POTATO IRRIGATION COSTS AND PRACTICES IN SUFFOLK COUNTY NEW YORK 1946

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SUMMARY

The 23 farms included in this study applied supplemental water by means of "rotary sprinkler" or "portable-pipe" systems. Costs were calculated for irrigation water supplied in the summer of 1946.

The cost of irrigating an acre of potatoes averaged about $21.43 or about $7.65 per inch of water applied. This was a cost rate of 28 cents per 1000 gallons of water pumped. These fugures were based on an average of about two 1.4 inch applications of water per season.

The average cost of applying 7 inches of water (five 1.4 inch applications) to an acre of potatoes, which is above the maximum to be expected even in the driest seasons in this part of Long Island, is about $33. With average yield increases of almost 60 bushels per acre over a period of several years when New York potatoes sold for an average of more than $1.10 per bushel obviously means that irrigation has paid well even after costs of handling added yields have been deducted from the gross profits of irrigation.

Overhead costs made up four-fifths of the total costs of irrigation on farms where two applications (1.4 inch each) of water were made per year. Depreciation was the largest item of expense making up one-half of the total cost. Labor accounted for one-eighth and fuel and power, one-twelfth of total costs. As more applications of water were made per season, labor and power operating costs became more important and, on farms where four seasonal applications were made, comprised about one-third the total cost of irrigation.

The investment per irrigated acre varied widely among farms largely due to the source of water and the amount of portable piping and underground

mains used. Average investment per irrigated acre was lowest (about $81 per acre) on farms having ponds and shallow wells as the source of water. On small farms with deep wells, investment cost was highest at $132 per irrigated acre. Average investment on farms pumping from deep wells and irrigating more than 75 crop acres was $109 per irrigated acre. Portable and underground piping made up about one-half total investment on most farms and wells and pond costs averaged about 10 per cent.

Of the farms studied five were irrigated from shallow wells or ponds with other farms using deep well turbines. On farms irrigating large acreages diesel engines were the most frequent power source.

The time required to cover the irrigated acreage of a farm is of great importance in comparing investment costs of irrigation on different farms. Most farmers thought an irrigation system should cover the acreage to be irrigated within 10 to 14 days.

Efficiency layout of distributing system and good design of power plant offer the most effective means of reducing investment costs and thereby costs of irrigation. The problem of reducing labor time requirements and drudgery depend largely on technical developements such as improved pipe-moving machines, lighter portable piping, possible larger sprinkler nozzles which apply water according to soil limitations, etc.

Benefits of irrigation water include increased yields, improved quality, insurance against crop failure, and possible protection against frost. Average yields at the Riverhead Research Farm experimental plots from 1938 to 1945 were increased 57 bushels per acre by use of irrigation water.

PURPOSE AND METHOD OF MAKING STUDY

PURPOSE OF STUDY

The purpose of this study is to make available information concerning the costs of supplemental irrigation as practiced in the Long Island potato area, and to show some factors affecting costs, based on the experiences of farmers. As a secondary motive, it is hoped that a brief discussion of farm irrigation practices and problems will also be useful in evaluating the economic need for additional water in other parts of New York State.

METHOD OF MAKING STUDY

The data were obtained by the survey method during the 1946 season. A record of equipment costs and a description of the farm and various parts of the irrigation system was made on 23 potato farms in Suffolk County, Long Island. Sketches of farm layouts were made and a water application summary sheet was completed for each farm. Labor requirements were tabulated.

To correlate the calculated costs of irrigation with expected gains, experimental yield data on potatoes grown at the Long Island Vegetable Research Farm has been compiled. No reliable estimates of yield increases resulting from irrigation were available at the farms visited. Rainfall distribution data from the weather records of the Research Farm were taken for the years corresponding to yield records.

DESCRIPTION OF AREA STUDIED

LOCATION OF AREA

The area is located about 75 miles east of New York City in the eastern part of Suffolk County, including parts of the towns of Riverhead, Southold and Southampton. Most of the records were taken in the glacial outwash Sassafras loamy soils region north of the village of Riverhead.

SOILS AND TOPOGRAPHY

The southward sloping plain of Long Island is gently rolling and somewhat irregular in topography. Lack of streams has resulted in a non-symmetrical drainage pattern. The Sassafras silt loams which predominate in the northern part of the area studied are among the most productive soils on Long Island, and within the upper third of productivity range among all soils of New York State. The Sassafras loams and sandy loams are more open and drouthy. Internal drainage is not a problem on any of these soils.

