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Appendix 1—Development of Croplands in the United States

Data used to show development of crop agricultural lands include the geospatial dataset “Potential Natural Vegetation” and compilations of the U.S. censuses of population and agriculture. A compilation of the agricultural censuses was also used to show state-level trends in harvested cropland.

The Potential Natural Vegetation (PNV) map in figure 1 is used as a surrogate for presettlement land cover in the United States. PNV is the “climax” vegetation that will occupy a site without disturbance or climatic change and is an expression of environmental factors such as terrain, soils, and climate across an area. The original PNV map was developed by Küchler (1964). The version used in this report is an updated digital geospatial dataset developed by the Missoula Fire Sciences Laboratory (2001).

The historical expansion of agriculture is shown by extracting county census of population for years prior to the agricultural census (fig. 2) and area of improved farmland from the agricultural census for 1850–2002 (fig. 3). In the conterminous United States, a census of population has been taken every 10 years since 1790, and information on agricultural

land use has been collected since 1850 at 10-year or 5-year intervals. Figure 2 shows the extent of settled area for 1790 and 1830, compiled by Waisanen and Bliss (2002) from the census of population, to show the probable extent of agriculture prior to the first agricultural census. Waisanen and Bliss used spatial historical county-boundary data and matched them to the tabular census data.

County-level census of agriculture area of improved farmland for 1850–1997 compiled by Waisanen and Bliss (2002) was used to show historical extent of agriculture (fig. 3). The tabular datasets, which are no longer available online, were provided by Norman Bliss, U.S. Geological Survey (written commun., 2011). The Waisanen and Bliss compilation is available through the 1997 agricultural census. Harvested cropland (improved farmland) for the 2002 census was obtained from the 2002 Census of Agriculture (U.S. Department of Agriculture, 2005).

Trends in harvested cropland for 1879–1997 (fig. 4) generated from state-level historical cropland area were compiled by Ramankutty and others (2010) from the agricultural censuses. Ramankutty and others provide a tabular dataset.

Appendix 2—Environmental Factors That Influence the Location of Crop Agriculture

The extent and amount of cropland in the United States are available from several sources. The most recent spatial datasets of cropland are in the Cropland Data Layer (U.S. Department of Agriculture, 2010), a raster, georeferenced, crop-specific land-cover data layer with a ground resolution of 56 m. It is produced from satellite imagery collected during the growing season. The overall accuracy of the crop-specific portion of the data is 94 percent (U.S. Department of Agriculture, 2010). The 2009 Cropland Data Layer was used for most of the illustrations in this report. This dataset shows the spatial extent of each land cover, including individual crops, at a 56-m-cell-size resolution. Several crops were grouped together for the purposes of this report and were used to generate the map in figure 5. Vegetables and ground fruit were grouped together, tree fruits (with the exception of citrus) and nuts were grouped together, and minor crops (in terms of total land area occupied) were grouped into the “other crops” category. These groups are given in table 2–1 and were used throughout the report. Breakdowns of the amount of land in each crop and crop group, shown in the bar graph in figure 5, are summarized in table 2–2. The area of land in each land-cover group for the 2009 Cropland Data Layer is summarized in table 2–3.

There is no reliable way in the Cropland Data Layer to differentiate between grassland and hay or between grassland and range used for pasture or livestock. The spectral signature for grassland and hay on satellite imagery is similar and difficult to distinguish. In addition, there is no way to determine whether grassy fields or range (shrubland) are used to graze livestock or simply left fallow. To derive these estimates for the report, supplemental information from the Economic Research Service (ERS) national compilation “Major Uses of Land in the United States, 2002” (Lubowski and others, 2006) was used to differentiate the national total land area used for hay, fallow, idle and cropland pasture, grassland, and range. The total area for each matching general land cover was similar for the 2002 and 2009 datasets (table 2–4). Land-cover percentages for hay and total grassland obtained from the 2002 data were applied to the 2009 data to obtain relative land area for grassland and range (table 2–4). The distinction between pasture, rangelands, and other grazing lands is available online at <http://www.epa.gov/oecaagct/anprgidx.html>.

Dot density maps for the extent of cropland and total cropland area for specialty crops are available from the 2007 Census of Agriculture (U.S. Department of Agriculture, 2009a). These maps are not available as digital datasets and were used in this report simply to illustrate the primary locations for some economically significant specialty crops that occupy relatively small land areas and are not readily visible on the national scale Cropland Data Layer maps (fig. 6). Total acreage for each specialty crop is given on the online maps. These values, along with the Map Number used to generate figure 6, are given in table 2–5.

Table 2-1. 2009 Cropland Data Layer land-cover codes and land-cover groups used in this report (U.S. Department of Agriculture, 2010b).[Ma, million acres; kkm², 1,000 square kilometers; NLCD, National Land Cover Database]

Cropland Data Layer land-cover code	Cropland Data Layer land-cover name	Land-use group	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total land
131	NLCD - Barren	Barren	19.89	80.51	1.05
		Barren Total	19.89	80.51	1.05
72	Citrus	Citrus	0.17	0.67	0.01
212	Oranges	Citrus	1.06	4.31	0.06
		Citrus Total	1.23	4.98	0.07
1	Corn	Corn	80.41	325.44	4.25
225	Dbl. Crop WinWht/Corn	Corn	0.03	0.14	0.00
226	Dbl. Crop Oats/Corn	Corn	0.00	0.01	0.00
237	Dbl. Crop Barley/Corn	Corn	0.02	0.10	0.00
241	Dbl. Crop Corn/Soybeans	Corn	0.00	0.01	0.00
		Corn Total	80.48	325.69	4.25
2	Cotton	Cotton	9.37	37.93	0.50
232	Dbl. Crop Lettuce/Upland Cotton	Cotton	0.01	0.03	0.00
238	Dbl. Crop WinWht/Cotton	Cotton	0.01	0.03	0.00
		Cotton Total	9.39	37.99	0.50
63	Woodland	Forest	0.98	3.98	0.05
141	NLCD - Deciduous Forest	Forest	245.55	993.72	12.98
142	NLCD - Evergreen Forest	Forest	250.07	1012.04	13.22
143	NLCD - Mixed Forest	Forest	28.55	115.54	1.51
		Forest Total	525.15	2125.28	27.76
36	Alfalfa	Grassland	10.86	43.96	0.57
37	Other Hays	Grassland	33.78	136.72	1.79
60	Switchgrass	Grassland	0.02	0.08	0.00
61	Fallow/Idle Cropland	Grassland	22.22	89.94	1.17
62	Pasture/Grass	Grassland	43.23	174.95	2.29
171	NLCD - Grassland Herbaceous	Grassland	262.60	1062.74	13.88
181	NLCD - Pasture/Hay	Grassland	109.52	443.23	5.79
		Grassland Total	482.24	1951.63	25.49
66	Cherry Orchard	Orchards and grapes	0.09	0.37	0.00
67	Peaches	Orchards and grapes	0.05	0.19	0.00
68	Apples	Orchards and grapes	0.16	0.66	0.01
69	Grapes	Orchards and grapes	0.45	1.82	0.02

Table 2-1. 2009 Cropland Data Layer land-cover codes and land-cover groups used in this report (U.S. Department of Agriculture, 2010b). —Continued[Ma, million acres; kkm², 1,000 square kilometers; NLCD, National Land Cover Database]

