the number of individuals affected by this labor displacement will be smaller than the figure quoted above. Nevertheless, the magnitude of the predicted job displacement is large enough to substantially contribute to unemployment in a number of counties in the state. For this reason, we have considered various policy recommendations intended to address this problem of job elimination in California agriculture.

A. Job Security

As has been pointed out by Martin and Hall, the impact of mechanization (or automation) upon the American labor force is not addressed in the existing body of public law, whether federal or state (1). The concept of "job property rights," which are employment related interests protected by law or contract, is alien to public law in the United States. In contrast with the situation in this country, most European nations have an extensive body of law adressing this subject. These European legal systems provide a comprehensive framework of job property rights. The following characterization of American law describes its lack of such protection:

> "The primary standard of American employment relations is the master-servant rule of a previous non-industrial era . . .

There is no recognition of job tenure as an interest protectable in its own right (2)."

Not only does the American legal structure fail to provide job protection for employees displaced by automation, the courts have established that employees not protected by collective bargaining agreements may be dismissed at will ". . . for good cause, for no cause, or even for cause morally wrong (3)." The extent of job security rights in Europe was summarized in a recent article by Yemin (4).

European nations that provide job protection through the legal system do so by two mechanisms. First, employers are required to co-operate with representatives of workers to avoid or minimize work force reductions. Second, and of possibly greater importance, employers are required to provide a series of benefits to dismissed workers. These include:

a). Advance notice or wages in lieu of notice for <u>all</u> dismissals (with or without cause);

b). Requirement that employers make a substantial contribution to provide workers with a minimal annual compensation;

c). Severance or redundancy allowance paid by the employer in the form of deferred compensation or supplemental unemployment benefits.

In the United States, such employer guaranteed benefits, if they exist at all, are included in collective bargaining agreements between employers and organizations representing employees. For this reason they are continually subject to renegotiation.

Those few instances of U. S. collective bargaining agreements providing assistance to workers displaced by mechanization or automation have provided only a limited range of benefits as contrasted with the extensive protection provided by law in most European nations. Of particular note are the two collective bargaining agreeements cited here:

a). Pacific Maritime Association and the I. L. W. U. Modernization and Mechanization Agreement in which employers contributed some $29,000,000 to an assistance fund over a 5½ year period as the "workers' share of the machine"(5);

b). Armour Automation Committee and Fund Agreement with the Amalgamated Meatcutters and Butcher Workmen in which the employer provided advance notice, severance pay, early retirmement, and supplemental unemployment benefit payments (6).

These agreements, together with a number of others, have been reviewed by the Diebold Institute for Public Policy Studies (7).

Although collective bargaining agreements remain the only examples in which the job rights of workers are addressed in the context of displacement of labor by automation, there are a considerable number of instances in which "job property rights" have been addressed in other circumstances. Most recently, loggers and sawmill employees in Northern California were provided special assistance as a result of the Redwood National Park Expansion Act. Because park expansion was intended to curtail timber operations, job displacement was perceived by the Congress to be a direct and immediate consequence of Federal action.

Again, the Trade Act of 1974 explicitly recognized that one side effect of relatively free trade might be layoffs in domestic industries that proved unable to compete with imported goods. Thus, certain benefits for employees facing this possibility were written into law. There are a number of other such instances wherein public law recognizes job property rights as incidental to some larger public policy objective.

When seen in this larger context of job property rights, employees experiencing lay-offs due to unrelated causes have, in fact, a common problem requiring a solution that goes to the cause of the problem. For example, the continuing large-scale movement of industrial enterprises out of Northern and Middle-Western states has had a serious impact on the work force of those states. The impact has been so great that severe repercussions have already been felt in the reduced tax base for the communities where shops had been located combined with sharply increasing demand for social services (8). Proposals have emerged from communities severely affected by this phenomenon of "runaway shops." Foremost among these are suggestions aimed at establishing some form of job property rights for workers adversely affected. The striking similarity to the problems faced by workers displaced by automation suggests that Federal action designed to provide some minimal level of job protection would address a broad range of seemingly unrelated issues.

RECOMMENDATION I: JOB SECURITY LEGISLATION

That proposals be drafted on the Federal level to establish a basic standard of job property rights for all employed persons. These rights include the right to a livelihood as well as substantial unemployment benefits and training, irrespective of the immediate cause (automation, runaway shop, labor dispute, or other factor). This approach is more far-reaching that the intent of the Full Employment and Balanced Growth Act of 1977 but aims at the root of the problem. As part of this approach, employers should be required to bear a substantial portion of the cost of benefits which accrue to their employees. At the same time, the degree of benefits to which workers are entitled could be regulated according to such measurable need factors as family income, education/skills, and age/employability.

