NCFAP
National Center for Food & Agricultural Policy

EXECUTIVE SUMMARY

THE VALUE OF HERBICIDES IN U.S. CROP PRODUCTION

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KEY FINDINGS

The widespread use of herbicides in crops grown throughout the United States has resulted in yield increases, savings for growers and reduced soil erosion.

For most crops, the national herbicide treated acreage exceeds 85 percent. Without herbicides, hand weeding and cultivation most likely would replace current practices. The national cost of these alternatives tops $14 billion annually, more than double what the nation's growers are spending on herbicides and their applications.

For 35 of the 40 crops studied, yields without herbicide use would be reduced by 5 to 67 percent. These estimates assume the likely substitution of cultivation and hand weeding. In most cases, yields without herbicide use can equal yields with herbicides, if growers substitute enough hand weeding; these labor requirements, however, are prohibitively expensive, and it is unlikely that growers would remain profitable without herbicide use.

For four crops, no yield change is projected since the assigned amount of tillage, hand weeding or alternative practices are sufficient to provide weed control equivalent to herbicide use. For one crop, grapes, the national estimated average loss is only 1 percent because California would experience no loss while other grape-producing states would face a loss of 12 to 35 percent. Although no yield losses are predicted for these crops, it may be unrealistic to assume that growers will incur the significant costs of the alternatives.

Economics
The nonuse of herbicides with likely substitution of alternatives would result in $13.3 billion loss in food and fiber production. This 288 billion pound loss represents approximately 21 percent of the national production of these 40 crops. Added to the increased cost of production, total grower net income would decline by $21 billion annually.

Labor Requirements
As a major replacement of herbicides for many crops, hand weeding requirements would increase by 1.2 billion hours. For field crops such as wheat, corn and soybeans, NCFAP researchers assigned a two-hour to five-hour increase per acre. Most fruit and vegetable crops are assigned 20-60 hours more hand weeding per acre. These high labor levels would still be inadequate to control all weeds, and yield losses would result.

Soil Erosion
Erosion of cropland has been reduced from an estimated 3.5 billion tons in 1938 to 1 billion tons in 1997. Much of this erosion reduction has occurred by reducing tillage. Without herbicide use, no-till agriculture becomes impossible, resulting in increased erosion estimated to be more than 300 billion pounds of soil annually or a 15 percent increase. Much of this soil erosion would enter waterways and significantly reduce quality of the nation's surface water.

Herbicide Nonuse 40 Crop Study Summary	
Total Acres Treated with Herbicides	220 million
Current Herbicide Cost to Growers	$6.6 billion
Herbicide Nonuse Cost Increase	$7.7 billion
Herbicide Nonuse Yield Loss (Volume)	288.5 billion pounds
Herbicide Nonuse Yield Loss (Value)	$13.3 billion
Herbicide Nonuse Labor	+ 1.2 billion hours
Herbicide Nonuse Erosion	+ 304 billion pounds
Herbicide Nonuse Net Income Impact	- $21 billion

INTRODUCTION

Herbicides are chemicals that kill plants. Selective herbicides are used in U.S. crop production to remove unwanted plants, weeds. These selective herbicides do not injure crop plants and are toxic to weeds.

Weeds compete with crops for moisture, nutrients, sunlight and space, resulting in significant crop losses. Natural weed populations in most fields are high enough to cause devastating yield losses if not controlled. Loss figures of 50 percent to 90 percent are common for crops grown in natural weed infestations. Weeds are different from other pests that pose problems in crop production because they are relatively constant while outbreaks of insects and disease pathogens are sporadic.

Each acre of cropland in the United States contains millions of buried weed seeds. Many weed seeds can survive in a dormant condition in the soil for several decades. In a typical year, five percent to 10 percent of these seeds germinate. The weed seed bank is replenished as a result of the very high seed production of individual weed plants. For most crops, it is critical that fields are kept weed-free during the first four to six weeks after planting to prevent serious yield losses.

The widespread use of herbicides began with development of synthetic organic chemicals in the 1940s. Herbicides replaced hand labor, which was becoming scarce and expensive, and growers reduced cultivation for killing weeds. Crop yields improved due to better weed control with herbicides. Cropland erosion was significantly reduced as growers relied on herbicides.

Every year, U.S. growers routinely apply herbicides to more than 85 percent of the acreage of most crops to kill weeds. Approximately 200 chemical active ingredients are used as herbicides. Specific herbicides that are used by growers of each crop are expected to kill more than 95 percent of the weeds that typically infest the crop. Some herbicides remain active in the soil for an extended period of time and kill weed seedlings as they germinate while other herbicides are applied to weed foliage and kill the plant after coming into contact or being absorbed.

Regulators and legislators often consider policies that would further increase regulation of herbicides. Some U.S. growers are farming without using herbicides. These organic growers use alternative methods such as tillage and hand weeding for killing weeds.

No single reference has been assembled that quantifies the contributions that herbicides have made to U.S. agriculture or quantifies the implications of a widespread movement away from herbicide use. This study was commissioned with a grant from CropLife America to fill the need for a comprehensive description of herbicides' value.