Cropland Data Layer land- cover code	Cropland Data Layer land-cover name	Land-use group	Land area, in Ma	Land area, in kkm²	Land area, in percent of total land
71	Other Tree Nuts	Orchards and grapes	0.26	1.04	0.01
73	Other Tree Fruits	Orchards and grapes	0.02	0.07	0.00
74	Pecans	Orchards and grapes	0.06	0.25	0.00
75	Almonds	Orchards and grapes	0.89	3.60	0.05
76	Walnuts	Orchards and grapes	0.32	1.30	0.02
77	Pear	Orchards and grapes	0.01	0.04	0.00
204	Pistachios	Orchards and grapes	0.11	0.46	0.01
210	Prunes	Orchards and grapes	0.05	0.19	0.00
211	Olives	Orchards and grapes	0.09	0.35	0.00
217	Pomegranates	Orchards and grapes	0.01	0.05	0.00
218	Nectarine	Orchards and grapes	0.00	0.00	0.00
220	Plums	Orchards and grapes	0.01	0.03	0.00
223	Apricots	Orchards and grapes	0.01	0.05	0.00
		Orchards and grapes Total	2.58	10.46	0.14
6	Sunflowers	Other crops	1.52	6.15	0.08
10	Peanuts	Other crops	1.20	4.86	0.06
11	Tobacco	Other crops	0.01	0.05	0.00
21	Barley	Other crops	2.27	9.17	0.12
25	Other Small Grains	Other crops	0.07	0.29	0.00
27	Rye	Other crops	0.33	1.33	0.02
28	Oats	Other crops	1.50	6.06	0.08
29	Millet	Other crops	0.38	1.53	0.02
30	Spelt	Other crops	0.00	0.01	0.00
31	Canola	Other crops	0.86	3.48	0.05
32	Flaxseed	Other crops	0.21	0.86	0.01
33	Safflower	Other crops	0.12	0.47	0.01
34	Rape Seed	Other crops	0.00	0.00	0.00
35	Mustard	Other crops	0.02	0.09	0.00
38	Camelina	Other crops	0.01	0.05	0.00
41	Sugarbeets	Other crops	0.97	3.92	0.05
44	Other Crops	Other crops	0.14	0.55	0.01
45	Sugarcane	Other crops	0.84	3.40	0.04

Table 2-1. 2009 Cropland Data Layer land-cover codes and land-cover groups used in this report (U.S. Department of Agriculture, 2010b). —Continued[Ma, million acres; kkm², 1,000 square kilometers; NLCD, National Land Cover Database]

Cropland Data Layer land-cover code	Cropland Data Layer land-cover name	Land-use group	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total land
56	Hops	Other crops	0.02	0.07	0.00
57	Herbs	Other crops	0.06	0.25	0.00
58	Clover/Wildflowers	Other crops	0.13	0.54	0.01
59	Seed/Sod Grass	Other crops	0.97	3.91	0.05
70	Christmas Trees	Other crops	0.06	0.25	0.00
92	Aquaculture	Other crops	0.17	0.67	0.01
205	Triticale	Other crops	0.06	0.22	0.00
224	Vetch	Other crops	0.00	0.01	0.00
	Other crops Total		11.91	48.19	0.63
3	Rice	Rice	3.35	13.54	0.18
	Rice Total		3.35	13.54	0.18
152	NLCD - Shrubland	Shrubland	416.72	1686.46	22.03
	Shrubland Total		416.72	1686.46	22.03
4	Sorghum	Sorghum	6.28	25.41	0.33
234	Dbl. Crop Durum Wht/Sorghum	Sorghum	0.01	0.02	0.00
235	Dbl. Crop Barley/Sorghum	Sorghum	0.01	0.02	0.00
236	Dbl. Crop WinWht/Sorghum	Sorghum	0.03	0.12	0.00
	Sorghum Total		6.32	25.57	0.33
5	Soybeans	Soybeans	70.57	285.61	3.73
26	W. Wht./Soy. Dbl. Crop	Soybeans	4.24	17.16	0.22
240	Dbl. Crop Soybeans/Oats	Soybeans	0.01	0.03	0.00
254	Dbl. Crop Barley/Soybeans	Soybeans	0.07	0.29	0.00
	Soybeans Total		74.89	303.09	3.96
121	NLCD - Developed/Open Space	Urban	72.27	292.48	3.82
122	NLCD - Developed/Low Intensity	Urban	27.73	112.22	1.47
123	NLCD - Developed/Medium Intensity	Urban	10.02	40.55	0.53
124	NLCD - Developed/High Intensity	Urban	3.31	13.38	0.17
	Urban Total		113.33	458.63	5.99
12	Sweet Corn	Vegetables and ground fruit	0.28	1.13	0.01
13	Pop. or Orn. Corn	Vegetables and ground fruit	0.11	0.44	0.01
14	Mint	Vegetables and ground fruit	0.02	0.07	0.00
42	Dry Beans	Vegetables and ground fruit	1.28	5.20	0.07

Table 2-1. 2009 Cropland Data Layer land-cover codes and land-cover groups used in this report (U.S. Department of Agriculture, 2010b). —Continued[Ma, million acres; kkm², 1,000 square kilometers; NLCD, National Land Cover Database]

Cropland Data Layer land-cover code	Cropland Data Layer land-cover name	Land-use group	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total land
43	Potatoes	Vegetables and ground fruit	0.99	4.00	0.05
46	Sweet Potatoes	Vegetables and ground fruit	0.03	0.12	0.00
47	Misc. Veggies. & Fruits	Vegetables and ground fruit	0.17	0.70	0.01
48	Watermelon	Vegetables and ground fruit	0.03	0.10	0.00
49	Onions	Vegetables and ground fruit	0.08	0.32	0.00
52	Lentils	Vegetables and ground fruit	0.36	1.46	0.02
53	Peas	Vegetables and ground fruit	0.91	3.70	0.05
54	Tomatoes	Vegetables and ground fruit	0.15	0.60	0.01
55	Caneberry	Vegetables and ground fruit	0.01	0.04	0.00
206	Carrots	Vegetables and ground fruit	0.00	0.01	0.00
207	Asparagus	Vegetables and ground fruit	0.00	0.01	0.00
208	Garlic	Vegetables and ground fruit	0.01	0.04	0.00
209	Cantaloupe	Vegetables and ground fruit	0.02	0.07	0.00
214	Broccoli	Vegetables and ground fruit	0.01	0.04	0.00
216	Peppers	Vegetables and ground fruit	0.01	0.05	0.00
219	Greens	Vegetables and ground fruit	0.01	0.02	0.00
221	Strawberries	Vegetables and ground fruit	0.02	0.09	0.00
222	Squash	Vegetables and ground fruit	0.01	0.06	0.00
227	Lettuce	Vegetables and ground fruit	0.04	0.15	0.00
229	Cucumber	Vegetables and ground fruit	0.00	0.01	0.00
230	Pumpkin	Vegetables and ground fruit	0.04	0.18	0.00
231	Dbl. Crop Lettuce/Cantaloupe	Vegetables and ground fruit	0.00	0.01	0.00
242	Blueberry	Vegetables and ground fruit	0.10	0.41	0.01
243	Cabbage	Vegetables and ground fruit	0.01	0.05	0.00
244	Cauliflower	Vegetables and ground fruit	0.00	0.01	0.00
245	Celery	Vegetables and ground fruit	0.00	0.01	0.00
246	Radish	Vegetables and ground fruit	0.00	0.01	0.00
247	Turnip	Vegetables and ground fruit	0.00	0.00	0.00
250	Cranberry	Vegetables and ground fruit	0.01	0.03	0.00
		Vegetables and ground fruit Total	4.73	19.16	0.25
87	Wetlands	Wetlands	0.09	0.35	0.00
190	NLCD - Woody Wetlands	Wetlands	67.32	272.45	3.56

Table 2-1. 2009 Cropland Data Layer land-cover codes and land-cover groups used in this report (U.S. Department of Agriculture, 2010b). —Continued[Ma, million acres; kkm², 1,000 square kilometers; NLCD, National Land Cover Database]

Cropland Data Layer land-cover code	Cropland Data Layer land-cover name	Land-use group	Land area, in Ma	Land area, in kkm²	Land area, in percent of total land
195	NLCD - Herbaceous Wetlands	Wetlands	19.75	79.92	1.04
		Wetlands Total	87.16	352.72	4.61
22	Durum Wheat	Wheat	2.23	9.01	0.12
23	Spring Wheat	Wheat	13.85	56.05	0.73
24	Winter Wheat	Wheat	36.19	146.45	1.91
		Wheat Total	52.26	211.51	2.76
		Total Land Cover	1891.63	7655.41	100.00
111	NLCD - Open Water	Water	32.69	132.31	1.70
		Water Total	32.69	132.31	1.70
112	NLCD - Perennial Ice/Snow	Perennial Ice/Snow	0.32	1.31	0.02
		Perennial Ice/Snow Total	0.32	1.31	0.02

Table 2–2. Land area in each crop or crop group in the 2009 Cropland Data Layer for the conterminous United States (U.S. Department of Agriculture, 2010b).[Ma, million acres; kkm², thousand square kilometers]

Crop or crop group	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total combined cropland
Corn	80.48	325.69	32.56
Soybeans	74.89	303.09	30.30
Wheat	52.26	211.51	21.15
Other crops	11.91	48.19	4.82
Cotton	9.39	37.99	3.80
Sorghum	6.32	25.57	2.56
Vegetables and ground fruit	4.73	19.16	1.92
Rice	3.35	13.54	1.35
Orchards and grapes	2.58	10.46	1.04
Citrus	1.23	4.98	0.50
All crops combined	247.14	1,000.18	100.00
Grassland and pasture; includes hay	482.24	1,951.63	

Table 2–3. Area of land in each land cover group for the 2009 Cropland Data Layer for the conterminous United States (U.S. Department of Agriculture, 2010b).[Ma, million acres; kkm², thousand square kilometers]

Land-cover category	2009 Cropland Data Layer, in Ma	2009 Cropland Data Layer, in kkm ²	Percent land cover
Cropland	247	1,000	13
Grassland and pasture; includes hay	482	1,952	25
Forest	525	2,125	28
Urban	113	459	6
Shrublands, wetlands, and barren	525	2,120	28
Total	1,892	7,656	100

Table 2-4. Comparison of land area in each land-cover group reported in “Major Uses of Land, 2002” (Lubowski and others, 2006) and the 2009 Cropland Data Layer (U.S. Department of Agriculture, 2010b), and estimated land area for land-cover groups not differentiated in the 2009 Cropland Data Layer for the conterminous United States.