CLIMATE

The climate of Long Island is modified by the maritime influence of the Atlantic Ocean, which gives this region a long growing season, rather high humidity, relatively mild winters and not excessively long summers, and a comparatively well distributed rainfall throughout the year. Average rainfall at Cutchogue, New York in the heart of the Riverhead-Southold potato growing district, was 45.24" for the 32 years from 1899 through 1930 1/. The average monthly distribution is shown in figure 1.

1/ Climatic Summary of the United States, U. S. D. A. Weather Bureau, (1930)

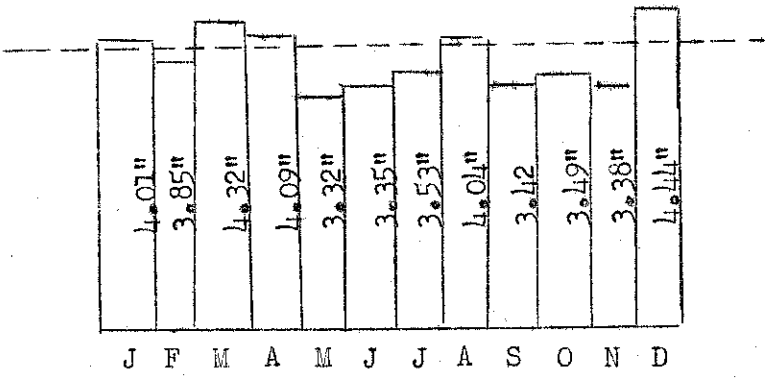

Figure 1. CUTCHOGUE, NEW YORK
AVERAGE ANNUAL RAINFALL—45.24"
32 YEARS, 1899-1930

Although several of these climatic features seem to favor a fairly low evaporation rate, the need for supplementary water is indicated more forcefully by the likelihood of dry periods. Some average monthly rainfall figures at Riverhead, New York for the critical period June through August are shown in table 1.

Table 1. AVERAGE MONTHLY RAINFALL* JUNE-AUGUST, RIVERHEAD, NEW YORK (1942-1946), COMPARED TO NORMAL**

Year	Rainfall, inches			
	June	July	August	Total, 3 months
Average (1927-46)	3.46	3.15	4.13	10.74
1942	3.10	4.90	7.56	15.56
1943	4.90	4.60	0.91	10.41
1944	1.55	0.50	1.44	3.49
1945	1.86	2.68	2.82	7.36
1946	3.62	3.38	12.77	19.77

* Data taken from weather records at the Long Island Vegetable Research Farm, Riverhead, New York
** Normal based on 20 years records, 1927-46

The average annual rainfall at the Setauket station, near the northwestern edge of the intensive Suffolk County potato-producing area was also about 45 inches over a period of 46 years; while at Southampton, on the south shore of the island, rainfall averaged 43.25 inches for the 19-year period.

The length of growing season averages about 192 days at Cutchogue, 187 days at Southampton, and 210 days at Setauket.

DESCRIPTION OF FARMS STUDIED

The farms selected for study represented a random sample of all farms having irrigation in the towns of Riverhead, Southold, and Southampton. The average number of acres per farm was about 139. This was considerably larger than the county average of 58 acres per farm in 1944 2/. Such a result might have been expected because of the fact that field irrigation by the rotary sprinkler portable-pipe method has developed largely on potatoes and cauliflower rather than on the more intensive vegetable crops. Also, a somewhat selective porcess of sampling is implied in the fact that less than one-half of the farmers growing potatoes have installed irrigation systems. According to a survey made by the Long Island Produce and Fertilizer Company in the early summer of 1946, 139 potato growers were irrigating their crops. 3/

2/ U. S. Census of Agriculture (New York), 1945

3/ Data furnished by Mr. S. P. Batchelder
Long Island Produce and Fertilizer Company, Riverhead, New York

No attempt was made to measure labor income or determine rates of production on the farms studied. Since the primary objective of this study was to determine costs of irrigation, more detailed information was obtained regarding the irrigation systems as such. Such information is included in the remainder of this publication.