It is highly unlikely that U.S. growers will have to produce their crops without herbicides in the foreseeable future. Nevertheless, the promotion of organic agriculture and increased regulation requires the public, policy makers, regulators, and the media to maintain an understanding of crop production realities in the United States and the implications of potential policy changes on that production.

METHODOLOGY

The purpose of this study is to document the value of herbicides in U.S. crop production. The study examined the role of herbicides in the production of 40 specific crops in the United States. Two methods are used. A literature review was conducted to gather historical information on weed control practices, and their costs and effectiveness for the periods of time before and after the introduction of herbicides. The literature review also focused on weed control practices of organic growers. Second, researchers calculated impacts of the nonuse of herbicides with the likely substitution of alternative weed control practices with their associated costs and effectiveness. Data and summary information are provided by crop and for each of the 48 contiguous states. Each case study quantifies cost changes and yield changes as a result of the nonuse of herbicides.

The full report lists over 400 references that document the historical and organic overviews. A list of key references is included in this executive summary.

BACKGROUND INFORMATION

The 40 crops selected for this study are listed in Table 1 and include representative field crops, vegetable crops, specialty, fruit, nut and berry crops. Table 1 presents 2001 national production and acreage estimates for each crop. The 40 crops total 255.7 million acres, with annual production of 1.4 trillion pounds of food and fiber and a combined value of $66.2 billion.

Table 1 also summarizes 2001 herbicide use for each of the 40 crops. An estimate is included of the percent of each crop's national acreage treated with herbicides. Nationally, it is estimated that 220 million, or 86 percent of the acres of the 40 crops are treated with herbicides. In addition, Table 1 contains estimates of herbicide active ingredient (pounds) used annually in each crop nationally. The 40 crops total 410 million pounds in herbicide use. Table 1 also contains estimates of the cost of herbicides. The cost estimate consists of three components: the cost of the product, the cost of application and technology fees for use of biotech herbicide tolerant seeds. The total cost of herbicide use for the 40 crops is $6.6 billion. With an average of 2.5 million weeds per acre, herbicides kill 550 trillion weeds on 220 million acres per year.

Literature Review

For each of the 40 crops, a literature review was conducted to collect information on current and historical usage of herbicides. This literature review is summarized for each crop in the full report (see Appendices A.1-A.40). For most of the crops, the historical record shows the rapid adoption of herbicide use in the United States in the 1950s-1960s and their continued use on 80 percent to 90 percent of the acreage since that time (Figure 1 [corn]).

The historical literature review revealed that herbicides replaced or reduced hand weeding and cultivation for weed control in most crops. Up to 120 hours of hand labor and 16 cultivation trips per acre had been used to kill weeds prior to the introduction of herbicides. In California, workers using short-handled hoes, a practice banned in the 1960s, accomplished much of this weeding. For some crops that are grown in dense plantings such as rice and wild blueberries, there was no reduction in hand weeding and cultivation since these practices were not widely used. For these crops, the impact of herbicide use was a dramatic increase in yields due to more effective weed control (Figures 2 and 3).

Figure 1: U.S. Corn Acreage Treated with Herbicides

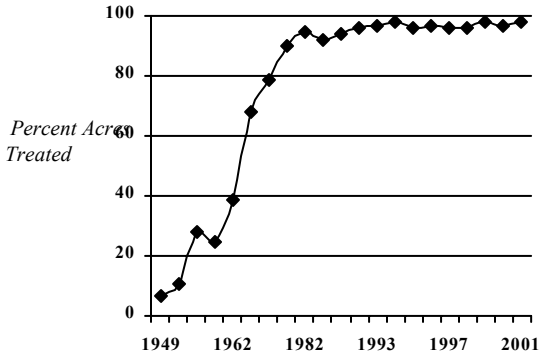


Figure 2: Maine Wild Blueberry Production
New Herbicides Introduced: 1970s- 1980s