[Ma, million acres; kkm², thousand square kilometers]

Land-cover category	“Major Uses of Land, 2002,” in Ma	“Major Uses of Land, 2002,” in kkm ²	Percent land cover for “Major Uses of Land, 2002”	2009 Cropland Data Layer, in Ma	2009 Cropland Data Layer, in kkm ²	Percent land cover for the Cropland Data Layer
Harvested cropland without hay	242	979	13	247	1,000	13
Hay	65	263	3	66 ¹	267	3
Crop failure and cultivated summer fallow	33	133	2	128 ²	518	7
Idle cropland	40	162	2			
Cropland pasture	62	251	3			
Total cropland	441	1,788	23	441³	1,785	23
Grassland and other pasture				288 ⁴	1,165	15
Range		Not differentiated		16		
Total grassland pasture and range	584	2,363	31	583⁶	2,359	31
Total forest	559	2,262	30	525	2,125	28
Total urban	59	239	3	113	459	6
Total miscellaneous and special uses	250	1,012	13	229⁷	927	12
Total land cover	1,893	7,664	100	1,892	7,655	100

¹ Hay based on 21 percent of harvested cropland per “Major Uses of Land, 2002.”

² Crop failure and cultivated summer fallow equal the difference between total cropland (based on 23 percent total land use per “Major Uses of Land, 2002”) and the sum of hay plus harvested cropland. The 128 Ma value was subtracted from the 482 Ma value for grassland and pasture in the Cropland Data Layer.

³ Total cropland based on 23 percent total land use per “Major Uses of Land, 2002.”

⁴ Grassland and other pasture based on 482 Ma from 2009 Cropland Data Layer, minus the sum of Hay (66 Ma) plus other cropland (128 Ma).

⁵ Range is the difference between the Total grassland pasture and range (583 Ma) and Grassland and other pasture (288 Ma).

⁶ Total grassland pasture and range based on 31 percent of Total land cover per “Major Uses of Land, 2002.”

⁷ Total miscellaneous based on difference between Total land cover (1,892 Ma) and the sum of all other categories (1,662 Ma).

Table 2–5. Total acreage grown for selected grain and specialty crops for the conterminous United States (U.S. Department of Agriculture, 2009a).[km², square kilometers; USDA, U.S. Department of Agriculture]

Crop	Area, in acres	Area, in km ²	USDA Map Number
Barley	3,521,957	14,253	07–M176
Oats	1,509,149	6,107	07–M178
Rye	267,361	1,082	07–M180
Sunflowers for oil	1,710,057	6,920	07–M182
Canola	1,149,682	4,653	07–M184
Sunflowers for seed	290,096	1,174	07–M183
Dry edible beans	1,455,549	5,890	07–M197
Dry edible peas	848,874	3,435	07–M198
Peanuts	12,000,564	48,565	07–M203
Potatoes	1,131,963	4,581	07–M199
Tobacco	359,846	1,456	07–M191
Sugarbeets	1,253,817	5,074	07–M201
Sugarcane	846,666	3,426	07–M202
Strawberries	60,353	244	07–M232
Blueberries	55,601	225	07–M231

Appendix 3—Elevation and Slope

The *National Elevation Dataset (NED)* can be used to identify those areas that are constrained for agricultural production by elevation and slope. The NED is composed of raster elevation data at a resolution of 1 arc-second (approximately 30 m) for the conterminous United States (Gesch, 2007; Gesch and others, 2002). The NED 30-m data are available in 1,390 separate raster data files and are too large, when combined, to be useful for national-scale analyses. To make the 30-m NED usable for national analyses, 30-m elevation raster data were bilinearly resampled to 100 m (NED 100 m) and assembled to 1-degree grids (Falcone, 2003). To determine the amount of cropland at higher elevations, the NED 100 m

was converted to 56 m and combined with the 2009 Cropland Data Layer to calculate the percentage of land area in each crop group for elevations higher than 2,000 m (table 3–1).

Percent slope was generated from the NED 100-m raster dataset by calculating a slope surface using the ARCInfo Spatial Analyst>Surface Analysis>Slope tool. To determine the amount of cropland on each slope category (fig. 7) the NED 100 m was converted to 56 m and was combined with the 2009 Cropland Data Layer to calculate the percentage of land area in each crop group for each slope category (1, 2, 3, and greater than 4 percent) (table 3–2). The combined raster dataset was used to generate a map showing the location of crops on land with 3 percent or greater slope (fig. 8).

Table 3–1. Land area in each crop or crop group above 2,000 meters elevation in the 2009 Cropland Data Layer for the conterminous United States (Falcone, 2003; U.S. Department of Agriculture, 2010b).

[m, meters; Ma, million acres; kkm², thousand square kilometers]

Crop or crop group	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total combined cropland above 2,000 m
Corn	0.0	0.01	0.07
Soybeans	0.0	0.0	0.0
Wheat	0.83	3.37	29.31
Other crops	1.12	4.55	39.53
Cotton	0.0	0.0	0.04
Sorghum	0.0	0.01	0.1
Vegetables and ground fruit	0.88	0.36	30.92
Rice	0.0	0.0	0.0
Orchards and grapes	0.0	0.0	0.0
Citrus	0.0	0.0	0.0
All crops above 2,000 m	2.84	11.51	100.00
All crops	247.14	1,000.18	1.15

Table 3–2. Land area in each crop or crop group for each slope range in the 2009 Cropland Data Layer for the conterminous United States (Falcone, 2003; U.S. Department of Agriculture, 2010b).

[Ma, million acres; kkm², thousand square kilometers]

Slope range, in percent	0 to 1			> 1 to 2			> 2 to 3			> 3 to 4			> 4		
Crop or crop group	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop
Corn	19.08	77.23	23.71	32.13	130.02	39.92	12.69	51.36	15.77	6.78	27.43	8.42	9.80	39.65	12.17
Soybeans	22.02	89.11	29.40	29.52	119.47	39.42	10.94	44.29	14.61	5.52	22.36	7.38	6.88	27.85	9.19
Wheat	10.24	41.44	19.59	22.14	89.59	42.36	8.95	36.21	17.12	4.50	18.22	8.61	6.44	26.05	12.32
Other crops	3.44	13.92	28.89	4.50	18.19	37.75	1.75	7.07	14.68	0.91	3.66	7.60	1.32	5.34	11.08
Cotton	3.68	14.89	39.19	4.43	17.94	47.23	0.82	3.33	8.76	0.29	1.16	3.06	0.17	0.67	1.76
Sorghum	1.80	7.30	28.56	2.79	11.28	44.11	0.97	3.92	15.32	0.44	1.78	6.97	0.32	1.29	5.04
Vegetables and ground fruit	1.24	5.02	26.18	1.77	7.18	37.49	0.70	2.83	14.76	0.36	1.44	7.53	0.66	2.69	14.04
Rice	2.51	10.13	74.80	0.80	3.25	24.03	0.03	0.11	0.84	0.01	0.02	0.17	0.01	0.02	0.16
Orchards and grapes	1.13	4.60	43.99	0.88	3.55	33.94	0.21	0.84	8.08	0.12	0.47	4.49	0.25	0.99	9.51
Citrus	0.76	3.08	61.77	0.32	1.28	25.79	0.07	0.30	5.95	0.03	0.13	2.64	0.05	0.19	3.85
All crops	65.91	266.73	26.67	99.29	401.81	40.17	37.13	150.25	15.02	18.95	76.67	7.67	25.87	104.71	10.47

Appendix 4—Climate

Cumulative growing degree-days and precipitation were used to identify favorable climates for the production of selected crops and crop groups. The 30-year average for 1971–2000 (normal) cumulative growing degree-day geospatial dataset (0.010281-degree cell size) was provided by Leonard Coop, Integrated Plant Protection Center, Oregon State University (written commun., 2009). Degree-day maps generated by Coop take into account elevation, terrain, and local effects to show degree-day accumulations over a given time period (Oregon State University, 2010). “Normal” refers to the 30-year annual average of climatological data (temperature, precipitation, growing degree-days). At the time of data compilation and writing for this report, the 1981–2010 normals were not available.