B. Unionization

In the United States job property rights relating to mechanization have been recognized only through collective bargaining agreements which include some special provision to provide benefits to displaced employees. Relatively few farm workers on a national scale are members of unions. However, in California there is a substantial number of unionized farm employees. For this reason it is not at all surprising that the issue of job property rights for farm employees should be raised with considerable force in that state.

While no collective bargaining agreements recognizing such rights have yet been signed, there are instances in which the United Farmworkers of America AFL-CIO has contracts requiring the employer to limit the employment of workers to certain agreed upon job categories (9). Presumably, such contracts would prohibit replacement of workers in existing categories with persons working in newly created categories (i. e., replacement of hand-harvest workers by machine operators). Thus it is possible that in future labor-management contracts affecting California farm employees, a provision recognizing job security rights might be included. This approach to establishing such employee rights on a nationwide scale requires that farm employees enjoy basic rights of free speech and association that are routinely the case in the industrial work place.

RECOMMENDATION II: PROTECTION OF THE RIGHT OF FARM EMPLOYEES FORMING EMPLOYEE ADVOCACY GROUPS

That Federal legislation be prepared, modeled on the California Agricultural Labor Relations Act, securing the right of farm employees to form and join employee advocacy organizations of their own choice through secret ballot union representation elections. The special characteristics of farm employment recognized in the exclusion of farm workers from the provisions of the National Labor Relations Act, require that legislation be developed that takes account of these characteristics. The California ALRA is a useful model for the peaceful resolution of disputes involving farm employees and at the same time recognizes the special needs of these workers.

C. Elimination of Investment Tax Credit for Employment Reducing Equipment

The 10% investment tax credit, widely used to stimulate new investment since the early 1960's, has been established on a permanent basis in U. S. law as a result of the Federal Tax Reform Act of 1978. Intended to stimulate new investment in the industrial sector, this one-time special tax reduction in fact encourages the replacement of labor by machine in agriculture. Thus, while designed to stimulate industrial employment, the effect on agricultural employment is, in the short-term, certainly negative. Padfield and Martin have observed that Capital is being utilized to replace Labor as part of an ongoing conflict over control of the production process (10). They point out that the factors influencing this tendency to replace Labor by Capital are:

a). The relative cost of capital and labor;

b). Replacement of skilled labor by unskilled labor, which leads to a work force that is easier to obtain and control.

If special tax breaks accrue to those replacing labor by capital, then such benefits clearly affect the relative cost of labor.

In this context, it is worth noting that the cost of hired labor on California fruit and vegetable farms has continuously decreased as a proportion of farm production expense over the past 15 years (11). Traditional economic analysis would suggest that this decreased reliance upon labor would contribute to a surplus of labor supply, thereby leading to a reduction of the price of labor (wages). While this is in accord with the facts regarding wage rates for hired labor, it is important in the present context to note that the availability of special tax credits on new capital equipment purchases tends to contribute to the decreased use of labor. By withdrawing this special incentive to purchase new machinery, it might well be possible to actually stimulate more employment in agriculture rather than less.

RECOMMENDATION III: ELIMINATION OF INVESTMENT TAX CREDITS FOR EMPLOYMENT REDUCING EQUIPMENT

That the 10% investment tax credit be disallowed if an enterprise employs fewer persons after the purchase of items for which the credit is sought as compared with the number of persons employed before such purchase.

D. Role of Public Agencies in Developing New Technologies

Both the U. S. Department of Agriculture and land grant colleges throughout the nation have made important contributions to the development of new technologies in agriculture. Traditionally, agricultural colleges have viewed their responsibility to the larger society to include research intended to increase the productivity of the nation's agricultural sector. At first sight it might appear that such research is "neutral" or "value free." However, efforts to evaluate the impact of this type of research indicate that immediate, short-term benefits have accrued only to a small segment of society and have not been widely shared.

A well documented study of the development of processing tomato mechanization by land grant college researchers placed the rate of return on the investment in research at 930% to 1,300% per year (12). This return accrued primarily to the private sector, although the University of California today continues to derive patent income from the more recent variants of the original tomato harvest machine (13). However, there has not been a complete accounting of the total social costs. Whether as welfare payments, or as other costs ancillary to the problems of displaced employees, these costs are paid by society as a whole, as were the costs of the crucial development work at the publicly supported land grant college system.

