Survey of Irrigation Methods in California in 2001

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Abstract: Reliable information on irrigation methods is important for determining agricultural water demand trends. Therefore, a study was conducted during 2002 to collect information on irrigation methods that were used by growers to irrigate their crops in 2001. The results were compared to earlier surveys to assess trends in cropping and irrigation methods. A one-page questionnaire was developed to collect information on irrigated land by crop and irrigation methods. The questionnaire was mailed to 10,000 growers in California that were randomly selected from a list of 58,000 growers by the California Department of Food and Agriculture, excluding rice, dry-land, and livestock producers. From 1972 to 2002, the area planted has increased from 15 to 31% for orchards and from 6 to 16% for vineyards. The area planted to vegetables has remained relatively static, while that planted to field crops has declined from 67 to 42% of the irrigated area. The land irrigated by low-volume (drip and microsprinkler) irrigation has increased by about 33%, while the amount of land irrigated by surface methods has decreased by about 31%. Sprinkler usage has decreased in orchards and vineyards, but it has increased in vegetable crops.

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Introduction

Surface (i.e., gravity-driven), sprinkler, and low-volume (i.e., drip and microsprinkler) irrigation are the main methods that are used by growers to irrigate crops within California. There is also a small amount of irrigated area with subsurface irrigation, where drain tiles or open channels are blocked to force water into the root zone of crops; however, the area is insignificant compared to other methods. The most appropriate irrigation method for a region depends upon physical site conditions, the crops being grown, amount of water available, and management skill.

In all irrigation methods, the goal is to attain high distribution uniformity with minimal runoff and deep percolation. Generally, more water is applied with surface and sprinkler irrigation on an annual basis than with drip and microsprinkler (drip/micro) systems because it is easier to achieve high distribution uniformity with the low-volume methods. For surface irrigation, it is often difficult to control the application depth of irrigation water because of uniformity and timing constraints. Typically, low-volume systems have lower wetted surface areas than other methods, and it can lead to less soil evaporation depending on the irrigation frequency of the other methods. Drip/micro-irrigation is generally more flexible for scheduling because timing and amount applied are more controlled by the irrigator than the water delivery system.

To update California's records on crops and irrigation methods, a survey was conducted by the California Department of Water Resources (CDWR) roughly every 10 years during recent decades. The survey data were analyzed and compared with earlier surveys to study how irrigation methods have changed and to make projections of future changes. This paper reports on the results from the 2001 irrigation survey and identifies trends in irrigation method usage.

Methodology

Questionnaire Design and Distribution

In 2002, a one-page grower questionnaire was mailed to 10,000 growers in California to determine what irrigation methods were used on which crops during 2001. The questionnaire can be downloaded from http://biomet.ucdavis.edu/ftp\ISS.pdf. The growers were randomly selected from a list of 58,000 growers by the California Department of Food and Agriculture, excluding rice, dry-land, and livestock producers. Rice-only growers, growers with nonirrigated farms, and livestock-only ranches were excluded from the randomly selected mailing list. Some questionnaires were mailed to each of the 58 counties within California, and the number mailed to each county was proportional to the ratio of growers residing in each county to the statewide total. There was an excellent 35% usable return rate. The 2001 questionnaire and its distribution were similar to the survey completed in 1991 (Snyder et al. 1996).

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Table 1. Crop Types Used in 1972, 1980, 1991, and 2001 Surveys

2001 crops	1991 crops	1980 crops	1972 crops
Alfalfa	Alfalfa	Alfalfa	Alfalfa
Grain	Small grains	Grain	Small grains, misc. hay
Corn	Corn	Corn	Corn
Cotton	Cotton	Cotton	Cotton
Other field crops, beans, safflower	Other field crops	Miscellaneous field	Other field crops
Pasture, turf grass, and landscape	Pasture	Pasture	Pasture
Almond and pistachio, other deciduous	Deciduous fruits and nut trees	Deciduous fruits and nut trees	Peaches and nectar/prunes/almonds/ walnuts
Subtropical trees	Subtropical	Subtropical	Citrus and avocado/other orchard
Sugar beets	Sugar beets	Sugar beets	Sugar beets
Tomato (fresh), tomato (process)	Processing tomatoes	Tomatoes	Tomatoes
Other truck crops, onion and garlic, potato, cucurbit	Vegetables (truck crops)	Miscellaneous truck	Beans, all types/potatoes/lettuce/other vegetable crops
Vineyard	Grapes and bush berries	Vineyard	Grapes
		Rice	Rice