The original dataset was provided in geographic coordinates that were reprojected into Albers Equal Area, resulting in a raster dataset with an approximately 1,013 m cell size. The raster dataset was then resampled (Nearest method) to 56 m cell size so that it could be combined with the Cropland Data Layer. To determine the amount of cropland for each range of degree-days (fig. 9) the 56-m degree-day raster dataset was combined with the 2009 Cropland Data Layer to calculate the percentage of land area in each crop group for each degree-day range (table 4–1).

Average annual 1971–2000 (normal) precipitation spatial data were obtained from the Parameter-elevation Regressions on Independent Slopes Model (PRISM) climate mapping system, Oregon State University (2008). Distribution of precipitation point measurements to a spatial raster dataset was accomplished by using the PRISM model, developed and applied by Chris Daly of the PRISM Climate Group at Oregon State University (2008). The precipitation raster dataset was then resampled (Nearest method) to 56 m cell size so that it could be combined with the 2009 Cropland Data Layer. To determine the amount of cropland for each precipitation range (fig. 10) the 56-m precipitation raster dataset was combined with the 2009 Cropland Data Layer to calculate the percentage of land area in each crop group for each precipitation range (table 4–2).

Generation of favorable water and heat (growing degree-day) boundaries for selected crops was done by combining the degree-day and precipitation raster datasets for selected crops. The most comprehensive list of growing degree-day thresholds was optioned from Fischer and others, 2002 (appendix IV). Water-requirement thresholds are available from Brouwer and Heibloem (1986). Thresholds used for the crops shown in figure 11 were obtained from these sources and are listed in table 4–3. For each crop, a separate raster dataset was extracted from the degree-day and precipitation raster dataset for the sub-optimal and optimal heat and water thresholds, resulting in four separate raster datasets for each crop. Using corn as an example, the sub-optimal heat requirement is 1,900 degree-days, so a raster dataset was generated by selecting all values greater than 1,900. The sub-optimal degree-day

and precipitation raster dataset for each crop was combined to result in a raster dataset showing the extent of sub-optimal conditions for that crop. The same process was used to generate the optimal raster dataset for each crop. The optimal and sub-optimal raster datasets were overlain to show the extent of favorable climate for selected crops, and the extent of each crop was subsequently overlain on the raster dataset maps. These maps are intended to be used as a general indication of the extent of favorable climate for specific crops. Many cultivars for each crop have been developed to extend the range in which they can be grown. In addition, irrigation can be used to extend the range into areas that do not receive enough precipitation to support the crop.

The extent of irrigated cropland from surface-water and groundwater sources was determined from “Estimated Use of Water in the United States, 2005” (Kenney and others, 2009). Irrigation water use includes water that is applied by an irrigation system to sustain plant growth in all agricultural and horticultural practices (Kenney and others, 2009). This source provides withdrawals of water for irrigation in million gallons per day. Also provided is total amount of irrigated land in acres. The extent of irrigated cropland from surface-water and groundwater sources (fig. 12) was generated by converting county-level withdrawal estimates for 2005 to withdrawals in thousand acre-feet per year and joining the converted withdrawals to a geospatial raster dataset generated by combining county boundaries and the 2009 Cropland Data Layer so that areas of irrigated cropland could be mapped. This method spreads the irrigation use across all the cropland in the county. In reality, only selected fields within each county are irrigated. More detailed information about the location of irrigated fields was not available at the time this report was written.

To supplement the extent of irrigated cropland, dot density maps are used to show the extent of irrigated cropland for selected crops (fig. 13). These maps are available from the 2007 Census of Agriculture (U.S. Department of Agriculture, 2009a). These maps are not available in this report as digital datasets and were used simply to illustrate the primary locations for irrigated cropland. Total irrigated acreage for each crop shown in figure 13 is given on the online maps. These values, along with the Map Number used to generate the figure, are given in table 4–4.

Areas of groundwater decline in the United States were obtained from Reilly and others (2008). The areas delineated on the upper map in figure 14 were generated from a combination of wells in the U.S. Geological Survey National Water Information System (NWIS) database where measured groundwater-level difference over time is greater than 12 m, and areas in excess of 1,000 km² that have groundwater-level decline in excess of 12 m in at least one confined aquifer since predevelopment or in excess of 7.5 m of decline in unconfined aquifers since predevelopment. The dataset of NWIS wells and the polygon areas shown in the map were provided by William Cunningham, U.S. Geological Survey (written commun., 2011) Well locations were converted to a 10-km² raster dataset so that cells that had one or more wells in decline

Table 4–1. Land area in each crop or crop group for each growing degree-day range in the 2009 Cropland Data Layer for the conterminous United States (Oregon State University, 2010; U.S. Department of Agriculture, 2010b).

[Ma, million acres; kkm², thousand square kilometers]

Category	0 to 2,000			> 2,000 to 3,000			> 3,000 to 4,000			> 4,000 to 5,000			> 5,000		
Crop or crop group	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop
Corn	0.79	3.19	0.98	35.89	145.23	44.59	32.94	133.31	40.93	6.13	24.82	7.62	4.73	19.15	5.88
Soybeans	1.01	4.07	1.34	28.85	116.74	38.52	26.14	105.80	34.91	11.67	47.25	15.59	7.22	29.23	9.64
Wheat	6.63	26.82	12.68	19.87	80.44	38.03	9.14	36.97	17.48	10.04	40.64	19.21	6.58	26.64	12.59
Other crops	2.54	10.28	21.34	5.10	20.62	42.79	0.53	2.13	4.41	0.82	3.31	6.87	2.93	11.85	24.59
Cotton	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.11	3.83	15.48	40.75	5.55	22.47	59.14
Sorghum	0.00	0.02	0.08	0.15	0.59	2.32	2.06	8.34	32.63	1.71	6.94	27.13	2.39	9.68	37.84
Vegetables and ground fruit	1.07	4.32	22.53	2.73	11.07	57.78	0.50	2.02	10.53	0.15	0.62	3.23	0.28	1.14	5.93
Rice	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	1.57	6.34	46.84	1.78	7.20	53.15
Orchards and grapes	0.03	0.12	1.12	0.24	0.98	9.35	0.14	0.55	5.27	0.89	3.60	34.40	1.29	5.22	49.87
Citrus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.12	0.00	0.01	0.12	1.23	4.97	99.76
All crops	12.04	48.75	4.87	92.79	375.56	37.55	71.45	289.20	28.91	36.83	149.07	14.90	34.00	137.61	13.76

Table 4–2. Land area in each crop or crop group for precipitation category in the 2009 Cropland Data Layer for the conterminous United States (Falcone, 2003; U.S. Department of Agriculture, 2010b).