DESCRIPTION OF IRRIGATION SYSTEMS STUDIED

Rotary sprinkler, or portable-pipe irrigation systems such as those described in this study were first used on the West Coast. The were developed in those parts of the more intensive cropping areas where the topography was somewhat irregular, soil extremely light and erodible, and where the permanent piping systems would have been undesirable because of their hindrance to cultivation and their high installation costs.

DISTRIBUTION OF WATER

The distributing equipment of these systems consists of 16 or 20 foot lengths of metal pipes which have a quick-acting coupling so that the separate lengths can be quickly connected and disconnected. These pipes are from 3 to 6 inches in diameter -- a 4 inch pipe carries up to 300 gallons per minute for short distances without excessive friction losses.

The main distribution line in most of the systems studied was a 6 or 8 inch asbestos cement or wrought iron pipe laid underground below the frost line and the working cultivation depth. The portable laterals are laid out at right angles to this line. When the desired amount has been distributed over whatever ground can be reached, the flow of water is stopped by means of a cutout riser valve at the distribution main, and the portable pipe is

moved across the field to a new position. The process is repeated until the field is irrigated. Some farmers discontinue irrigation while the lateral is being moved; others have a second line (or more) so that one may be in operation while the other is being moved.

Small riser pipes for the revolving nozzles (or sprinkler heads) are welded to the lateral piping to lift the point of spray discharge above the plant growth. The sprinkler heads observed were all of the water-actuated "kicker" type, dual nozzle, revolving slowly at about one revolution per minute. The size of sprinkler is governed by potential soil absorption rate, water pressure available, and type of crop being irrigated. Most sprinklers used for potato and cauliflower irrigation in Suffolk County discharged about 10 to 15 GPM at working pressures of 30-50 pounds (per square inch).

A good feature of these systems is that all the equipment can be removed from the field and stored when not in actual use.

WATER SUPPLY

The source of water was deep wells 4/ on 18 of the 23 farms studied. Five systems drew water from shallow wells or ponds. Source of water is an important economic consideration from the standpoint of first investment costs, reliability of water supply and power operation costs.

4/ A deep well is arbitrarily defined as one in which the water level is more than 20 feet below the pumping surface -- approximately the practical limit of suction lift for a well-designed centrifugal pump.

PUMPS AND POWER

Deep well turbines were installed on all farms having deep wells as a source of water supply. Centrifugal pumps were used on the five farms which pumped water from ponds or shallow wells.

Electric motors were used to power two of the systems studied. The number of electric plants was limited by the distance of most farms from a line where three-phase power is available.

Sources of power on the 21 farms not using electric motors were 16 diesel engines, 10 gasoline engines, and 1 tractor.

RESULTS OF STUDY

COSTS OF APPLYING WATER

The costs of applying irrigation water include both overhead and operating items. "Overhead Costs" as the term is used herein, consists of both fixed and variable annual increments. "Operating Costs" include expenses of labor, fuel, and power.

As considered in this study, overhead costs represent about 60 to 90 per cent of the total cost of irrigating potatoes during a season. As a general practice, a maximum of about four or five applications of water would be expected in the driest years experienced on Long Island. The importance of labor and power operating expenses as a proportional share (percentage) of total costs obviously increases as the system is used more frequently throughout the year, since many of the overhead costs are relatively fixed.

Overhead Costs

Overhead costs account for a large portion of the total costs of irrigating potatoes by the rotary sprinkler method. Since these overhead costs are largely a function of capital investment tables 2 and 3 show the average irrigation system investments made on farms visited in this survey. While it is difficult to make an accurate estimate of the variation in such elements of overhead costs as depreciation and repairs, some reasonable assumption can be made to show how the relative importance of overhead costs varies with number of times the irrigation system is used annually.

Table 4. IRRIGATED ACREAGE AND INVESTMENT

21 Farms Having Gasoline-or Diesel-Powered Irrigation Pumps, Suffolk County, 1946

Source of water	Farm group	Number of farms	Irrigated acreage		Average investment	
			Size*	Average number of acres per farm	Per farm	Per irrigated acre
Deep Wells	I	13	Large	152	$16,589	$109
	II	4	Small	54	7,106	132
Shallow Wells or ponds,	III	4	Small	36	2,901	81
AVERAGE, all farms		21	----	111	$12,175	$110

* Large - more than 75 acres

The average farm which had a shallow well or pond as a ready source of water was able to keep investment costs per acre at about three-fourths that for the average farm pumping from a deep well. To justify a deep well irrigation system, a relatively large operation seemed to be desirable in view of high "first costs" of installing an irrigation system. Group I farms

having an average of 152 acres irrigated per farm invested $109 per acre irrigated, while Group II farms having an average of 54 irrigated acres per farm invested $132 per irrigated acre (See table 4 for identification of groups).