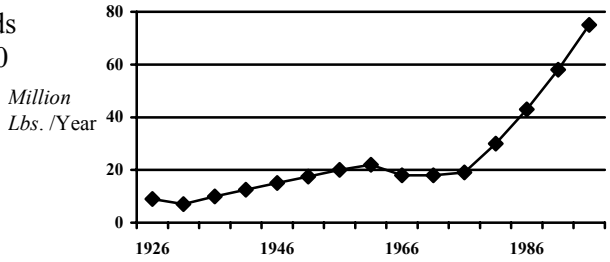


Figure 3: U.S. Rice Yields
Herbicides Introduced: 1950s

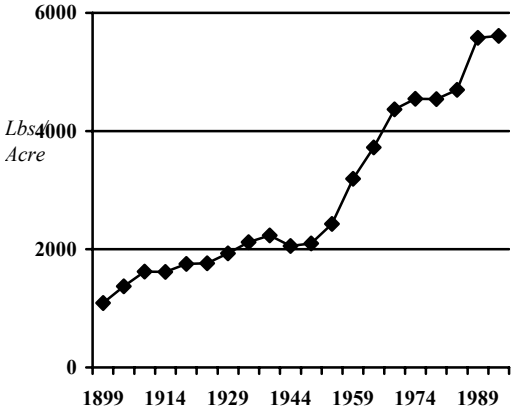


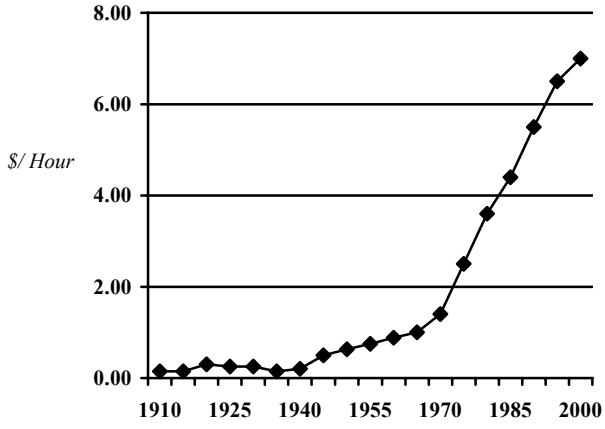
Table 1: 40 Crops 2001 Production & Herbicide Use						
	Production			*Herbicide Use*		
Crop	*Acreage (000)*	*Value (Million $)*	*Volume (Million lbs)*	*Percent Acres Treated*	*Pounds / Year (000)*	*Total Cost (000$)*
Almonds	525	732	1,354	86	1,229	20,533
Apples	430	1,477	9,628	63	1,530	17,715
Artichokes	8	58	100	58	12	419
Asparagus	77	230	208	91	213	2,833
Blueberries	24	23	75	95	14	652
Broccoli	141	504	2,042	51	211	2,398
Canola	1,494	176	1,998	99	718	30,603
Carrots	121	577	4,005	98	169	3,739
Celery	29	277	1,882	85	50	696
Citrus	1,094	2,638	34,806	95	7,879	80,607
Corn	75,752	19,209	736,000	98	206,052	2,265,353
Cotton	15,787	3,384	9,600	95	33,113	559,963
Cranberries	34	99	532	95	120	3,109
Cucumbers	59	212	1,089	60	252	3,505
Dry Beans	1,430	414	1,954	99	3,799	40,030
Grapes	930	2,921	13,104	75	1,831	27,932
Green Beans	210	112	1,397	96	743	6,548
Green Peas	217	102	774	94	245	4,051
Hops	36	126	66	95	71	1,201
Hot Peppers	33	88	311	95	111	1,547
Lettuce	306	1,907	10,053	62	290	8,477
Mint	98	96	8	95	375	10,392
Onions	167	703	6,708	88	568	8,268
Peaches	151	496	2,440	66	234	2,978
Peanuts	1,543	1,003	4,239	97	3,038	63,896
Potatoes	1,267	2,591	44,476	93	3,109	45,450
Raspberries	12	46	92	91	34	674
Rice	3,335	896	21,304	98	15,736	217,996
Sorghum	10,252	998	28,784	91	16,579	134,918
Soybeans	74,105	12,446	174,000	96	76,604	2,110,780
Spinach	15	17	284	90	37	471
Strawberries	47	1,085	1,666	39	75	1,420
Sugarbeets	1,371	1,113	52,000	98	2,398	138,163
Sugarcane	1,029	942	70,000	95	5,904	51,323
Sunflowers	2,653	317	3,480	95	1,841	26,347
Sweet Corn	733	772	9,050	90	1,890	16,134
Sweet Potatoes	98	210	1,435	70	71	1,664
Tomatoes	411	1,665	22,192	96	684	11,593
Wheat	59,617	5,553	120,000	55	21,789	649,779
Wild Rice	19	10	6	10	1	9
Total	255,660	66,225	1,393,142	(86)	409,619	6,574,166

Notes: Corn for grain only. Spinach, green beans and green peas for processing only.
Wild rice Minnesota only. Blueberries Maine only.
Fumigants not included.

For two crops, corn and soybeans, previous studies statistically determined the contribution of herbicides to improved yields. Herbicides accounted for 20 percent of the increase in corn yields between 1964 and 1979 and 62 percent of the yield increase in soybeans 1965-79.

For several crops (cotton, carrots and onions), dramatic improvements in crop yield did not occur following the adoption of herbicide use. For these crops, an adequate amount of hand labor had been previously used to remove weeds and prevent yield loss. The adoption of herbicide use was spurred by a desire to reduce weed control costs since labor was becoming more expensive and scarce. A mass exodus occurred in the late 1940s and early 1950s as workers moved from rural areas to urban areas. As a result of a scarce labor supply, the farm wage rate quadrupled in the early 1950s and has increased even further since then (Figure 4). Growers who were used to paying $.10/hour were faced with paying $.50/hour in the early 1950s and $1.00/hour in the 1960s. Herbicides were adopted to lower the costs of weeding. For example, in a 1957 experiment in onions, an $8/acre herbicide application substituted for 55 hours of labor, which was budgeted at $41/acre.