[mm/yr, millimeters per year; Ma, million acres; kkm², thousand square kilometers]

Precipitation category, in mm/yr	0 to 538			> 538 to 913			> 913 to 1,271			> 1,271 to 2,032			> 2,032		
Crop or crop group	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop
Corn	8.87	35.89	11.02	39.97	161.76	49.67	27.83	112.61	34.58	3.81	15.42	4.73	0.00	0.00	0.00
Soybeans	5.24	21.21	7.00	30.83	124.76	41.16	30.04	121.59	40.12	8.78	35.53	11.72	0.00	0.00	0.00
Wheat	31.42	127.18	60.13	18.24	73.82	34.90	2.33	9.45	4.47	0.26	1.06	0.50	0.00	0.00	0.00
Other crops	6.78	27.44	56.95	1.70	6.86	14.24	1.66	6.74	13.98	1.76	7.14	14.81	0.00	0.01	0.03
Cotton	4.13	16.69	43.95	1.78	7.22	19.01	1.76	7.11	18.72	1.72	6.96	18.33	0.00	0.00	0.00
Sorghum	1.64	6.63	25.92	4.03	16.29	63.70	0.57	2.30	9.00	0.09	0.35	1.39	0.00	0.00	0.00
Vegetables and ground fruit	3.04	12.31	64.23	1.02	4.14	21.59	0.56	2.27	11.84	0.11	0.45	2.34	0.00	0.00	0.00
Rice	0.41	1.65	12.15	0.18	0.73	5.36	1.26	5.08	37.51	1.51	6.09	44.97	0.00	0.00	0.00
Orchards and grapes	1.84	7.47	71.40	0.38	1.53	14.64	0.25	1.00	9.55	0.11	0.46	4.39	0.00	0.00	0.02
Citrus	0.15	0.60	12.10	0.00	0.01	0.22	0.52	2.10	42.07	0.56	2.27	45.60	0.00	0.00	0.00
All crops	63.50	256.99	25.69	98.14	397.19	39.71	66.77	270.26	27.02	18.71	75.73	7.57	0.00	0.02	0.00

could be tagged as an area in decline. The polygon areas of groundwater-level decline also were converted to a raster dataset. The Well raster and Area raster datasets were combined to generate a map showing areas of groundwater-level decline.

The combined dataset was then combined with the 2009 Cropland Data Layer so that cropland in areas of groundwater-level decline could be identified (fig. 14, lower map).

Table 4-3. Optimal and sub-optimal heat and water requirements for selected crops.

[Sources: Fischer and others, 2002, Appendix IV, Temperature regime requirements of crops/LUTs; Brouwer and Heibloem, 1986, chapter 3, Crop water needs, 3.3.4, Indicative values of crop water needs. mm/yr, millimeters per year]

Crop	Sub-optimal heat requirements, in accumulated growing degree-days	Optimal heat requirements, in accumulated growing degree-days	Sub-optimal water requirements, in mm/yr	Optimal water requirements, in mm/yr
Corn (Maize sub-tropics)	1,900	2,400	500	800
Soybeans	1,700	2,000	450	700
Wheat (winter)	1,200	1,300	450	650
Wheat (spring)	1,400	1,800	450	650
Cotton	2,700	3,000	700	1,300
Sorghum (lowland sorghum)	2,200	2,500	450	650
Rice (Indica, wetland—southern U.S.)	2,400	3,000	450	700
Rice (Japonica, wetland—California)	1,800	2,200	450	700

Table 4-4. Total irrigated acreage for selected crops for 2007 for the conterminous United States (U.S. Department of Agriculture, 2009a).

[km², square kilometers; USDA, U.S. Department of Agriculture]

Crop	Total area, in acres	Total area, in km ²	Irrigated area, in acres	Irrigated area, in km ²	Irrigated area, in percent	USDA Map Number
Corn	86,248,542	349,035	13,156,769	53,244	15	07–M164
Soybeans	63,915,821	258,658	5,237,075	21,194	8	07–M194
Wheat	50,932,969	206,118	3,364,079	13,614	7	07–M173
Cotton	10,493,238	42,465	4,035,610	16,332	38	07–M186
Sorghum	6,769,834	27,397	845,214	3,420	12	07–M169
Rice	2,758,792	11,164	2,758,792	11,164	100	07–M180
Vegetables	4,682,588	18,950	3,068,485	12,418	66	07–M218
Orchards	5,039,476	20,394	3,981,316	16,112	79	07–M233

Appendix 5—Soil

Dot density maps are used to show the distribution of cropland treated with commercial fertilizer, lime, and soil conditioners, as well as cropland treated with manure (fig. 15). These maps (Map Numbers 07–M103 and 07–M105) are available from the 2007 Census of Agriculture (U.S. Department of Agriculture, 2009b). These maps are not available as digital datasets in this report and were used simply to illustrate the primary extent of treated cropland.

The percentage of cropland acres treated with nitrogen, phosphate, and potash for selected crops (fig. 15) was obtained from fertilizer use data estimated by the Economic Research Service (U.S. Department of Agriculture, 2010a). The average annual percentage of cropland acres treated was calculated for 1989–2007.

The soils capability class and hazard class data were obtained from the U.S. Department of Agriculture (2006) U.S. General Soils Map (STATSGO) dataset. The dataset consists of tabular data in Microsoft Access format and vector spatial data. The spatial data consists of soils-association polygons identified by a unique map unit (MUKEY) code. The MUKEY is used to relate the spatial data to the tabular

data. Each soils association consists of two or more major soil components that occur together in a similar pattern so that the patterns and proportions of major soils are alike within a single association. The Component table includes soil properties for all the soil components in the United States and can be linked to the soils associations through the MUKEY.

Capability class and hazard class are soil properties available in the Component table. The major soil component (the largest areal extent within a soils association) was used to assign a capability class and hazard class for each soils-association polygon. The definitions for land capability class and hazard class are described by Helms (1992) and are listed in table 5–1. To determine the amount of cropland in each class (fig. 16), the soils capability class was assigned to each soils-association polygon for the United States, converted to a 56-m-cell-size raster dataset, and combined with the 2009 Cropland Data Layer to calculate the percentage of land area in each crop group for each land capability class (I, II, III, IV, and V–VIII) (table 5–1). The combined raster dataset was used to generate a map showing the location of cropland on soils with severe or very severe limitations that require special conservation or management practices (fig. 17).

Table 5–1. Land area in each crop or crop group for each land capability class in the 2009 Cropland Data Layer for the conterminous United States (U.S. Department of Agriculture, 2006, 2010b).

[Ma, million acres; kkm², thousand square kilometers]

Land capability class	I			II			III			IV			V, VI, VII, and VIII		
Crop or crop group	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop
Corn	7.27	29.42	9.03	42.87	173.48	53.26	20.26	81.97	25.17	5.30	21.46	6.59	4.78	19.36	5.94
Soybeans	6.65	26.91	8.88	40.32	163.19	53.84	19.23	77.81	25.67	4.80	19.41	6.40	3.90	15.77	5.20
Wheat	1.24	5.00	2.36	20.57	83.26	39.37	18.02	72.91	34.47	7.27	29.42	13.91	5.17	20.91	9.89
Other crops	0.56	2.25	4.66	4.59	18.56	38.51	3.25	13.15	27.28	1.59	6.45	13.38	1.93	7.79	16.17
Cotton	0.70	2.82	7.41	2.30	9.32	24.52	4.09	16.54	43.54	1.16	4.70	12.37	1.14	4.62	12.16
Sorghum	0.17	0.68	2.67	3.06	12.38	48.43	2.23	9.02	35.29	0.45	1.82	7.12	0.41	1.66	6.49
Vegetables and ground fruit	0.08	0.32	1.69	1.68	6.79	35.42	0.93	3.76	19.63	0.71	2.89	15.07	1.33	5.40	28.19
Rice	0.07	0.28	2.04	0.69	2.79	20.63	1.86	7.50	55.38	0.64	2.57	18.98	0.10	0.40	2.96
Orchards and grapes	0.04	0.17	1.61	0.21	0.83	7.95	0.68	2.75	26.30	1.04	4.20	40.12	0.62	2.51	24.03
Citrus	0.00	0.00	0.00	0.00	0.01	0.14	0.36	1.46	29.27	0.77	3.12	62.71	0.10	0.39	7.89
All crops	16.77	67.87	6.79	116.28	470.63	47.05	70.89	286.91	28.69	23.72	95.99	9.60	19.47	78.79	7.88

Class I soils have slight limitations that restrict their use.

Class II soils have moderate limitations that reduce the choice of plants or require moderate conservation practices.

Class III soils have severe limitations that reduce the choice of plants or require special conservation practices or both.

Class IV soils have very severe limitations that restrict the choice of plants or require very careful management or both.

Class V, VI, VII, and VIII soils have very severe limitations that make them unsuited to cultivation.

Appendix 6—Soil Water

Soil hazard class (also called soil sub-class) was used to show soils where the dominant hazard is from climate, soil limitations, erosion, or excess water. The methods for determining soil hazard class for cropland is the same as the method for determining soils capability class as explained in appendix 5. To determine the amount of cropland in each hazard class (fig. 18), the class was assigned to each soils-association polygon, converted to a 56-m-cell-size raster dataset, and combined with the 2009 Cropland Data Layer to calculate the percentage of land area in each crop group for each land capability hazard class (Climate, Soil, Erosion, and Water) (table 6–1). The combined raster dataset was used to generate a map showing the location of cropland on soils in each hazard class (fig. 19).