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Table 2. IRRIGATED ACREAGE AND INVESTMENT

2 Group IV Farms Having Electric-Powered Irrigation Pumps, Suffolk County 1946

Source of water	Farm number	Number of acres irrigated	Investment	
			Total	Per irrigated acre
Deep Well	14	75	$8,698	$116
Shallow Well	15	80	9,005	113
AVERAGE, 2 farms	--	78	$8,852	$114

The range of irrigation system investment per acre irrigated was wide, varying from $52 to $180. Among the most important factors which cause this variability are:

1. Source of water
2. Efficiency of plant design and layout
3. Time required to cover irrigated acreage.
4. Type and age of power equipment
5. Year of installation

Overhead costs per acre irrigated (calculated for two applications of water in 1946) also vary widely within farms grouped by similar types of installations. The individual farm pattern of variation in investment or first costs, and in overhead costs per acre irrigated is shown in table 4.

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Table 5. INVESTMENT AND ANNUAL OVERHEAD COSTS

23 Farms, Suffolk County, 1946

Group number and description*	Farm number	Number of irrigated acres	Investment per irrigated acre	Annual** overhead costs per irrigated acre	Percent annual overhead costs were of investment costs
	1	190	$101	$16.50	15
	2	250	111	15.85	14
	3	165	103	14.58	14
	4	135	91	13.70	15
	5	170	82	13.10	16
	6	195	146	20.83	14
GROUP I	7	195	88	14.10	16
	8	200	107	15.70	15
Deep Wells,	9	96	125	17.73	14
Large Plants	10	80	180	25.75	14
	11	120	88	13.02	15
	12	92	132	18.89	14
	13	85	111	17.14	15
GROUP II	16	40	168	27.58	16
	17	65	108	16.49	15
Deep Wells,	18	37	127	18.54	15
Small Plants	19	75	134	20.72	15
GROUP III	20	25	141	23.56	17
Shallow Wells,	21	30	100	15.77	16
or Ponds	22	50	52	8.00	15
Small Plants	23	40	61	8.62	14
GROUP IV					
Electric	14	75	116	17.00	15
Power	15	80	113	17.16	15

* Groups No. I, II, and III have gasoline- or diesel-powered irrigation systems.
Large Plants - those with more than 75 irrigated acres

** Two applications - 1946

Annual overhead costs per acre irrigated range from $8.00 on Farm 22, which pumps water from a pond, to $27.58 on Farm 16, which has a deep well and irrigates only 40 acres from a system with the capacity to cover almost twice as much. Annual overhead costs in each case are nearly proportional to the amount of investment per acre irrigated.

The costs of portable and underground piping were about half of total investment on most farms. Well or pond costs averaged about 10 per cent of the total investment costs for all farms. Power and pump costs varied considerably with type of installation.

Table 4. DISTRIBUTION OF INVESTMENT COSTS

23 Farms, Suffolk County, 1946

Farm group*	Well or pond	Power	Pump assembly	Underground main	Portable lines	Other	Total
			Per cent of investment				
I	9	14	19	18	34	6	100
II	13	5	32	9	31	10	100
III	12	12	18	---	55	3	100
IV	11	8	15	25	30	11	100
All farms	10	12	20	17	34	7	100
			Amount of investment				
I	$1,536	$2,309	$3,109	$3,062	$5,556	$1,017	$16,589
II	928	387	2,250	675	2,174	692	7,106
III	356	334	523	---	1,598	90	2,901
IV	950	668	1,300	2,245	2,685	1,004	8,852
All farms	$1,174	$1,489	$2,352	$2,043	$4,030	$ 798	$11,886

* See table 4 for description of groups

Well costs on Group II farms, which irrigated an average of 54 acres per farm (See table 2) averaged $928, or over $17 per irrigated acre. The cost of shallow wells or ponds on Group III farms average $356, or less than $10

These figures serve to emphasize the importance of an efficient layout and well-planned design of the entire irrigation system, in order to make full use of the capital investment required. A large part of these overhead costs, which represent altogether about three-fourths of the cost of irrigation, depend on the amount of original investments. The most effective means of keeping overhead costs at the lowest practicable level is by reducing investment costs per acre to the minimum which is consistent with good irrigation practice requirements.