Various social critics have argued that the land-grant college system is in need of reform because its research programs tend to benefit only certain segments of rural society (14). While the direction of such reforms is open to continuing discussion, there seems little doubt that farm employees have not received immediate, short-term benefits from the research programs of the land-grant college system. Because these colleges receive substantial support from Federal agencies, there is a Federal interest in the operation of the colleges. Federal agencies could choose, for example, to require that land-grant colleges initiate programs to provide immediate benefits to farm workers displaced by Federally supported research programs.

RECOMMENDATION IV: LAND-GRANT COLLEGE PROGRAMS TO ASSIST FARM EMPLOYEES

That continued Federal funding of the land-grant college system be contingent upon development of substantial programs designed to provide immediate benefits for farm employees. Assessment of the needs of farm employees should be developed by advisory committees composed entirely of persons with substantial experience as farm employees. Such needs might include technical and non-technical classes as well as services normally supplied to farm operators through the Agricultural Extension Service.

E. Adjustment Assistance and Retraining Programs

Padfield and Martin noted that training alone cannot solve the problems of the unemployed:

> ". . . to retrain the unemployed who have been replaced by labor reducing technologies without at the same time adding more jobs to the total market, tends to aggrevate the condition retraining seeks to alleviate by increasing competition for the available jobs (15)."

Title III of the Comprehensive Employment and Training Act (CETA) authorizes the Secretary of Labor to establish manpower services to special target groups. Under Section 303, the Division of Farmworker Programs administers program funds designed to meet the needs of migrant and seasonal farm workers. Implicit in these programs is the notion that farm work is undesirable and that training for non-farm jobs is the most important objective. Moreover, the sub-group "migrant farm workers" is seen as especially in need of assistance to enable such persons to "escape" from the migrant farm work cycle. On the administrative level this unwritten agenda is translated into rules and regulations establishing eligibility and defining desirable activities for participants.

Examination of what little information is available concerning the hired farm labor force in California suggests that:

a). Most farm workers reside in the communities where they are employed;

b). A very substantial fraction of such workers are employed for only a short period in farm work and are either unemployed or work in other industries for the balance of the year.

For example, persons employed in the processing tomato harvest might work most of the eight week harvest season and thereby earn the major share of their annual income in this period. Such a worker is likely to be either unemployed or employed in other industries for some 44 weeks of the year. Whether or not such a worker is a "genuine" farm worker cannot be decided by administrative regulation. Rather, elimination of the job that worker depended on for the major share of his/her livelihood faces the whole society with the problem of adjustment assistance.

What is suggested by this analysis is that programs that seek to identify farm workers as "special" may be narrowly designed (although we do not suggest that this is intentionally the case). In order to more clearly meet the needs of persons employed as hired farm workers, it may be necessary to re-think the whole approach. That is, it may prove to be more useful to speak of "rural workers," referring thereby to persons who live or work in a predominantly rural setting and who derive a substantial part of their livelihood from farm employment. With this approach, programs of adjustment assistance and re-training can be designed to more clearly correspond to the lives of rural people.

Programs of adjustment assistance have been advocated by rural people in California over the past several years, largely in response to labor displacing technologies. Comparision of these demands with current Section 303 migrant programs indicates that there is substantial room for incorporation of ideas and programs articulated by some organized groups of rural people. This suggests that re-design of Section 303 programs might well be a high priority. Rural advocacy groups composed entirely of rural workers should play a central role in this re-design process. Groups that have exhibited autonomy, such as farm worker producer cooperatives, farm worker service centers, and farm employee advocacy organizations would appear to be ideally suited for this purpose. By contrast, CETA prime sponsors or other groups playing a brokerage role between Federal agencies and rural people would be especially ill-suited for this task, since they have a vested interest in maintaining this brokerage relationship.

RECOMMENDATION V: RE-DESIGN OF ADJUSTMENT ASSISTANCE PROGRAMS FOR RURAL PEOPLE

That Section 303 CETA programs be re-designed to more closely correspond to the needs of rural people. That this process of re-design be directed by representatives of the consitutencies that such programs are intended to serve, as opposed to such intermediaries as Section 303 prime sponsors. The intent of the re-design process is to broaden the definitions utilized to more realistically take account of the actual employment history of rural workers.