Soils hazard Water was used to determine areas where artificial drainage is likely needed to support agriculture. Artificial drainage includes both surface drainage (manmade ditches and canals) and subsurface drainage (tile drains). Specific information about the location of ditches and tile drains was not available at the time of this writing. Jaynes and James (2007) found that using this soil hazard class with row crops is a reasonable estimate of where artificial drainage will be. In reality, drainage may be placed in areas that are not in the soil hazard class Water and, conversely, not all cultivated land in the soil hazard class Water is drained. The illustrations and charts in figure 20 are used to show the areas likely requiring drainage to remove excess water in order to cultivate cropland.

Further differentiation of hazard class Water for soils likely using either surface or subsurface drainage was determined by overlaying artificial drainage raster dataset with the 1992 Natural Resources Inventory county-level conservation practice raster dataset (c606—subsurface drainage and c607—surface drainage, field ditches) (Michael Wieczorek, U.S. Geological Survey, written commun., 2010). This was done to generate the surface- and subsurface-drainage maps in figure 20 so that the reader can get a general idea of the locations where each type of artificial drainage is predominant. The value of each cell in the raster dataset represents the estimated percentage of the 1-km cell that is covered by or subject to a

particular agricultural practice, on agricultural land by county. Federal Lands are excluded from the set and are designated as NODATA. (Data from 1992 are available at <http://water.usgs.gov/GIS/metadata/usgswrd/XML/ofr041189606.xml>.)

To determine the amount of cropland that is likely either artificially drained or not artificially drained (fig. 20, bar graph), the soils hazard class raster dataset for Water was converted to a 56-m-cell-size raster dataset and combined with the 2009 Cropland Data Layer to calculate the percentage of land area in each crop group that is artificially drained and all other cropland not artificially drained (table 6–2). The National Resources Inventory dataset was not at high enough resolution to differentiate the amount of cropland artificially drained by surface or subsurface methods.

Average annual runoff and recharge (1971–2000) are spatial datasets provided by David Wolock (U.S. Geological Survey, written commun., 2010). The 1951–1980 data were previously published for runoff (Gebert and others, 1987) and for recharge (Wolock, 2003). Methods used to generate the 1951–1980 datasets are described in the metadata of the dataset and are the same methods used to generate the 1971–2000 datasets.

The recharge map (fig. 22) is an index of long-term average natural groundwater recharge, and it was created by multiplying a raster of base-flow index values by a raster of average annual runoff values derived from a 1971–2000 average annual runoff contour map. Average annual runoff is long-term average streamflow expressed on a per-unit-area basis. The concept used to construct the dataset is based on two assumptions: (1) long-term average natural groundwater recharge is equal to long-term average natural groundwater discharge to streams, and (2) the base-flow index reasonably represents, over the long term, the percentage of natural ground-water discharge in streamflow (Wolock, 2003).

To determine the amount of cropland for each runoff and recharge range (figs. 21 and 22) the spatial data were converted to a 56-m raster dataset and combined with the 2009 Cropland Data Layer to calculate the percentage of land area in each crop group for each runoff and recharge range (tables 6–3 and 6–4).

Table 6–1. Land area in each crop or crop group for each land hazard class in the 2009 Cropland Data Layer for the conterminous United States (U.S. Department of Agriculture, 2006, 2010b).

[Ma, million acres; kkm², thousand square kilometers]

Land hazard class	Undefined			Climate			Erosion			Soils			Water		
Crop or crop group	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop
Corn	7.48	30.29	9.30	4.09	16.53	5.08	42.07	170.24	52.27	5.65	22.85	7.01	21.20	85.78	26.34
Soybeans	6.91	27.96	9.23	2.21	8.93	2.95	34.07	137.89	45.49	4.08	16.50	5.44	27.63	111.81	36.89
Wheat	1.33	5.39	2.55	8.56	34.63	16.37	33.96	137.44	64.98	4.41	17.84	8.43	4.01	16.21	7.66
Other crops	0.65	2.63	5.46	1.79	7.24	15.02	5.70	23.08	47.90	1.42	5.76	11.96	2.34	9.47	19.66
Cotton	0.70	2.85	7.49	0.55	2.23	5.86	5.41	21.87	57.56	0.99	4.00	10.53	1.74	7.05	18.55
Sorghum	0.18	0.72	2.82	1.39	5.64	22.05	3.41	13.79	53.94	0.85	3.44	13.47	0.49	1.97	7.72
Vegetables and ground fruit	0.12	0.48	2.50	0.72	2.90	15.13	2.34	9.46	49.39	0.74	3.00	15.64	0.82	3.32	17.34
Rice	0.07	0.30	2.19	0.03	0.11	0.81	0.20	0.80	5.92	0.13	0.51	3.73	2.93	11.83	87.35
Orchards and grapes	0.05	0.19	1.85	0.83	3.37	32.18	0.65	2.63	25.12	0.80	3.24	30.93	0.26	1.04	9.93
Citrus	0.00	0.01	0.14	0.05	0.21	4.18	0.05	0.20	4.11	0.29	1.18	23.68	0.84	3.38	67.89
All crops	17.39	70.38	7.04	20.07	81.23	8.12	127.02	514.11	51.40	19.22	77.78	7.78	61.81	250.19	25.01

Climate class is made up of soils for which the climate—the temperature or lack of moisture—is the major hazard or limitation.

Erosion class is made up of soils for which the susceptibility to erosion is the dominant problem or hazard affecting their use. Erosion susceptibility and past erosion damage are the major soil factors that affect soils in this subclass.

Soils class is made up of soils that have soil limitations within the rooting zone, such as shallowness of the rooting zone, stones, low moisture-holding capacity, low fertility that is difficult to correct, and salinity or sodium content.

Water class is made up of soils for which excess water is the dominant hazard or limitation affecting their use. Poor soil drainage, wetness, a high water table, and overflow are factors that affect these soils.

Table 6–2. Land area in each crop or crop group that is artificially drained in the 2009 Cropland Data Layer for the conterminous United States (U.S. Department of Agriculture, 2006,2010b; Michael Wieczorek, U.S. Geological Survey, written commun., 2010).

[Ma, million acres; kkm², thousand square kilometers]

Crop or crop group	Not artificially drained			Artificially drained		
	Land area , in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area , in Ma	Land area, in kkm ²	Land area, in percent of total for crop
Corn	59.19	239.54	73.55	21.29	86.15	26.45
Soybeans	47.23	191.15	63.07	27.66	111.94	36.93
Wheat	48.27	195.37	92.37	3.99	16.14	7.63
Other crops	9.56	38.69	80.29	2.35	9.50	19.71
Cotton	7.65	30.95	81.47	1.74	7.04	18.53
Sorghum	5.82	23.54	92.07	0.50	2.03	7.93
Vegetables and ground fruit	3.91	15.83	82.64	0.82	3.33	17.36
Rice	0.41	1.64	12.12	2.94	11.90	87.88
Orchards and grapes	2.32	9.42	90.01	0.26	1.04	9.99
Citrus	0.41	1.64	32.99	0.82	3.34	67.01
All crops	184.76	747.79	74.77	62.36	252.39	25.23

Table 6–3. Land area in each crop or crop group for each runoff category in the 2009 Cropland Data Layer for the conterminous United States (David M. Wolock. U.S. Geological Survey, written commun. 2009; U.S. Department of Agriculture, 2010b).