Figure 4: U.S. Hired Farm Worker Wage Rate



For many crops, the primary means of killing weeds prior to herbicides was cultivation, which can be quite effective if performed at the optimal time for weed removal. However, the historical record is clear that cultivation was not always performed in a timely fashion, particularly due to late season infestations that could not be cultivated because of crop size and wet fields that prevented the use of tractors when weeds needed to be removed. As a result, yield losses often occurred, and in extreme cases, fields were not harvested due to weeds. In a 1932 Illinois study, it was estimated that on 10 percent of the cropland there was, in a normal year, one-half or greater crop loss due to weeds. Cultivation lowered yields of some crops, such as potatoes and apples, due to root pruning and damage to trees. For some crops, such as corn, the need to cultivate led to very wide plant spacing to accommodate cultivation on all four sides of each plant. With the substitution of herbicide use, crops such as corn could be planted closer together, which increased per acre yields.

Organic Production

The United States Department of Agriculture (USDA) estimates that there were 1.2 million acres of organic certified cropland in the United States in 2001. Organic farmers do not use synthetic chemicals for pest control. The problem of controlling weeds without herbicides has been cited numerous times as the single biggest obstacle that organic growers encounter. Out of 30 research areas, organic farmers ranked weed control as the number one priority in three national surveys (1993, 1995, 1997). USDA recently stated that weed control costs of organic vegetable growers in California can be $1000/acre in comparison to $50/acre that conventional growers spend on herbicides.

A literature search was conducted to identify the extent to which organic growers of the 40 crops in this study use hand weeding and cultivation for weed control. For 14 of the crops, additional hand weeding of two hours to 165 hours was identified for organic production. For 14 of the crops, additional tillage of one to nine trips per acre was identified for organic production. Organic rice yields in California and organic blueberry yields in Maine are 50 percent and 75 percent lower, respectively, than conventional. For 10 of the crops, organic production yields are 13 percent to 80 percent lower than conventional yields.

HERBICIDE VALUE ESTIMATION

Estimates of the value of herbicides were made in terms of the economic value to growers, reduced need for labor and less soil erosion. These estimates are based on a simulation of the nonuse of herbicides by U.S. growers and the substitution of likely alternative practices as well as their costs and effectiveness in comparison to herbicide use.

Table 2 identifies the likely substitution and costs of hand weeding and cultivation for each crop if herbicides were not used. These estimates are drawn from the historical record and from the information collected on organic practices.

Up to 64 hours per acre of hand weeding and up to nine cultivations have been specified as alternatives. Each hour of hand weeding is estimated to cost $8.75, which includes a wage, supervisory and other costs associated with employing a work crew of hand laborers. Each tillage trip is estimated to cost $4.50/acre. By multiplying the per acre cost of the likely alternatives times the number of acres treated with herbicides, estimates are made of the total cost of the alternative weed control practices.

For 36 crops, the alternatives cost more than the use of herbicides. For the other four crops, the cost of alternatives is less because, in one instance, growers are assumed not to implement any alternative practice (wild rice); for three other crops (rice, sorghum, canola), only a few cultivation trips have been specified as alternatives. The national cost of the alternatives is $14.3 billion per year, which is $7.7 billion higher than current expenditures on herbicides ($6.6 billion).

Table 2 shows estimates of the likely impacts on crop yields of not using herbicides and using the likely alternatives. These estimates are drawn from a series of studies conducted in the 1990s by the USDA, Weed Science Society of America (WSSA), and American Farm Bureau Federation (AFBF). For 35 crops, yields are projected to decrease by 5 percent to 67 percent without herbicide use. These impact estimates are consistent with the historical record and with the record of organic production. All of the studies relied on university weed science specialists to specify the likely yield changes that would result if growers used readily available alternatives to herbicides. These expert opinions are based on research trials conducted by the specialists as well as their knowledge about growers with alternative practices. The specialists also factored into the estimates how timely weed removal would be with cultivation and how available hand labor would be for weeding.

Most specialists projected some increase in hand labor but not enough to prevent some yield loss. For example, if enough hand weeding is used, yields can be equivalent to herbicides: corn (60 hours/acre), cotton (67 hours/acre), lettuce (224 hours-424 hours/acre), onions (1067 hours/acre), and tomatoes (182 hours-259 hours/acre). These labor requirements are far greater than those specified as alternatives in this study: corn (five hours/acre), cotton (13 hours/acre), lettuce (38 hours/acre), onions (64 hours/acre), and tomatoes (37 hours/acre).

For four crops, no yield change is projected since the amount of tillage, hand weeding or other alternative practice is assumed sufficient to provide control equal to herbicides (celery, citrus, hot peppers and raspberries). In addition, for grapes, the national loss is 1 percent, which is a weighted average of no loss in California and a 12 percent to 35 percent loss in other states.

In some cases the yield loss estimates reflect increased crop damage due to cultivation (potatoes, apples) or lower quality harvested crop due to weed contamination (mint).

In total, the nonuse of herbicides and the likely substitution of alternatives would result in a loss of $13.3 billion in food and fiber production, totaling 288 billion pounds. The total impact of herbicide nonuse would be an income loss of $21 billion, which includes $7.7 billion in increased costs for weed control and $13.3 billion in yield losses.