Previous irrigation system surveys were conducted in 1972 (Stewart 1975) and 1980 (Hagan and Wagner 1983). In the earlier studies, the irrigated crop area was estimated by UC Cooperative Extension Specialists and farm advisors in each county.

Crops

In the survey questionnaire, growers were asked to state the main county in which they farmed and the area they planted to each of 20 possible crops by irrigation method within that county during 2001. The 2002 survey included a 20-crop category as opposed to a 13-crop category used in the 1991 survey, which also differed somewhat from earlier surveys. A list of crops used in 1972, 1980, 1991, and 2001 surveys are shown in Table 1.

Irrigation Methods

Irrigation method choices included surface (gravity), sprinkler, low-volume (microsprinkler/drip), and subsurface. For details on the methods, see Merriam and Keller (1978). General descriptions are given below.

Subsurface Irrigation

In subsurface irrigation, underground pipes or open ditches are blocked to back up groundwater and force it up into a crop root zone. This method is mainly used in the Sacramento-San Joaquin River Delta.

Surface Irrigation

Surface irrigation includes wild flood, border, basin, furrow irrigation without sprinklers, wheel-line sprinklers followed by furrow irrigation, and hand move sprinklers followed by furrow irrigation. Land that is irrigated initially with sprinklers and later with furrows is included under the surface irrigation category.

Sprinkler Irrigation

Sprinkler methods include solid set, hand move, linear move, wheel line, hose pull, and other types including center pivot, gun type, etc.

Low-Volume (Drip and Microsprinkler) Irrigation

Drip/microirrigation includes all low-volume systems including surface and buried drip irrigation, microirrigation, and minisprinklers.

Microsprinklers were included with surface and buried drip in the low-volume method category in the 2002 survey, while they were listed in the sprinkler category in the 1991 study. To be consistent, microsprinkler areas from the 1991 survey were combined with surface and buried drip methods to compare with the 2002 results. In addition to previous DWR surveys, comparisons were also made with data on method trends in 1994 and 1995 reported by Edinger-Marshal and Letey (1996).

Results and Discussion

The total irrigated land from the 1991 and 2001 surveys were 218,480 and 206,150 ha, respectively, having a difference of only 5.6%. The 2001 survey sample size represents nearly 5.6% of the irrigated land in California.

Irrigation Methods in 2001

Table 2 presents the 2001 irrigated area by crop and irrigation method, and the percentage of irrigated land by crop categories for each of the four irrigation methods is shown in Table 3. In general, field crops were surface irrigated, whereas tree and vine crops were irrigated mostly with low-volume systems.

Comparisons with 1991

The irrigated land area for each crop and irrigation methods during 2001 and 1991 are shown in Tables 2 and 4, respectively. To simplify comparisons, the crops were combined into four crop groups and the percentages of the total area irrigated by each of the four irrigation-method categories are shown for 1991 and 2001 (Table 5). An increase in drip and microsprinkler irrigation and a decrease in surface irrigation were evident for all categories but the field crops.