[mm/y, millimeters per year, Ma, million acres; kkm², thousand square kilometers]

Runoff category, in mm/yr	0 to 214			> 214 to 628			> 628 to 1,355			> 1,255 to 2,976			> 2,976		
Crop or crop group	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop
Corn	29.61	119.84	36.80	27.88	112.84	34.65	18.15	73.44	22.55	4.74	19.16	5.88	0.10	0.41	0.13
Soybeans	27.21	110.13	36.34	27.75	112.32	37.06	16.74	67.73	22.35	3.14	12.71	4.19	0.05	0.20	0.07
Wheat	44.25	179.08	84.67	5.19	21.01	9.93	2.21	8.94	4.23	0.53	2.15	1.02	0.08	0.34	0.16
Other crops	6.55	26.49	54.96	2.13	8.63	17.91	1.45	5.85	12.15	1.65	6.66	13.81	0.14	0.56	1.17
Cotton	6.39	25.86	68.07	1.05	4.25	11.18	1.53	6.21	16.34	0.40	1.60	4.22	0.02	0.07	0.19
Sorghum	6.05	24.48	95.72	0.20	0.80	3.14	0.04	0.17	0.67	0.03	0.11	0.45	0.00	0.01	0.02
Vegetables and ground fruit	2.42	9.79	51.10	0.89	3.61	18.87	0.90	3.66	19.12	0.48	1.93	10.06	0.04	0.16	0.86
Rice	2.28	9.22	68.07	0.37	1.51	11.18	0.55	2.21	16.34	0.14	0.57	4.22	0.01	0.03	0.19
Orchards and grapes	1.19	4.82	46.08	0.48	1.94	18.52	0.59	2.38	22.79	0.26	1.06	10.14	0.06	0.26	2.47
Citrus	1.00	4.05	81.29	0.08	0.31	6.19	0.12	0.48	9.68	0.03	0.14	2.84	0.00	0.00	0.00
All crops	125.28	507.04	50.70	66.89	270.74	27.07	43.02	174.14	17.41	11.43	46.25	4.62	0.50	2.01	0.20

Appendix 7—Other Land Uses in Competition for Agricultural Lands

The Potential Natural Vegetation (PNV) map was generalized by grouping PNV classes into Broadleaf Forests, Needleleaf Forests, Grasslands, and Scrublands (Missoula Fire Sciences Laboratory, 2001). Wetland areas are not a category on the PNV map and were added by combining Water hazard class soils (see Appendix 6, table 6–1) to the PNV (U.S. Department of Agriculture, 2006).

To determine the amount of cropland that has been converted from the “natural” state, the PNV polygons were converted to a 56-m raster dataset and first combined with the Water-hazard-class soils. The resulting raster dataset was then combined with the 2009 Cropland Data Layer to calculate the percentage of “natural” land area that has converted to each crop (tables 7–1, 7–2, and 7–3; fig. 23).

Table 7–1. Land area in each potential natural vegetation type converted to cropland, and grassland and hay for the conterminous United States (Missoula Fire Sciences Laboratory, 2001; U.S. Department of Agriculture, 2006).

[Ma, million acres; kkm², thousand square kilometers]

Potential natural vegetation type	Wetlands			Broadleaf forests			Needleleaf forests			Grasslands			Shrublands		
Crop or crop group	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop
Total potential natural vegetation land area	246	995	13	511	2067	27	284	1148	15	549	2220	29	303	1225	16
Potential natural vegetation converted to cropland	62	250	25	47	190	19	0	0	0	129	520	52	7	30	3
Potential natural vegetation converted to grassland and hay	43	176	9	106	429	22	29	117	6	265	1073	55	39	156	8

Table 7–2. Land area in each crop or crop group for each potential natural vegetation type in the 2009 Cropland Data Layer for the conterminous United States (Missoula Fire Sciences Laboratory, 2001; U.S. Department of Agriculture, 2010b).

[Ma, million acres; kkm², thousand square kilometers]

Potential natural vegetation type	Wetlands			Broadleaf forests			Needleleaf forests			Grasslands			Shrublands			Total cropland		
Crop or crop group	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop	Land area, in Ma	Land area, in kkm ²	Land area, in percent of total for crop
Corn	20.92	84.68	26.00	19.32	78.17	24.00	0.80	3.26	1.00	38.63	156.33	48.00	0.80	3.26	1.00	80.48	325.69	100.00
Soybeans	27.71	112.14	37.00	17.97	72.74	24.00	0.00	0.00	0.00	29.21	118.21	39.00	0.00	0.00	0.00	74.89	303.09	100.00
Wheat	4.18	16.92	8.00	2.61	10.58	5.00	0.52	2.12	1.00	42.33	171.32	81.00	2.61	10.58	5.00	52.26	211.51	100.00
Other crops	2.38	9.64	20.00	2.38	9.64	20.00	0.24	0.96	2.00	5.60	22.65	47.00	1.31	5.30	11.00	11.91	48.19	100.00
Cotton	1.78	7.22	19.00	1.88	7.60	20.00	0.00	0.00	0.00	5.16	20.89	55.00	0.56	2.28	6.00	9.39	37.99	100.00
Sorghum	0.51	2.05	8.00	0.32	1.28	5.00	0.00	0.00	0.00	4.80	19.43	76.00	0.70	2.81	11.00	6.32	25.57	100.00
Vegetables and ground fruit	0.80	3.26	17.00	0.66	2.68	14.00	0.19	0.77	4.00	1.99	8.05	42.00	1.09	4.41	23.00	4.73	19.16	100.00
Rice	2.95	11.92	88.00	0.23	0.95	7.00	0.00	0.00	0.00	0.17	0.68	5.00	0.00	0.00	0.00	3.35	13.54	100.00
Orchards and grapes	0.26	1.05	10.00	0.57	2.30	22.00	0.05	0.21	2.00	1.37	5.54	53.00	0.34	1.36	13.00	2.58	10.46	100.00
Citrus	0.82	3.34	67.00	0.31	1.25	25.00	0.00	0.00	0.00	0.09	0.35	7.00	0.01	0.05	1.00	1.23	4.98	100.00
All crops	61.78	250.05	25.00	46.95	190.03	19.00	2.47	10.00	1.00	128.50	520.09	52.00	7.41	30.01	3.00	247.12	1,000.18	100.00
Grassland and hay	43.38	176.68	9.00	106.4	429.44	22.00	28.92	117.12	6.00	265.1	1,073.6	55.00	38.56	156.16	8.00	482.00	1,953.00	100.00

Table 7–3. Land area for each potential natural vegetation class in cropland and in grassland.[kkm², thousand square kilometers]

Natural vegetation class	Total land area in class (kkm²)	Total cropland area in class (kkm²)^a	Total grassland and hay area in class (kkm²)^b	Percent of land in class converted to cropland (%)	Percent of land in class converted to grassland and hay (%)	Percent of total agricultural land (%)
Broadleaf Forests	2,092	190	429	9.1	20.5	21.0
Needleleaf Forests	1,163	10	117	0.9	10.1	4.3
Grassland	2,208	520	1,074	23.6	48.6	54.0
Wetland	1,014	250	177	24.7	17.5	14.5
Shrublands	1,271	30	156	2.4	12.3	6.3
All land	7,748	1,000	1,953			

^a Not including grasslands and hay.^b Grasslands converted to grassland; may or may not include lands that have been reseeded and otherwise disturbed.

Appendix 8—Summary of Data Sources and Online Links to Datasets

The data sources used to generate this report and the associated online links to selected datasets are summarized in table 8–1. An effort was made to use readily available data. In some cases, the data were not yet published and thus are cited as written communications.

Table 8–1. Summary of data sources and online links to datasets.

[m, meters]

Index letter	Dataset name	Type of data	Resolution (cell size) in square meters	Scale	Figures	Tables	Reference	Link
A	Potential Natural Vegetation	Geospatial polygon dataset	Original map refined to match 500-m National Elevation Dataset	National	1		Missoula Fire Sciences Laboratory, 2001	http://www.fs.fed.us/fire/fuelman/pnv.htm
B	1790 and 1830 Population Census	Report (tabular data from Norman Bliss, U.S. Geological Survey, written commun., 2011)		County	2		Waisanen and Bliss, 2002	http://www.agu.org/pubs/crossref/2002/2001GB001843.shtml
C	1850–1997 Census of Agriculture (improved farmland)	Report (tabular data from Norman Bliss, U.S. Geological Survey, written commun., 2011)		County	3		Waisanen and Bliss, 2002	http://www.agu.org/pubs/crossref/2002/2001GB001843.shtml
D	2002 Census of Agriculture (county-level total harvested cropland)	Tabular dataset		County	3		U.S. Department of Agriculture, 2005	http://www.agcensus.usda.gov/Publications/2002/index.asp
E	1879–1997 Census of Agriculture (state-level cropland area)	Report and tabular dataset		State	4		Ramankutty and others, 2010	http://www.informaworld.com/smpp/ftinterface~db=all~content=a922418004?tab=multimedia
F	2009 Cropland Data Layer	Geospatial raster dataset	56 m	Local	5	Appendix 2, tables 2–1, 2–2, 2–3, and 2–4	U.S. Department of Agriculture, 2010b	http://www.nass.usda.gov/research/Cropland/SARS1a.htm
G	Major Uses of Land in the United States, 2002	Report		National		Appendix 2, table 2–4	Lubowski and others, 2006	http://www.ers.usda.gov/Publications/EIB14/
H	Dot density grain and specialty crops (2007)	Map report		National	6	Appendix 2, table 2–5	U.S. Department of Agriculture, 2009a	http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Ag_Atlas_Maps/Crops_and_Plants/index.asp
I	National Elevation Data resampled to 100 m	Geospatial raster dataset	100 m, resampled from 30-m dataset	Local	7		Falcone, 2003	ftp://ftpext.usgs.gov/pub/er/va/reston/NAWQA_ENS/GIS_DATA/elevation/