Table 2: Herbicide Nonuse Alternative Costs and Yield Losses by Crop							
	Alternatives			Production Impact			Total Impact
Crop	*Hand Labor (Hours/ Acre)*	*Tillage (Trips/ Acre)*	*Net Increase (000$)*	*% Yield Loss*	*Million Lbs.*	*Million $*	*000 $*
Almonds	7	0	23,424	5	58.2	31.5	54,924
Apples	20	2	32,149	15	909.8	139.6	171,749
Artichokes	23	0	587	16	9.3	5.4	5,987
Asparagus	5	5	1,805	55	104.1	115.1	116,905
Blueberries	5	0	354	67	47.7	14.6	14,954
Broccoli	20	2	10,482	14	145.8	36.0	46,482
Canola	0	2	-17,292	45	890.1	78.4	61,108
Carrots	14	2	11,909	48	1,884.0	271.4	283,309
Celery	60	4	12,879	0	0	0	12,879
Citrus	0	0	334,993	0	0	0	334,993
Corn	5	4	2,318,781	20	144,256.0	3,765.0	6,083,781
Cotton	13	7	1,618,496	27	2,462.4	868.0	2,486,496
Cranberries	20	0	2,491	50	252.7	47.0	49,491
Cucumbers	30	3	6,155	66	431.2	84.0	90,155
Dry Beans	16	2	170,954	25	483.6	102.5	273,454
Grapes	8	2	27,210	1	98.3	21.9	49,110
Green Beans	12	2	16,480	20	268.2	21.5	37,980
Green Peas	12	2	19,205	20	145.5	19.2	38,405
Hops	35	6	10,129	25	15.7	29.9	40,029
Hot Peppers	60	0	14,728	0	0	0	14,728
Lettuce	38	2	56,408	13	810.3	153.7	210,108
Mint	18	0	4,255	58	4.4	53.0	57,255
Onions	64	2	75,375	43	2,538.3	266.0	341,375
Peaches	6	0	2,272	11	177.1	36.0	38,272
Peanuts	10	2	80,564	52	2,138.2	505.9	586,464
Potatoes	10	5	84,130	32	13,236.1	771.1	855,230
Raspberries	43	9	3,910	0	0	0	3,910
Rice	0	4	-159,172	53	11,065.3	465.4	306,228
Sorghum	0	3	-8,977	26	6,810.3	236.1	227,123
Soybeans	5	4	2,282,176	26	43,430.4	3,106.5	5,388,676
Spinach	20	3	2,168	50	127.8	7.6	9,768
Strawberries	30	4	3,629	30	194.9	126.9	130,529
Sugarbeets	15	2	50,333	29	14,778.4	316.3	366,633
Sugarcane	25	3	175,585	25	16,625.0	223.7	399,285
Sunflowers	0	7	53,033	16	529.0	48.2	101,233
Sweet Corn	5	3	21,651	25	2,036.2	173.7	195,351
Sweet Potatoes	24	2	13,447	20	200.9	29.4	42,847
Tomatoes	37	8	130,148	23	4,900.0	367.6	497,748
Wheat	2	2	219,129	25	16,500.0	763.0	982,129
Wild Rice	0	0	-9	50	0.3	.5	491
Total	----------	----------	7,705,974	(21)	288,565.5	13,301.6	21,007,574

For almonds and citrus, costs are in mowing, increased fertilizer, cover crops and irrigation.
These costs total $36/acre in almonds and $400/ acre in citrus.

Labor Requirements

A major replacement of herbicide use would be hand weeding. Field crops such as wheat, corn and soybeans are projected to use two to five hours of hand weeding per acre. Most fruit and vegetable crops are projected to use 20 hours to 60 hours per acre.

For the nation, an 1.2 billion hours of hand weeding by 7.2 million seasonal workers would be required assuming that, for each crop, the weeding would be completed during a four-week period. This is a significant increase over the 1 million hired workers currently employed by U.S. farmers. Approximately 10 times the amount of labor specified in this study would be required to prevent any yield loss in comparison to herbicides.

Soil Erosion

Erosion of cropland was reduced in the U.S. from an estimated 3.5 billion tons in 1938 to about 1 billion tons in 1997. The tillage reduction associated with the increased use of herbicides played a significant role in erosion reduction. No-till, in which the soil is left undisturbed, is the most effective soil-conserving system and can reduce erosion by 90 percent or more. The average rate of erosion on a cultivated crop acre is 2.9 tons greater than on an uncultivated acre.

The elimination of tillage means that the farmer must rely on herbicides to control weeds. Currently, there are 52 million acres of no-till cropland in the United States.

A significant increase in cultivation is projected if herbicides were not used in crop production. Without the use of herbicides, U.S. farmers could no longer grow crops using no-till methods. Without herbicides, farmers who currently use no-till methods would have to use tillage to control weeds. As a result, the acres that are currently in no-till would no longer be subject to the lower erosion rates associated with non-cultivated cropland but, rather, would be likely to erode at the higher rates associated with cultivated cropland. The national impact on soil erosion would be an increase of 304 billion pounds per year as a result of farmers no longer using no till methods. Much of this soil erosion would enter waterways and significantly reduce the nation's surface water quality.