Over the past several years autonomous advocacy groups of rural people in California have responded to labor displacing technologies with proposals that appear as worthy of support as any of the existing Section 303 migrant programs. These proposals include:

a). Emergency assistance to displaced workers without regard to citizenship status or other eligibility criterion;

b). Training programs tied to existing job openings as opposed to "training programs" that consist entirely of classes in English as a second language;

c). Citizenship classes offered by bi-lingual instructors to enable non-citizens to obtain citizenship status;

d). Making public farmlands available to farm worker producer co-operatives (these croplands are owned by Federal, State, and Local agencies);

e). Making funding available to new farm worker producer co-operatives in the form of short-term (production) loans;

f). Improvements in housing and health facilities designed to benefit rural people, e. g., maintaining state-owned labor camps on a year-round basis (as opposed to the current six-month open period).

F. Comprehensive Field Survey of Hired Farm Employees in California

The most recently conducted comprehensive study of California hired farm workers was conducted in 1965, nearly 14 years ago. While several important studies of some components of this work force have been carried out in recent years, most notably the study of women farm workers in 1977, we have only a very sketchy and incomplete picture of this sector of the labor force. Since intelligently designed programs intended to address the problems facing such workers must be based upon an accurate knowledge of this work force, a large scale study is clearly in order. Such a study should rely primarily upon field interviews conducted at work places throughout the state at various times of the year. Since interviews with thousands of workers will be required to obtain a picture that is valid, the effort required will be substantial. Properly designed questions would also enable comparisions to be made with the 1965 study to identify major trends in the farm work force.

RECOMMENDATION VI: FIELD STUDY OF CALIFORNIA HIRED FARM WORKERS

That the Department of Labor sponsor a comprehensive statewide field survey of California hired farm workers. That the interview techniques follow the pattern set by the 1965 study by the California Assembly, and that of the 1978 study by the California Commission on the Status of Women.

G. Environmental Impacts of Chemical Use

The successful use of chemical sprays that set, ripen, harden, or loosen developing fruit is crucial to the mechanization of the harvest of some crops. Before these compounds can be used in California, they must be evaluated and registered by two government regulatory agencies: the U. S. Environmental Protection Agency, and the California Department of Food and Agriculture. The use of these compounds has environmental impacts beyonds the immediate fate of the chemical itself. In facilitating harvest mechanization, the deleterious effects of these chemicals can include:

a). Soil compaction from harvest machines;

b). Less diversified cropping patterns as a result of the increasing scale of production needed to use harvest machines efficiently;

c). Increased reliance on fossil fuels needed to operate machinery;

d). Increased solid waste disposal as packing sheds and processors handle machine-harvest loads of produce which often contain more dirt and debris than hand harvested ones.

RECOMMENDATION VII: RECOGNITION OF THE INCREASED ENVIRONMENTAL IMPACT OF AGRICULTURAL CHEMICALS ANCILLARY TO MECHANIZATION

That the Environmental Protection Agency and the California Department of Food and Agriculture consider the increased environmental impact that is concomitant with the registration of chemical compounds that facilitate harvest mechanization.

Notes.

1. Philip Martin, Candice Hall "Labor Displacement and Public Policy" Technological Change, Farm Mechanization, and Agricultural Employment California. University. Division of Agricultural Sciences, Price Publication 4085 (1978)

2. Ibid., page 212

3. Payne vs. Western & A. R. R., 81 Tenn. 507, 51920 (1884); cited by Martin and Hall, op cit.

4. Yemin "Job Security: Influence of I. L. O. Standards and Recent Trends" 113 International Labor Relations 17 (1976)

5. Ross "Waterfront Labor" 21 Labor Law Journal 397 (1970)

6. G. P. Schultz "The Fort Worth Project of the Armour Automation Committee" 87 Monthly Labor Review 53 (1964)

7. Labor Management Contracts and Technological Change The Diebold Institute for Public Policy Studies, (Praeger, New York 1969)

8. Edward Kelley Industrial Exodus Conference on Alternative State and Local Public Policies (Washington D. C., October 1977)

9. Legal staff, United Farmworkers of America AFL-CIO private communication

10. Harland Padfield, William E. Martin Farmers, Workers and Machines (Univ. of Arizona Press, Tuscon 1965) pp. 293-296

11. See Figures 3-3 and 3-4, page 36.

12. Andrew Schmitz, David Seckler "Mechanized Agriculture and Social Welfare: The Case of the Tomato Harvester" American Journal of Ag.

Econ. 52:4 November 1970 569-577

13. California. Legislature. Joint Legislative Audit Committee, Office of the Auditor General The University of California System: Patent and Royalty Program Report 715.2 (Sacramento, October 6, 1977)

14. See for example:
Jim Hightower, et al Hard Tomatoes, Hard Times Agribusiness Accountability Project (Schenkman, Cambridge Mass., 1972).