Table 8–1. Summary of data sources and online links to datasets.—Continued

[m, meters]

Index letter	Dataset name	Type of data	Resolution (cell size) in square meters	Scale	Figures	Tables	Reference	Link
J	Combined slope and cropland bar graph (fig. 7) and map (fig. 8)	Geospatial raster data generated from F and I	100 m resampled to 56 m	Local	7, 8	Appendix 3, tables 3–1 and 3–2	Generated for this report	
K	Average growing degree-day	Map, (geospatial raster dataset from Leonard Coop, Oregon State University, written commun., 2009)	1,000 m	Local	9		Oregon State University, 2010	http://uspest.org/wea/indextable.html
L	Combined growing degree-day and cropland	Geospatial raster data generated from F and K	1,000 m resampled to 56 m	Local	9	Appendix 4, table 4–1	Oregon State University, 2008	
M	Average precipitation	Geospatial raster dataset	1,000 m	Local	10		Generated for this report	http://www.prism.oregonstate.edu/
N	Combined precipitation and cropland	Geospatial raster data generated from F and M	1,000 m resampled to 56 m	Local	10	Appendix 4, table 4–2	Generated for this report	
O	Threshold for growing degree days for selected crops	Report		Global	11	Appendix 4, table 4–3	Fischer and others, 2002	http://www.iiasa.ac.at/Research/LUC/GAEZ/index.htm
P	Threshold for water requirements for selected crops	Report		Global	11	Appendix 4, table 4–3	Brouwer and Heibloem, 1986;	http://www.fao.org/docrep/s2022e/s2022e07.htm
Q	Dot density maps of selected crops, 2007	Map report		National	11	Appendix 4, table 4–4	U.S. Department of Agriculture, 2009a	http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Ag_Atlas_Maps/Crops_and_Plants/index.asp
R	Favorable climate for selected crops	Generated from L and N based on thresholds O and P, and dot density maps of crops Q		National	11		Generated for this report	
S	Water withdrawals for irrigation	Tabular dataset		County	12		Kenney and others, 2009	http://water.usgs.gov/watuse/data/2005/

Table 8–1. Summary of data sources and online links to datasets.—Continued

[m, meters]

Index letter	Dataset name	Type of data	Resolution (cell size) in square meters	Scale	Figures	Tables	Reference	Link
T	Extent of irrigated cropland	Geospatial raster data generated from F and S	56 m resampled from 1,000-m county boundaries	County	12		Generated for this report	
U	Dot density maps of irrigated cropland, 2007	Map report		National	13		U.S. Department of Agriculture, 2009a	http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Ag_Atlas_Maps/Crops_and_Plants/index.asp
V	Areas of groundwater-level decline	Geospatial polygon dataset	Generalized polygons (resolution unknown)	National	14		Report: Reilly and others, 2008; Geospatial dataset from William Cunningham, U.S. Geological Survey, written commun., 2011	http://pubs.usgs.gov/circ/1323/
W	Wells with measured groundwater-level decline	Geospatial point dataset	Variable accuracy—documented in the U.S. Geological Survey, National Water Information System database	Local	14		Report: Reilly and others, 2008; List of wells used in the report were provided by William Cunningham, U.S. Geological Survey, written commun., 2011	http://pubs.usgs.gov/circ/1323/ and http://waterdata.usgs.gov/nwis
X	Areas with 1 or more wells that have measured groundwater-level decline	Geospatial raster data generated from W	10,000 m	Regional	14		Generated for this report	
Y	Cropland in areas that have groundwater-level decline	Geospatial raster data generated from F, V, and X	56 m resampled from 10,000 m	Regional	14		Generated for this report	

Table 8–1. Summary of data sources and online links to datasets.—Continued

[m, meters]

Index letter	Dataset name	Type of data	Resolution (cell size) in square meters	Scale	Figures	Tables	Reference	Link
Z	Dot density maps for fertilizer and manure	Map report		National	15		U.S. Department of Agriculture, 2009a	http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Ag_Atlas_Maps/Farms/index.asp
AA	Percentage of cropland treated with fertilizer	Tabular data		National	15		U.S. Department of Agriculture, 2010a	http://www.ers.usda.gov/Data/FertilizerUse/
AB	Land capability class (from U.S. General Soils Map)	Geospatial vector and tabular dataset	Approximately 6,000 m	Regional	16		U.S. Department of Agriculture, 2006	http://soildatamart.nrcs.usda.gov/USDGSM.aspx
AC	Cropland on each land capability class	Geospatial raster data generated from F and AB	56 m resampled from 6,000 m	Regional	16	Appendix 5, table 5–1	Generated for this report	
AD	Cropland on soils that have limitations	Geospatial raster data generated from F and AB	56 m resampled from 6,000 m	Regional	17		Generated for this report	
AE	Soil hazard class (from U.S. General Soils Map)	Geospatial vector and tabular dataset	Approximately 6,000 m	Regional	18		U.S. Department of Agriculture, 2006	http://soildatamart.nrcs.usda.gov/USDGSM.aspx
AF	Cropland on soils in each hazard class	Geospatial raster data generated from F and AE	56 m resampled from 6,000 m	Regional	18	Appendix 6, table 6–1	Generated for this report	
AG	Cropland on soils in each hazard class (separated by hazard)	Geospatial raster data generated from F and AE	56 m resampled from 6,000 m	Regional	19		Generated for this report	
AH	Cropland on soils where artificial drainage is likely	Geospatial raster generated from AE (Water hazard class)	56 m resampled from 6,000 m	Regional	20	Appendix 6, table 6–2	Generated for this report	

Table 8-1. Summary of data sources and online links to datasets.—Continued

[m, meters]

Index letter	Dataset name	Type of data	Resolution (cell size) in square meters	Scale	Figures	Tables	Reference	Link
AI	Areas where surface or subsurface drainage is likely	Geospatial raster dataset based on 1992 Natural Resources Inventory county-level agricultural practices (c606—subsurface drainage and C607) and 1992 National Land Cover	1,000 m	County	20		Michael Wieczorek, U.S. Geological Survey, digital dataset, 2002	http://water.usgs.gov/GIS/metadata/usgswrd/XML/ofr041189606.xml
AJ	Average annual runoff (1971–2000)	Geospatial raster dataset	1,000 m	Regional (source data 1:2,000,000)	21		David M. Wolock, U.S. Geological Survey, written commun., 2009	Older dataset available from : http://water.usgs.gov/GIS/metadata/usgswrd/XML/runoff.xml
AK	Cropland on annual runoff	Geospatial raster data generated from F and AJ	56 m resampled from 1,000 m	Regional	21	Appendix 6, table 6–3	Generated for this report	
AL	Average annual recharge (1971–2000)	Geospatial raster dataset	1,000 m	Regional (source data 1:2,000,000)	22		David M. Wolock, U.S. Geological Survey, written commun., 2009	Older dataset available from : http://water.usgs.gov/GIS/metadata/usgswrd/XML/rech48grd.xml
AM	Cropland on annual recharge	Geospatial raster data generated from F and AL	56 m resampled from 1,000 m	Regional	22	Appendix 6, table 6–4	Generated for this report	
AN	Potential Natural Vegetation with wetlands	Geospatial raster data generated from A and AE (Water hazard class)	56 m resampled from 6,000 m	Regional	23		Generated for this report	
AO	Cropland on potential natural vegetation and wetlands	Geospatial raster data generated from F and AN	56 m resampled from 6,000 m	Regional	23	Appendix 7, tables 7–1, 7–2, and 7–3	Generated for this report	

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