Labor Operating Costs

Labor costs constituted about one-eighth of the total costs of applying water where two applications were made annually; about one-fifth of four applications were made per year. The average cost of labor for all farms studied was $1.42 per acre-application of 1.4 inches or about $1.00 per acre inch.

Table 7. LABOR COSTS BY FARM GROUPS*

23 Farms, Suffolk County, 1946

Farm group	Number of farms	Man hours per acre per application	Cost per acre per application	Inches water per application	Cost per acre-inch
I	13	1.9	$1.48	1.4	$1.06
II	4	1.7	1.38	1.4	0.99
III	4	1.3	1.12	1.2	0.93
IV	2	2.1	1.69	1.4	1.21
AVERAGE, all farms		1.75	$1.42	1.4	$1.01

* See table 4 for description of groups

It seems likely that labor costs were lowest on Group III farms because a considerable portion of labor on these small-irrigated acreage farms was family labor. No attempt is made to explain the higher rate on Group IV farms. But it may be significant to point out that this figure is based on the records of only two farms.

The time spent in actual pipe-moving in the field was about 70 per cent of the total labor required for irrigation. "Other pipe handling" accounted for about 12 per cent of labor time, and "Tending pump and other" labor was about 17 per cent of the total.

The proportion of time spent in actually moving pipe between stands in the field would be less if more water were applied per stand. Time spent in tending pump and other incidental labor would increase with the amount of time during which water is being applied, but actual pipe moving time depends on the number of times the pipe is moved rather than on the water application time.

Table 8. DISTRIBUTION OF LABOR

23 Farms, Suffolk County, 1946

Farm group*	Per cent of total labor spent on: Pipe moving in field	Other pipe-handling	Tending pump and other	Total	Inches of water per application	Total hours: Per acre-application	Per acre-inch
I	71	12	17	100	1.4	1.9	1.4
II	73	7	20	100	1.4	1.7	1.2
III	69	14	17	100	1.2	1.3	1.1
IV	68	12	20	100	1.4	2.1	1.5
AVERAGE, all farms	71	12	17	100	1.4	1.75	1.25

* See table 4 for description of groups.

Five farms in Group I which used pipe-moving machines averaged 1.9 hours labor per acre-application, or about the same as the average for all farms in Group I, which have deep wells and large irrigated acreages. Seventy-one per cent of the labor required on these farms was spent in field pipe-moving.

These figures tend to indicate that the pipe-moving machines now in use in these areas do not save time in the pipe-moving operations. The five survey farms using pipemovers in 1946 had five- or six-man crews employed in the field pipe-moving. The average for other large-scale, deep well farms was a four man crew; for the smaller farms, a 3-man crew was typical.

Table 9. FIELD PIPE-MOVING SUMMARY

22 Farms, Suffolk County, 1946

Size of irrigated acreage	Method of pipe-moving	Number of farms	Number of men in pipe-moving crew	Distance moved (in feet)	Man minutes per 1000 feet of pipe-moved
Large	Machine	5	5.4	66	93
	Hand	9	3.8	61	92
Small	Hand	8	3.1	61	81
Average, all farms	Machine and Hand	22	3.9	62	88

About ninety-three minutes moving time per 1,000 feet of pipimg was required on the farms using pipe-movers, compared with ninety-two minutes per 1,000 feet on nine other farms irrigating large acreages and having similar installations. These figures are calculated for moving piping an average distance of about 66 feet across the rows for the five "pipe-mover" farms. Average distance moved on the nine farms which moved pipes by hand was 61 feet.

Power Operating Costs

Fuel and power costs were about eight per cent of the cost of applying water. This proportion increases as more applications were made per year (See figures 2, 3, and 4). The average power cost of applying an inch of water was 58 cents per acre, or about 2 cents per 1,000 gallons. This includes fuel or electric power for pumping, a charge for truck or tractor used in trailer haulage of pipes and for pipe-mover haulage on the five farms which moved pipes in the field by machine.

