# **Environmental footprints of beef cattle production in the United States**

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Supplementary Information

**Table S1.** Important characteristics of farms and ranches simulated throughout seven regions of the U.S.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Location | Animal numbers1 | | | Grazed forage, ha | | | Hay  land2, ha | Crop area, ha | |
|  | Cows | Stockers | Feeders | Perennial | Annual | Stalks | Corn | Forage3 |
| **Northeast** |  |  |  |  |  |  |  |  |  |
| Maine | 40 | 26 | 0 | 74 | 0 | 0 | 0 | 0 | 20 |
| Maryland | 20 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 0 |
|  | 40 | 27 | 26 | 34 | 11 | 0 | 11 | 0 | 14 |
| New Jersey | 36 | 25 | 0 | 37 | 0 | 0 | 0 | 10 | 10 |
| New York | 50 | 0 | 0 | 50 | 0 | 0 | 22 | 0 | 0 |
|  | 50 | 32 | 32 | 70 | 0 | 11 | 32 | 11 | 8 |
| Ohio | 25 | 0 | 0 | 49 | 0 | 0 | 10 | 0 | 0 |
|  | 50 | 0 | 0 | 31.5 | 0 | 0 | 0 | 1 | 11.5 |
|  | 85 | 51 | 0 | 94 | 0 | 0 | 0 | 10 | 10 |
| Pennsylvania | 15 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 0 |
|  | 40 | 26 | 0 | 47 | 0 | 0 | 18 | 5 | 0 |
|  | 100 | 66 | 66 | 80 | 0 | 27 | 30 | 27 | 0 |
| Vermont | 30 | 21 | 21 | 67 | 0 | 0 | 24 | 0 | 8 |
| West Virginia | 100 | 0 | 0 | 90 | 0 | 0 | 31.5 | 0 | 10 |
|  | 75 | 53 | 0 | 133 | 0 | 0 | 0 | 0 | 25 |
|  | 0 | 300 | 0 | 215 | 0 | 0 | 0 | 0 | 0 |
| **Southeast** |  |  |  |  |  |  |  |  |  |
| Alabama | 100 | 0 | 0 | 100 | 30 | 0 | 17 | 0 | 0 |
| Arkansas | 160 | 0 | 0 | 208 | 0 | 0 | 34 | 0 | 0 |
|  | 200 | 150 | 0 | 360 | 0 | 0 | 51 | 0 | 0 |
| Florida | 750 | 0 | 0 | 2500 | 0 | 0 | 0 | 0 | 0 |
|  | 7500 | 0 | 0 | 25000 | 0 | 0 | 0 | 0 | 0 |
|  | 900 | 641 | 630 | 4000 | 0 | 0 | 0 | 0 | 60 |
| Georgia | 75 | 47 | 0 | 99 | 28 | 0 | 21 | 0 | 0 |
| Kentucky | 30 | 0 | 0 | 34 | 0 | 0 | 8 | 0 | 9 |
|  | 80 | 57 | 0 | 135 | 0 | 0 | 33 | 9 | 0 |
| Mississippi | 115 | 79 | 0 | 160 | 0 | 0 | 30 | 0 | 0 |
| North Carolina | 60 | 38 | 37 | 104 | 18 | 0 | 18 | 0 | 0 |
| Louisiana | 125 | 0 | 0 | 142 | 0 | 0 | 0 | 0 | 0 |
| South Carolina | 30 | 0 | 0 | 26 | 9 | 0 | 7 | 0 | 0 |
| Tennessee | 35 | 0 | 0 | 36 | 0 | 0 | 6 | 0 | 0 |
|  | 65 | 45 | 0 | 88 | 0 | 0 | 13 | 0 | 9 |
|  | 0 | 800 | 0 | 400 | 0 | 0 | 0 | 0 | 0 |
| Virginia | 125 | 87 | 86 | 240 | 0 | 0 | 45 | 0 | 65 |
|  |  |  |  |  |  |  |  |  |  |

1Bulls were included with the number varying across the region to service of about 20 cows per bull (Asem-Hiablie et al., 2016).

2Hectares of perennial grassland harvested as hay in a spring harvest and grazed the remainder of the year.

3Either alfalfa or a small grain harvested and fed as hay or silage and grassland not grazed at any time of the year.