RESULTS BY STATE

Impact estimates for the 40 crops were made for major producing states. The likely substitution of hand weeding and tillage as well as associated yield losses were estimated for each state based on information from the USDA, WSSA and AFBF reports used for the national-level analysis. The national impacts shown in Table 2 are weighted averages of the impact estimates for individual states.

Impact estimates were calculated for two or more crops for each of the 48 contiguous states. These estimates were based on USDA, WSSA and AFBF reports. The individual crop impact estimates for each state have been summed to the state level and are shown in Table 3. The national total estimates shown in Table 2 do not match with sums of the state estimates shown in Table 3 since not all producing states were included in the state-level analysis for each crop. Table 3 displays two of the crop yield loss estimates for each state.

Table 3 shows that four states (California, Illinois, Iowa, Texas) would account for 31 percent of the total impact of not using herbicides. Table 4 shows state-by-state estimates of the impacts on production volume, number of laborers required for hand weeding and increased erosion that are projected to occur if herbicides are not used in U.S. crop production.

According to Table 4, Iowa would incur the largest yield loss, while Texas would need more than a half million more farm workers if herbicide use is eliminated. Illinois would face the largest increase in soil erosion.

By using herbicides, growers in each state gain from reducing their costs and/or increasing their yield. In most cases, both occur. As such, without herbicides, growers in each state would experience increased costs and lower yields.

Table 3: Herbicide Nonuse Alternative Costs and Yield Losses by State					
State	**Increased Weed Control Cost (000$)**	**Production Impact (000$)**	**Total Impact (000$)**	**Selected Crop Yield Loss (percent)**	
AL	79,553	164,275	243,828	Cotton -25	Peanuts -75
AZ	47,639	84,058	131,697	Corn –23	Cotton -30
AR	144,688	671,917	816,605	Cotton -40	Rice -53
CA	359,213	899,173	1,258,386	Carrots -45	Tomatoes -20
CO	90,967	109,045	200,012	Onions -23	Sugarbeets -10
CT	363	1,259	1,622	Peaches -12	Sweet Corn -12
DE	4,850	36,195	41,045	Wheat -50	Sweet Corn -30
FL	356,060	485,132	841,192	Sweet Corn -17	Strawberries -55
GA	195,746	532,769	728,515	Cotton -65	Peanuts -60
ID	42,712	402,178	444,890	Hops –25	Potatoes -35
IL	651,008	1,191,742	1,842,750	Corn –22	Soybeans -22
IN	356,875	446,818	803,693	Mint –58	Cucumbers -59
IA	534,156	1,434,355	1,968,511	Corn –25	Soybeans -29
KS	257,506	221,626	479,132	Sorghum -15	Wheat -10
KY	45,285	102,390	147,675	Soybeans -28	Sorghum -10
LA	146,439	353,432	499,871	Rice –53	Sugarcane -44
ME	4,887	35,206	40,093	Apples -45	Blueberries -67
MD	21,750	62,392	84,142	Corn –31	Peaches -14
MA	1,473	18,654	20,127	Tomatoes -30	Cranberries -50
MI	205,563	436,220	641,783	Asparagus -50	Potatoes -50
MN	449,402	488,454	937,856	Wheat -30	Green Peas -15
MS	174,123	335,522	509,645	Rice –53	Cotton -40
MO	244,315	632,296	876,611	Grapes -25	Soybeans -45
MT	57,399	95,622	153,021	Wheat -30	Sugarbeets -11
NE	448,457	444,856	893,313	Dry Beans -25	Corn -12
NV	647	4,229	4,876	Potatoes -30	Wheat -25
NH	357	759	1,116	Apples –5	Sweet Corn -15
NJ	1,288	67,381	68,669	Lettuce -50	Spinach -50
NM	28,461	27,779	56,240	Cotton -32	Onions-15
NY	27,506	106,223	133,729	Potatoes -30	Grapes -12
NC	184,956	348,218	533,174	Cotton-70	Peanuts -66
ND	158,412	462,539	620,951	Canola -45	Sugarbeets -24
OH	251,037	586,622	837,659	Potatoes -52	Tomatoes -25
OK	85,525	48,738	134,263	Cotton -25	Peanuts -40
OR	33,294	165,956	199,250	Mint –58	Grapes -15
PA	41,600	61,567	103,167	Apples -20	Sweet Corn -20
RI	56	202	258	Potatoes -20	Apples -10
SC	44,174	67,615	111,789	Peaches -40	Peanuts -52
SD	255,303	269,223	524,526	Potatoes -21	Sunflowers -16
TN	112,272	122,121	234,393	Apples -27	Soybeans -30
TX	762,476	632,446	1,394,922	Cotton -30	Onions -25
UT	3,120	6,250	9,370	Wheat -22	Dry Beans -29
VT	367	1,206	1,573	Apples -17	Sweet Corn -15
VA	35,747	70,950	106,697	Tomatoes -40	Peanuts -22
WA	84,970	654,552	739,522	Potatoes -55	Asparagus -55
WV	490	1,387	1,877	Wheat -17	Peaches -25
WI	145,349	210,392	355,741	Potatoes -33	Green Peas -12
WY	7,432	8,560	15,992	Dry Beans -23	Corn -20

Note: Impact estimates for most states are based on five to 10 crops (see full report). Two selected crop estimates are shown for illustrative purposes.