Table 10. POWER COSTS BY FARM GROUPS

23 Farms, Suffolk County, 1946

Farm group	Number of farms	Power operating costs per acre-inch			
		Fuel and lubrication	Trailer haulage	Pipe-mover haulage	Total
I	13	$0.37	$0.03	$0.26*	$0.50
II	4	0.89	0.02	----	0.91
III	4	0.55	0.02	----	0.57
IV	2	0.44**	0.02	----	0.46
AVERAGE all farms,23		$0.50	$0.02	$0.26	$0.58

* Five farms only
** Costs of electric power

Power costs per acre-inch were greatest on Group II farms -- these having deep wells and a relatively small irrigated acreage. However, of the four farms in Group II, two systems were powered by a second hand engine; while eleven of the thirteen farms in Group I have new (and therefore presumably more efficient) power systems installed.

COMBINED IRRIGATION COSTS

Tables 11 and 12 show the overhead and operating costs of making one application of water to an acre of potatoes on 23 Suffolk County farms in 1946. These figures are calculated for an acre-application, (one application of water to an acre) rather than an acre inch, since an application of water rather than an inch is the unit in terms of which farmers speak in their estimates of water usage.

Table 11. IRRIGATION OVERHEAD AND OPERATING COSTS*

23 Potato Farms, Suffolk County, 1946

Source of power	Number of farms	Overhead costs per acre*	Operating costs per acre		Total cost per acre	Inches of water per application
			Fuel and Power	Labor		
Electric	2	$15.37	$0.64	$1.69	$17.70	1.4
Gasoline or Diesel	21	15.26	0.83	1.40	17.49	1.4
AVERAGE, all farms	23	$15.27	$0.81	$1.42	$17.50	1.4

* For one application of water annually

If two applications of water are made per season, the cost of irrigating an acre of potatoes averages $21.43 per acre for all farms surveyed. This is approximately $7.65 per acre-inch of water applied, or about 28 cents per 1000 gallons (1 acre-inch equals 27,154 gallons).

The sample of irrigation systems powered by electric motors is admittedly too small to be considered reliable from the standpoints of standard statistical tests of significance. However, since the cost rate of electrical energy is essentially the same for two farms as it would be for twenty, it

is interesting to note than that "fuel and power" operating costs for the electric installations was about 20 per cent less than for systems powered by internal combustion engines. This difference would have been greater had the acreage irrigated per month by electrical installation been increased, because of higher rate per kilowatt-hour for the first 200 kilowatt-hours. The average acreage irrigated per farm by these two units was only 80 acres in June and July of 1946, as compared with an average of 141 acres per farm for all other installations during the same period.

As shown by table 11, overhead costs do not vary significantly between electric and other installations. No explanation for the higher labor costs on farms having electric power is apparant. It is unlikely that the source of power is the factor responsible for such difference in labor costs, since most of the labor required is for pipe-moving operations. copy

Table 12. IRRIGATION OVERHEAD AND OPERATING COSTS,* DIESEL AND GASOLINE POWER SYSTEMS

21 Potato Farms, Suffolk County, 1946

Source of water	Group	Irrigated acreage**	Number of farms	Overhead costs per acre	Operating costs per acre		Inches of water per application
					Fuel and power	Labor	
Deep Well	I	Large	13	$15.01	$0.70	$1.48	1.4
	II	Small	4	18.75	1.25	1.38	1.4
Shallow Well or Pond	III	Small	4	12.59	0.68	1.12	1.2

* One annual application of water

** "Large" is arbitrarily defined as an irrigated acreage of more than 75

Total costs per acre of applying water were greatest for those farms pumping water from deep wells for a comparatively small irrigated acreage. Shallow-well or pond systems had an average annual overhead cost per acre of less than $13, while the small-acreage, deep-well units' overhead costs averaged almost $19 per acre. Operating costs were also higher on these Group II systems. Group III systems have lowest labor operating costs; possibly one important reason for this is the fact that family labor comprised a larger portion of the total labor on these farms than on the farms in other groups.