**Table S1.** Continued.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Location | Animal numbers1 | | | Grazed forage, ha | | | Hay  land2, ha | Crop area, ha | |
|  | Cows | Stockers | Feeders | Perennial | Annual | Stalks | Corn | Alfalfa |
| **Midwest** |  |  |  |  |  |  |  |  |  |
| Minnesota | 100 | 0 | 0 | 110 | 0 | 100 | 30 | 0 | 0 |
|  | 200 | 127 | 125 | 325 | 0 | 100 | 0 | 67 | 0 |
| Wisconsin | 50 | 0 | 0 | 55 | 0 | 50 | 8 | 0 | 0 |
|  | 70 | 44 | 44 | 115 | 0 | 120 | 0 | 15 | 0 |
| Michigan | 80 | 51 | 0 | 115 | 15 | 0 | 43 | 0 | 0 |
|  | 200 | 127 | 125 | 325 | 0 | 100 | 0 | 50 | 0 |
| Iowa | 300 | 0 | 0 | 330 | 0 | 120 | 103 | 0 | 0 |
|  | 81 | 51 | 50 | 130 | 0 | 140 | 0 | 11 | 17 |
| Illinois | 200 | 0 | 0 | 220 | 0 | 160 | 48 | 0 | 0 |
|  | 50 | 32 | 32 | 80 | 0 | 80 | 0 | 6 | 9 |
| Indiana | 20 | 0 | 0 | 22 | 0 | 0 | 7 | 0 | 0 |
| Missouri | 500 | 0 | 0 | 550 | 0 | 0 | 155 | 0 | 0 |
|  | 300 | 191 | 0 | 430 | 60 | 0 | 125 | 0 | 0 |
| **Northern Plains** |  |  |  |  |  |  |  |  |  |
| North Dakota |  |  |  |  |  |  |  |  |  |
| Eastern | 100 | 64 | 63 | 380 | 0 | 50 | 0 | 0 | 0 |
| Central | 300 | 190 | 0 | 1300 | 0 | 300 | 130 | 0 | 50 |
| Western | 80 | 0 | 0 | 550 | 0 | 0 | 0 | 0 | 21 |
| South Dakota |  |  |  |  |  |  |  |  |  |
| Eastern | 100 | 64 | 63 | 380 | 0 | 50 | 0 | 17 | 31 |
| Eastern | 175 | 0 | 0 | 500 | 0 | 0 | 53 | 0 | 0 |
| Western | 275 | 0 | 0 | 1900 | 0 | 0 | 148 | 0 | 0 |
| Western | 500 | 319 | 0 | 4800 | 0 | 0 | 145 | 0 | 80 |
| Nebraska |  |  |  |  |  |  |  |  |  |
| Eastern | 75 | 0 | 0 | 218 | 0 | 120 | 19 | 0 | 0 |
| Eastern | 150 | 104 | 103 | 477 | 100 | 400 | 0 | 24 | 46 |
| Central | 248 | 0 | 0 | 815 | 0 | 350 | 125 | 0 | 0 |
| Central | 300 | 209 | 0 | 870 | 0 | 500 | 90 | 0 | 0 |
| Central | 350 | 234 | 231 | 1555 | 0 | 900 | 61 | 45 | 49 |
| Western | 490 | 0 | 0 | 3352 | 0 | 750 | 209 | 0 | 0 |
| Western | 750 | 485 | 0 | 6754 | 500 | 0 | 0 | 0 | 0 |
| Western | 1000 | 649 | 640 | 9648 | 0 | 0 | 246 | 129 | 160 |

1Bulls were included with the number varying across the region to service of about 18 cows per bull (Asem-Hiablie et al., 2016).

2Hectares of perennial grassland harvested as hay in a spring harvest and grazed the remainder of the year and grassland not grazed at any time of the year.

**Table S1**. Continued

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | Animal numbers1 | | | Grazed forage, ha | | | | Hay | | Crop area, ha | | | | |
| Location | Cows | | Stockers | Feeders | | Perennial | Annual | Land2 | | Corn | | | Alfalfa | | |
| **Southern Plains** |  | |  |  | |  |  |  | |  | | |  | | |
| Kansas |  | |  |  | |  |  |  | | | |  | |  |
| Eastern | 450 | | 314 | 0 | | 1460 | 40 | 121 | | | | 0 | | 0 |
| Eastern | 0 | | 2300 | 0 | | 2715 | 85 | 205 | | | | 0 | | 0 |
| Central | 300 | | 0 | 0 | | 1650 | 150 | 100 | | | | 0 | | 0 |
| Central | 50 | | 0 | 0 | | 300 | 0 | 11 | | | | 0 | | 0 |
| Central | 400 | | 282 | 280 | | 2725 | 275 | 163 | | | | 0 | | 0 |
| Western | 450 | | 0 | 0 | | 7000 | 0 | 0 | | | | 0 | | 0 |
| Western | 500 | | 370 | 0 | | 9500 | 500 | 0 | | | | 0 | | 0 |
| Oklahoma |  | |  |  | |  |  |  | | | |  | |  |
| Eastern | 100 | | 0 | 0 | | 210 | 16 | 22 | | | | 0 | | 0 |
| Eastern | 50 | | 35 | 34 | | 150 | 13 | 16 | | | | 0 | | 0 |
| Eastern | 0 | | 2000 | 0 | | 2600 | 0 | 146 | | | | 0 | | 0 |
| Central | 500 | | 0 | 0 | | 3000 | 0 | 106 | | | | 0 | | 0 |
| Central | 150 | | 107 | 0 | | 1300 | 100 | 0 | | | | 0 | | 0 |
| Western | 80 | | 0 | 0 | | 1200 | 0 | 0 | | | | 0 | | 0 |
| Western | 120 | | 86 | 0 | | 2175 | 125 | 48 | | | | 0 | | 0 |
| Texas |  | |  |  | |  |  |  | | | |  | |  |
| Eastern | 500 | | 0 | 0 | | 1100 | 0 | 115 | | | | 0 | | 0 |
| Eastern | 0 | | 1000 | 980 | | 1300 | 0 | 228 | | | | 0 | | 0 |
| Central | 300 | | 0 | 0 | | 1800 | 0 | 0 | | | | 0 | | 0 |
| Central | 500 | | 315 | 0 | | 3800 | 460 | 0 | | | | 0 | | 0 |
| Central | 0 | | 1000 | 0 | | 1440 | 360 | 0 | | | | 0 | | 0 |
| Central | 1000 | | 720 | 712 | | 5200 | 750 | 217 | | | | 0 | | 0 |
| Western | 200 | | 0 | 0 | | 3800 | 0 | 0 | | | | 0 | | 0 |
| Western | 300 | | 216 | 0 | | 5800 | 0 | 0 | | | | 0 | | 0 |