Table 2. Irrigated Land (ha) by Crop and Irrigation Method Reported for 2001

	Irrigation method[a]															
	SS	Surface						Sprinkler						Low-volume		
Crop	SS	WF	BR	BN	FW	SSR	SHM	PT	HM	LM	SR	CP	HP	MM	SD	BD
Corn	1,693	746	1,891	26	9,345	0	138	20	1	0	0	89	0	0	1	0
Cotton	154	0	283	0	13,135	809	40	264	512	0	0	0	0	0	0	0
Dry beans	0	8	28	49	453	0	156	0	362	0	0	162	0	0	0	0
Grains	236	779	7,084	28	1,360	29	60	32	568	20	289	204	12	0	2	0
Safflower	127	105	100	34	263	0	0	0	243	0	0	0	0	0	0	0
Sugar beet	0	0	0	0	691	0	0	0	0	0	0	0	0	0	0	1
Other field crops	10	81	1,386	0	1,183	0	0	6	225	2	118	51	0	3	49	0
Alfalfa	625	518	19,456	91	2,149	0	190	19	979	949	1,749	1,151	16	0	0	0
Pasture	609	4,500	4,150	98	344	453	130	348	1,027	819	235	91	82	0	0	0
Cucurbit	0	7	6	0	111	0	56	2	81	0	10	0	0	0	20	104
Onion-garlic	0	0	0	0	123	0	237	334	129	0	0	0	0	0	1	0
Potato	0	0	0	0	15	0	0	17	1,105	0	0	0	0	0	93	0
Tomato (fresh)	0	0	0	0	739	124	817	1	0	0	0	0	0	0	163	897
Tomato (process)	0	0	0	0	1,541	200	349	0	930	0	0	0	0	0	30	30
Other truck crops	0	0	0	12	2,270	0	2,828	111	5,214	4	0	5	42	99	2,630	931
Almond-pistachio	64	660	4,034	506	206	63	732	3,201	332	0	4	0	111	13,968	7,647	761
Other deciduous	64	530	1,836	238	2,445	23	15	3,227	1,007	32	32	40	313	2,228	2,825	229
Subtropical trees	145	68	87	446	926	45	41	1,468	149	2	188	23	171	10,274	1,772	244
Turfgrass-landscape	1	0	2	0	0	0	0	17	83	0	243	0	10	10	30	0
Vineyard	62	74	307	223	6,108	26	49	2,731	106	0	0	12	0	423	21,395	1,053

[a]SS=subsurface; WF=wild flood; BR=border; BN=basin; FW=furrow; SSR=furrow and side-roll sprinkler; SHM=furrow and hand-move sprinkler; PT=permanent sprinkler; HM=hand-move sprinkler; LM=linear-move sprinkler; SR=side-roll sprinkler; CP=center-pivot sprinkler; HP=hose-pull sprinkler; MM=microsprinkler; SD=surface drip; and BD=buried drip.

Table 3. Percentage of Irrigated Land Area by Crop and Irrigation Category Reported for 2001 (Rounded to the Nearest Percentage)

Crop	Gravity	Sprinkler	Drip/Micro	Other
Corn	87	1	0	12
Cotton	94	5	0	1
Dry beans	57	43	0	0
Grains	87	11	0	2
Safflower	58	28	0	15
Sugar beet	100	0	0	0
Other field crops	85	13	2	0
Alfalfa	80	17	0	2
Pasture	75	20	0	5
Cucurbit	45	24	31	0
Onion-garlic	44	56	0	0
Potato	1	91	8	0
Tomato (fresh)	61	0	39	0
Tomato (process)	68	30	2	0
Other truck crops	36	38	26	0
Almond-Pistachio	19	11	69	0
Other deciduous	34	31	35	0
Subtropical trees	10	13	77	1
Turfgrass-landscape	1	89	10	0
Vineyard	21	9	70	0
Total	**49**	**16**	**33**	**2**

Comparisons with Earlier Years

Trends in irrigation method usage are shown in Fig. 1, and trends in cropping are shown in Fig. 2 for the period 1972 to 2001. The percentage of irrigated land by irrigation method shows decreasing use of surface irrigation and increasing use of drip and microsprinkler irrigation (Fig. 1). Clearly, much of the change in irrigation systems was driven by the decrease in field crop planting and an increase in orchards and vineyards where micro/drip irrigation is more widely practiced (Figs. 1 and 2).

There was a small temporary decrease in sprinkler irrigation and a sustained increase in micro/drip irrigation in the 1991 survey. Since 1991 was late in a drought that lasted about five years, it is believed that the drop in sprinkler usage resulted as a response to drought. Because micro/drip irrigation is perceived to reduce evapotranspiration losses, it is likely that the increase in micro/drip irrigation in the 1991 survey was also a response to drought. Following the drought, the area irrigated with micro/drip irrigation did not decrease. Since the capital costs to install micro/drip systems is somewhat high, several years of operation are commonly needed to justify the investment.