15. Padfield and Martin, op cit., page 293

APPENDIX A

CALCULATION OF INITIAL EMPLOYMENT

To estimate the harvest employment (E_i) in the 13 prioritized crops on a county by county basis, the total annual work-weeks of harvest employment reported in the Farm Labor Report 881-A was tallied for these crops over a 3 year period (1975-77) and then averaged. Since only 24 weeks of the year are reported, the estimate of the actual average work-weeks of employment in the 52 weeks of the years was derived by multiplying total work-weeks reported by 52/24, or 2.133. Peak harvest employment was averaged on a county by county basis for the same 3 year period.

Harvest employment reported in broader activity categories was estimated by using averages of data in three years of Pre-Season Farm Labor Reports DE-3416. In crops where machine-harvest employment was to be calculated, the 3 year average of Pre-Season data was also used. To estimate the portion of harvest labor required to harvest only the processing sector of a crop, Pre-Season data were used if given. Otherwise, employment was pro-rated on the basis of 3 year average tonnage of production given by the California Crop and Livestock Reporting Service.

APPENDIX B

ANALYSIS OF THE CALIFORNIA EDD FARM LABOR REPORT 881-A

The data used to prepare the Farm Labor Report 881-A is recorded in the Pre-Season Farm Labor Reports DE-3416, which are not published. Analysis of the EDD survey methodology, and of the data in these "Pre-Season" reports reveals limits to the accuracy of the Report 881-A.

Worker Productivity. The EDD "Agribusiness Representatives" who compile the report do not rely on scientific measurement of worker productivity, but instead use their informal survey of farm advisors and growers to make their estimates. The jobs themselves are ambiguously defined, without a precise definition of what tasks are included in the productivity estimates.

Hours of Weekly Employment. Because this estimate is not based on worker interviews, employment records, or other accurate source, it too is only a rough approximation.

Adoption of New Technology. The 1977 Pre-Season reports of employment in the harvest of processing tomatoes, peaches, wine grapes, and olives were based on estimates of harvest machine adoption that were smaller than those given by commodity associations, machinery manufacturers, and researchers at public agencies. The Report may be slow to reflect changes in employment caused by adoption of new technology.

Classification of Employment. One difficulty in utilizing the report is the lack of standardized job categories. Jobs of different activities in the same crop may be included together. Harvest employment includes hauling and on-farm packing-shed workers as well. More than half of the employment reported is not classified by a specific job, but listed as "All Other Agriculture."

Modification of Data. All of the data is subject to review and modification by the EDD Agricultural Reporting Unit, which prepares the published report. The administrative manual calls for the "Agribusiness Representatives" to review their employment estimates once a year. No changes in the basis of their estimates are to be made without clearance from the Agricultural Reporting Unit. According to the manual:

> "This is done in order to achieve the smooth integration of the new data into the total labor force statistics. Proper timing of the introduction of the new employment levels is a vital element in this coordination." (EDD Administrative Manual for Preparation of the Pre-Season Farm Labor Report DE-3416, Section 357.32, Amendment No. 585, February 24, 1976).

This procedure of adjusting the data does not rely on any more accurate concept of employment held by the Agricultural Reporting Unit, but instead the intent to retain the continuity of the report.

Not a Count of Individuals. The data in the Farm Labor Report 881-A cannot be regarded as a count of the number of individuals employed in California agriculture. This is best explained by an example offered in the administrative manual for those who prepare the Report:

> "A crew of 100 men are cutting lettuce on Monday and Tuesday. On Wednesday, 50 of the men quit and are replaced by 50 others. At noon, Thursday, cutting is complete and the crew moves into harvest activities in another crop. The total number of individuals working during the week was 150 but the number of man-weeks was 70." (EDD Administrative Manual for Preparation of Report DE-881, Section 358.15)

The number of work-weeks was calculated by dividing the total number of work-days of harvest work done in the week, 350 in the example, by the average number of working days in a week, 5 in the example. Although 150 individuals worked in the harvest during the example week, the Farm Labor Report would record only 70 working (i. e., 70 work-weeks).

The erroneous reliance on the Farm Labor Report as a count of individuals in the farm labor force is fostered, in part, by the EDD methodology which classifies labor demand as being filled by "Farmers and family," "Hired regular," or "Seasonal domestic" workers. The EDD is using the demand data, in effect, as a description of farm labor supply.