Table 4: Herbicide Nonuse Impacts on Production, Labor and Erosion By State			
State	**Production Loss (Million Lbs.)**	**# Laborers Needed**	**Erosion Increase (Million Lbs.)**
ALABAMA	826	70,566	5,392
ARIZONA	482	35,771	4
ARKANSAS	10,833	179,695	4,381
CALIFORNIA	9,003	274,940	5
COLORADO	2,241	69,422	1,540
CONNECTICUT	4	317	37
DELAWARE	801	10,713	748
FLORIDA	4,297	101,261	140
GEORGIA	2,476	172,711	5,657
IDAHO	9,424	71,240	1,402
ILLINOIS	26,121	659,836	48,731
INDIANA	9,941	353,462	20,615
IOWA	31,012	679,500	41,466
KANSAS	5,447	211,636	11,357
KENTUCKY	2,106	69,111	11,420
LOUISIANA	16,361	173,565	1,297
MAINE	294	4,875	4
MARYLAND	1,317	30,574	4,391
MASSACHUSETTS	81	2,230	35
MICHIGAN	9,800	188,216	4,162
MINNESOTA	13,552	506,150	1,648
MISSISSIPPI	3,956	179,971	6,494
MISSOURI	11,832	261,928	31,066
MONTANA	1,890	54,393	3,568
NEBRASKA	10,368	420,682	16,651
NEVADA	67	428	0
NEW HAMPSHIRE	2	263	3
NEW JERSEY	442	8,396	842
NEW MEXICO	320	22,059	177
NEW YORK	1,181	39,041	733
NORTH CAROLINA	2,652	158,004	11,652
NORTH DAKOTA	9,527	270,900	4,194
OHIO	11,950	242,957	10,090
OKLAHOMA	607	64,024	2,289
OREGON	2,273	34,110	891
PENNSYLVANIA	878	50,519	4,019
RHODE ISLAND	2	53	0
SOUTH CAROLINA	708	48,104	1,773
SOUTH DAKOTA	5,992	263,777	10,786
TENNESSEE	1,756	104,567	20,027
TEXAS	10,158	547,706	1,610
UTAH	112	2,710	31
VERMONT	5	264	17
VIRGINIA	886	41,630	5,856
WASHINGTON	9,427	86,997	2,808
WEST VIRGINIA	21	1,388	33
WISCONSIN	3,796	151,910	4,383
WYOMING	235	8,760	58

These impact estimates are sums of all crops studied, not just selected crops shown in Table 3.

CONCLUSIONS

Every year, U.S. growers choose herbicides as the primary method to kill weeds that would otherwise significantly lower yields. An average U.S. cropland acre is treated with two pounds of herbicide active ingredient costing $30/acre.

If U.S. farmers employed an additional 7 million hand weeders and increased cultivation, overall crop production would decline by 21 percent, which is equivalent to 288 billion pounds of food and fiber. If farmers could not pass along their increased costs to buyers, then the $7.7 billion increased production cost combined with lost production valued at $13.3 billion would result in reduced grower net income of $21 billion, or 40 percent of the total net income of American farmers. NCFAP researchers made no attempt to estimate the number of farmers who would stop producing crops given this reduction in income.

To estimate the value of herbicides, NCFAP simulated their nonuse and replacement with available alternatives. Another approach would be to simulate the amount of labor necessary to prevent any yield loss. However, the large estimated labor requirement (70 million workers) would have been of limited use in policy discussions.

Herbicides are essential if the U.S. is to maintain current yields. Even though there is an equally effective alternative for most crops, hand weeding, cost and labor scarcity mean it is unlikely growers could substitute enough hand labor to maintain yields. The Environmental Protection Agency regularly approves emergency herbicide registrations because growers cannot afford to use hand labor to remove weeds.

NCFAP assigned sufficient hand weeding to prevent yield loss to four crops. This assignment, however, was made merely to illustrate that hand labor could prevent yield losses. In actuality, the growers of celery, citrus, hot peppers and raspberries would be unlikely to employ the weeders specified, and yield losses would occur. It is equally unlikely that growers of other crops in the study would employ the number of workers specified because the workers needed for weeding is seven times the current number of farm workers. As a result, yield losses would be higher for all the studied crops. Therefore, the NCFAP estimates represent the minimum economic impact of the nonuse of herbicides.

No consumer price increases and no food shortages are estimated. The estimated losses could be made up with increased imports meaning a $13.3 billion worsening of the trade balance.