Trends in the percentage of land irrigated by drip/micro systems, sprinklers, and surface irrigation for the four crop categories from the 1972, 1980, 1991, and 2001 surveys are shown in Table 5. Little change has occurred in the irrigation methods used on field crops, but a definite trend for increased use of drip and microsprinkler irrigation for orchards and vineyards. For sprinklers, the main changes were an increase of 16% in use on vegetable crops and a decrease of 16% in use for orchards during the last decade. The largest changes in irrigation method usage were related to the increase in drip and microsprinkler irrigation and a drop in surface irrigation, particularly in orchard and vine crops (Table 5).

Table 4. Irrigated Land (ha) by Crop[a] and Irrigation Method[b] Reported for 1991

	Irrigation method[a]																
	Surface						Sprinkler						Low volume				SS
Crop	WF	BR	BN	FW	SSR	SHM	PT	HM	LM	SR	HP	OR	MM	SD	BD	DS	SS
ALF	1,868	20,151	229	1,765	0	0	18	1,280	0	1,204	209	809	121	10	0	0	263
SGR	512	9,171	183	3,528	68	781	0	751	40	824	0	121	0	0	0	0	67
CRN	228	1,856	14	4,578	18	550	0	0	0	0	0	0	0	0	0	0	65
CTN	0	5,407	0	16,370	162	4,769	190	1,557	0	0	0	101	0	0	65	0	0
OTH	735	3,652	787	3,635	143	292	279	167	0	441	0	54	17	9	68	0	49
PAS	3,756	3,789	67	1,063	0	64	204	809	18	71	69	111	0	0	0	0	660
DEC	1,735	8,445	397	5,225	169	436	11,552	3,249	49	3	966	179	3,775	3,516	1,522	490	104
SUB	105	101	226	1,310	0	95	1,400	118	16	98	836	69	10,286	1,193	58	9	0
SBT	0	72	0	3,492	316	575	47	634	0	0	0	0	0	0	0	0	0
TOM	0	136	0	5,390	668	6,853	30	604	0	279	0	0	0	0	121	0	0
VEG	125	218	61	5,316	866	4,152	3,295	1,458	987	0	0	0	1	1,100	1,692	202	0
VIN	526	1,223	316	7,045	190	193	2,513	112	0	0	36	0	15	8,745	121	62	57
Total	9,590	54,221	2,279	58,717	2,600	18,759	19,528	10,738	1,110	2,919	2,116	1,444	14,214	14,573	3,647	763	1,265

[a]ALF=alfalfa; SGR=small grains; CRN=corn; CTN=cotton; OTH=other field crops; PAS=pasture; DEC=deciduous orchard; SUB=subtropical orchard; SBT=sugar beet; TOM=tomato; VEG=vegetables; and VIN=vineyards.

[b]WF=wild flood; BR=border; BN=basin; FW=furrow; SSR=furrow with side-roll sprinklers; SHM=furrow with hand-move sprinklers; PT =permanent sprinkler; HM=hand-move sprinkler; LM=linear-move sprinkler; SR=side-roll sprinkler; HP=hose pull; OR=other type sprinkler; MM =microsprinkler; SD=surface drip; BD=buried drip; DS=drip-following sprinkler; and SS=subsurface.

The irrigation system trends seemed to be mainly related to the transition from field to orchard and vine crops, regardless of the region within the state. Trends similar to the presented statewide averages were observed in the major agricultural regions (San Juaquin and Sacramento Valleys), where the main transition from field to permanent crops has occurred.

Orchardists have adopted the use of microsprinklers to improve distribution uniformity, flexibility in scheduling, fertilizer application, protection against frost damage, and higher production. Except for the frost protection, viticulturalists prefer elevated drip irrigation systems for similar reasons. In addition, the elevated drip lines do not interfere with cultural practices. The labor time for managing and maintaining drip/micro systems are comparable to other methods, but the type of labor is different and growers tend to prefer the low-volume systems.