Costs Per Acre In 1946

The total cost of irrigation as calculated for two applications of water in 1946 is $21.43 per acre. This means that each application of water or about 1.4 inches as measured in this study, costs about $10.71 per acre. If five applications per season are made, however, this cost can be materially reduced -- to about $6.64 per acre per application or $33.21 per acre, total cost for 7 inches of water. This is a water cost rate of about 17 cents per 1,000 gallons.

Cost Variation With Number of Annual Applications

The portions of irrigation costs distributed between overhead and operation costs, as indicated by this study, vary considerably depending on the number of applications of water made per year. Figures 2 through 4 show a comparison of cost distribution by percentage for a varying number of annual applications.

Figure 2. ONE APPLICATION

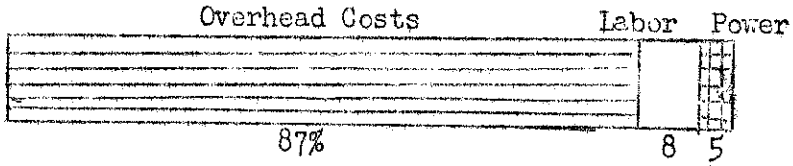


Figure 3. TWO APPLICATIONS

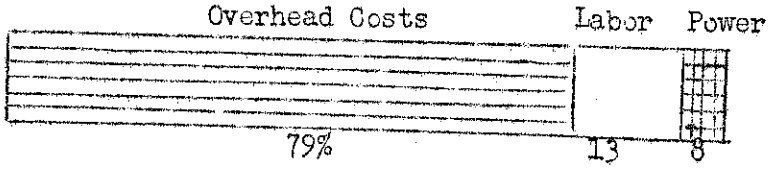
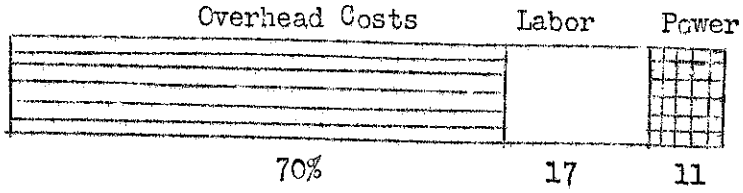


Figure 4. FOUR APPLICATIONS



RELATION OF DISTRIBUTION OF IRRIGATION COSTS PER ACRE TO NUMBER OF ANNUAL APPLICATIONS

From the data presented thus far, it is easily seen that irrigation costs are very difficult to measure, and interpretation of such cost estimates must be used with extreme caution. A comparison of total annual costs with added returns resulting from irrigation serves better than cost estimates per acre-inch or acre-irrigation to give the true picture of results.

While five water applications can be made annually at a total cost of only about twice that for one application, the measure of costs in dollars per volume of water applied is unrealistic without some concept of usual practices and expected returns.

RECORD OF YIELD INCREASES FROM IRRIGATION

During an "average" year, those Suffolk County potato farmers having irrigation systems normally make about two to four applications of water to their potato crop during the growing season. The frequency of irrigation depends on capacity of irrigation plant and availability of labor, as well as climatic conditions. For purposes of making approximate comparisons of costs and added yields, costs of irrigation for three 1.4 inch water applications annually will be used.

Potato Yields and Summer Rainfall

While no reliable yield increase data are available from the farms surveyed, the Long Island Vegetable Research Farm, Riverhead, Long Island, has conducted various irrigation-fertilizer experiments on potatoes since 1938. The test plots are located on a Sassafras silt loam which is similar in character to that of much of the potato area sampled. Cultural practices on these experimental tests were also very similar to those used by farmers in the area.

Table 13. SUMMER RAINFALL AND YIELD OF POTATOES, IRRIGATED AND NON-IRRIGATED PLOTS

Long Island Vegetable Research Farm, 1938-45

Year	Yield per acre, bushels		Increase in yield per acre		Rainfall, inches (June, July, August)
	Non-irrigated	Irrigated	Bushels	Per cent	
1938	429	430	1	---	14.99
1939	150	361	211	141	10.77
1940	218	252	34	16	10.59
1941	350	407	57	16	11.51
1942	252	231	-21	-8	15.56
1943	215	204	-11	-5	10.41
1944	113	268	155	137	3.49
1945	342	375	33	10	7.36
AVERAGE	259	316	57	22	10.58

The record of yield increases in table 13 for Green Mountain Potatoes, with fertilizer applications of 2000 pounds 5-8-5 fertilizer per acre. Water was applied at the rate of one inch per week, cumulative, throughout the growing season in 1938, 1939, and 1940. This means, for instance, that a 4-inch rainfall in any week would be considered a four weeks' supply and no irrigation water would be applied until at least 4 weeks later. The periods of irrigation in the years 1941 through 1945 were variable, but water was applied at the cumulative rate of one inch per week from about June 1 to August 15.