Herbicide use is only 60 years old and yet, societal changes have occurred that make it impossible to return to previous weed control practices. Migration of workers from rural areas has created shortages of farm workers. The average wage rate for farm workers has increased by 7000 percent in the last 60 years. Farmers who paid $10/acre for hand weeding in the 1940s would face a labor cost of $700/acre at today's rates. The use of herbicides at $30-50/acre remains the most cost-effective alternative. To put herbicide use in perspective, research examining weed control practices of organic growers shows they often do not employ enough laborers to prevent yield losses. A vast expansion of organic crop acreage in the US is unlikely due to the high costs of hand weeding. In fact, organic growers cite weed control without herbicides as their biggest problem. Herbicides are used on 220 million acres of cropland while organic cropland totals 1 million acres. The amount of labor necessary for a vast expansion of organic growing is not available.

Herbicide use has enabled U.S. farmers to significantly reduce their use of tillage for weed control. The reduction in tillage has resulted in less erosion. Without herbicides, U.S. growers would no longer be able to practice no-till crop production. The abandonment of no-till farming would result in an increase of 304 billion pounds of soil erosion.

This study is the first comprehensive documentation of the role that herbicides play in U.S. crop production. Herbicide use is routine for farmers and poorly understood by the public and the media. This report is meant to stimulate discussion of the importance of herbicides and to clearly indicate the choices and consequences of farming without their use.

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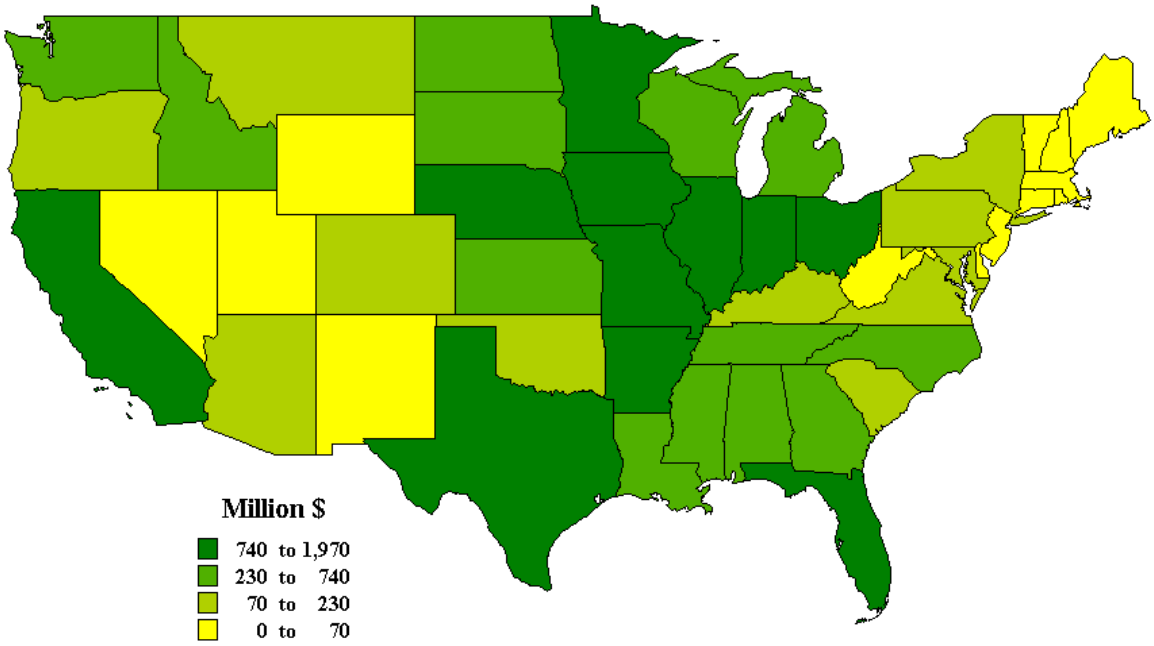
Economic Impact: Herbicide Nonuse By State



Weeds and Herbicides: Where Do They Come From?

Herbicides traditionally have been discovered by screening chemical compounds for activity against a spectrum of weeds and lack of activity against targeted crops. Millions of chemicals have been screened; approximately 200 are currently in use in the United States. In recent years, genetic engineering techniques have been used to create transgenic crop varieties that are tolerant to specific herbicides due to insertion of genetic material from another organism. Approximately one-fourth of U.S. crop acreage treated with herbicides is planted to biotech herbicide tolerant crop varieties of corn, cotton, canola and soybeans. Herbicides are registered by the EPA upon review of safety studies characterizing ecological and human health effects.

Individual weed plants are prolific seed producers. Here are seed counts for some common weed species:

Weed Seed Production and Length of Seed Survival in Soil		
Weed Species	# of Seeds Per Plant	Length of Survival in Undisturbed Soil (Years)
Common Cocklebur	900	8
Common Lambsquarters	72,450	39
Common Ragweed	3,380	39
Green Foxtail	34,000	39
Pennsylvania Smartweed	19,300	30
Redroot Pigweed	117,400	10
Velvetleaf	2,000	10

Much of the information used in this report was drawn from reports and peer-reviewed journals published by the Weed Science Society of America (*Weed Science* and *Weed Technology*). Additional information was drawn from the proceedings of regional weed science societies. For more information on WSSA, visit its website at www.wssa.net.

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