Table 5. Percentages of Irrigated Land by Four Crop Categories and Irrigation Methods Reported for (a) 1991 and (b) 2001 (Rounded to the Nearest Percentage)

Method	Field	Vegetable	Orchard	Vineyard	All
(a) Reported for 1991					
Surface	89	71	32	45	67
Sprinkler	9	20	32	13	17
Micro/drip	0	9	36	42	15
Subsurface	1	0	0	0	1
Total	100	100	100	100	100
(b) Reported in 2001					
Surface	84	43	20	21	50
Sprinkler	12	36	16	9	16
Micro/drip	0	21	63	70	33
Subsurface	4	0	0	0	2
Total	100	100	100	100	100

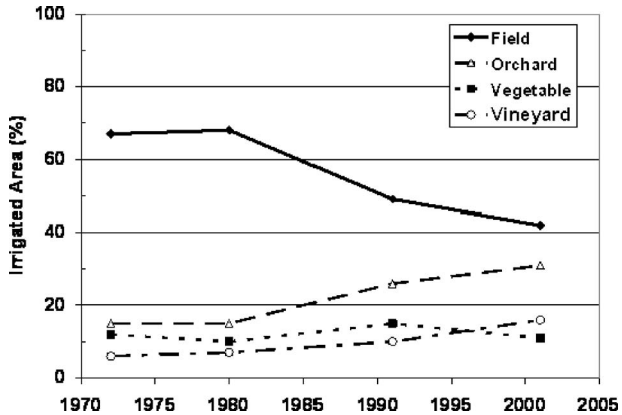

Fig. 1. Trends in irrigated area (%) by irrigation system category

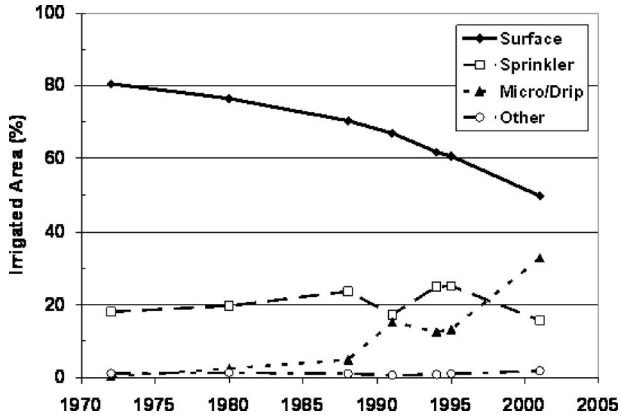

Fig. 2. Trends in irrigated area (%) by crop category

Conclusions

The results of the 2001 irrigation system survey demonstrate consistent trends in crop area as well as the irrigation methods used in the various crops based on the information collected from a variety of sources. A decrease in use of surface irrigation by about 30% from 1972 until 2001 and an increase in the use of drip/microsystems by about 31% were observed. The changes are mainly due to a drop in field crop planting (26%), which are predominantly surface irrigated, and an increase in orchard and vineyard planting (26%), which are mainly irrigated by drip/microsystems in recent years. In the last decade, surface irrigation decreased about 28% and sprinkler and drip/microirrigation increased about 28%. This information is important for long-range water resource planning.

References

Edinger-Marshal, S., and Letey, J. (1996). "Irrigation shifts toward sprinklers, drip and microsprinklers." *Calif. Agric.*, 51(3), 38–40.

Hagan, R. M., and Wagner, R. J. (1983). "Irrigation methods in California: An update." California Dept. of Water Resources Division of Planning and Local Assistance, Sacramento, Calif.

Merriam, J. L., and Keller, J. (1978). "Farm irrigation system evaluation: A guide for management." Agriculture and Irrigation Engineering Dept., Utah State Univ., Logan, Utah.

Snyder, R. L., Plas, M. A., and Grieshop, J. I. (1996). "Irrigation methods used in California: Grower survey." *J. Irrig. Drain. Eng.*, 122(4), 259–262.

Stewart, J. I. (1975). "Irrigation in California: A report to the State Water Resources Control Board." *Standard Agreement No. 2-2-65*, Univ. of California and the California Water Resources Control Board, Sacramento, Calif.