Yield increases varied widely from year to year. In three years of favorable weather, yields on irrigated plots were slightly less or showed no significant increase. Moderate increases averaged about 15 per cent for 1940,1941 and 1945. In 1939, and 1944, however, yields were increased about 140 per cent.

The average yield increase on irrigated plots was about 57 bushels per acre, or one-fifth more than on non-irrigated plots. In 1939, an increase of 211 bushels per acre was obtained on irrigated plots, however. Such an increase would more than pay for the cost of installing an irrigation system.

Yield Results With Varying Rates of Fertilizer Application

The results of irrigated potato yields with varying amount of fertilizers are of interest and economic significance in studying the experimental data on the Research Farm at Riverhead (table 14).

Table 14. RELATION OF POTATO YIELDS ON IRRIGATED AND NON-IRRIGATED PLOTS TO VARYING RATES OF FERTILIZER APPLICATION, 1938 - 1940

Long Island Vegetable Research Farm, Riverhead, New York

Year	Pounds 5-8-5 fertilizer applied per acre											
	1200			1600			2000			2500		
	Yield, bushels per acre											
	Non-irrig.	Irrig.	Incr.	Non-irrig.	Irrig.	Incr.	Non-irrig.	Irrig.	Incr.	Non-irrig.	Irrig.	Incr.
1938	370	368	-7	425	436	11	429	430	1			
1939	160	342	182	142	351	209	150	361	211			
1940*	372	421	49	382	396	14	384	443	59	357	369	12
1940*	211	239	27	217	225	8	218	252	34	203	210	7
AVERAGE			63			61			76			

* Two experiments were conducted in 1940

These data are of limited scope, yet they indicate what we might expect; namely, that it may be more profitable to use larger amounts of fertilizer when irrigation water is added than without such supplementary water supply -- if we consider that factors of production are combined in such

a way as to maximize in each case.

For a 2000 pound application of 5-8-5 fertilizer per acre, average potato yields on irrigated plots at the Riverhead Research Farm over a 3-year period were 76 bushels per acre more than on unirrigated plots with a similar fertilizer application. This increase was greater by about 13 bushels per acre than for those irrigated plots having 1,200 pounds per acre fertilizer application. Tests made in 1940 on irrigated and non-irrigated plots treated with 2,500 pounds per acre of 5-8-5 fertilizer showed smaller yield increases than those with 2,000 pound applications; and, significantly, both irrigated and non-irrigated plot yields were decreased at this high rate of fertilizer application. These results are not conclusive, but may be illustrative of the general relationship between water supply and fertilizer utilization.

Time of Applying Water

The season during which irrigation is carried out is an important factor affecting yield increases. The results of the Research Farm experiments at Riverhead show, in general, that better yields were obtained on plots where irrigation water was applied from June 1 through August 15 than for plots irrigated only a part of this period. Yield on plots irrigated during May were not significantly larger than those of un-irrigated plots. In four years experiments, 1941-45, yields were increased 22 per cent on plots irrigated from June 1 through August 15; 18 per cent yield increases were made on plots irrigated from July 1 to August 15.

Table 15. POTATO YIELDS WITHOUT IRRIGATION AND WITH IRRIGATION DURING VARIOUS PERIODS OF GROWING SEASON

Long Island Vegetable Research Farm, 1941-44

Year	Not irrigated	Irrigated		
		June 1 to August 15	July 1 to August 15	May 1 to June 1
	Bushels per acre			
1941	350	421	393	372**
1942	252	231*	276	259***
1943	215	204	216	205
1944	113	268	210	113
AVERAGE	232	281	274	237

Note: All irrigation applied to supplement rainfall to a cumulative total of 1 inch per week.

* Irrigated from June 10 to August 15
** Irrigated from Emergence to June 1
*** Irrigated from May 10 to June 10