1Bulls were included with the number varying across the region to service of about 20 cows per bull (Asem Hiablie et al., 2015).

2Hectares of perennial grassland harvested as hay in a spring harvest and grazed the remainder of the year and grassland not grazed at any time of the year.

**Table S1**. Continued.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Location | Animal numbers1 | | | Grazed forage, ha | | | Hay land2, ha | Crop area, ha | |
|  | Cows | Stockers | Feeders | Perennial | Annual | Stalks | Corn | Alfalfa |
| **Northwest** |  |  |  |  |  |  |  |  |  |
| Idaho | 160 | 0 | 0 | 1,700 | 100 | 0 | 94 | 0 | 0 |
|  | 350 | 0 | 0 | 4,000 | 0 | 175 | 0 | 0 | 54 |
| Montana | 190 | 0 | 0 | 2,000 | 110 | 0 | 100 | 0 | 0 |
|  | 580 | 0 | 0 | 6,800 | 0 | 0 | 0 | 0 | 103 |
|  | 400 | 0 | 0 | 4,500 | 0 | 0 | 195 | 0 | 0 |
|  | 900 | 570 | 0 | 14,500 | 0 | 0 | 0 | 0 | 200 |
|  | 700 | 480 | 0 | 9,000 | 0 | 0 | 385 | 0 | 0 |
| Oregon | 75 | 0 | 0 | 600 | 0 | 0 | 0 | 0 | 18 |
|  | 235 | 0 | 0 | 2,000 | 0 | 0 | 0 | 0 | 0 |
|  | 240 | 168 | 165 | 2,700 | 0 | 34 | 282 | 34 | 0 |
| Washington | 60 | 0 | 0 | 600 | 0 | 30 | 0 | 0 | 0 |
|  | 250 | 187 | 183 | 1,075 | 0 | 0 | 210 | 0 | 0 |
| Wyoming | 350 | 0 | 0 | 5,600 | 200 | 0 | 174 | 0 | 0 |
|  | 750 | 0 | 0 | 12,000 | 0 | 0 | 0 | 0 | 0 |
|  | 150 | 95 | 0 | 3,300 | 0 | 0 | 66 | 0 | 60 |
|  | 575 | 422 | 417 | 9,200 | 0 | 0 | 0 | 0 | 193 |
| **Southwest** |  |  |  |  |  |  |  |  |  |
| Arizona | 115 | 0 | 0 | 4,600 | 0 | 0 | 0 | 0 | 10 |
| California | 136 | 0 | 0 | 1,825 | 0 | 0 | 85 | 0 | 0 |
|  | 242 | 161 | 0 | 1,850 | 250 | 0 | 0 | 0 | 0 |
|  | 180 | 125 | 123 | 1,620 | 120 | 0 | 69 | 0 | 0 |
| Colorado | 300 | 0 | 0 | 4,800 | 0 | 150 | 0 | 0 | 28 |
|  | 180 | 0 | 0 | 3,400 | 0 | 0 | 0 | 0 | 0 |
|  | 450 | 301 | 0 | 9,000 | 0 | 260 | 310 | 0 | 0 |
|  | 46 | 30 | 30 | 860 | 40 | 0 | 0 | 0 | 0 |
|  | 250 | 173 | 171 | 7,000 | 0 | 0 | 160 | 0 | 0 |
|  | 700 | 505 | 499 | 3,100 | 0 | 0 | 0 | 0 | 0 |
| Hawaii | 300 | 0 | 0 | 600 | 0 | 0 | 0 | 0 | 0 |
| Nevada | 650 | 0 | 0 | 8,400 | 0 | 0 | 112 | 0 | 55 |
| New Mexico | 60 | 0 | 0 | 7,800 | 0 | 0 | 0 | 0 | 0 |
|  | 0 | 2,100 | 0 | 13,440 | 0 | 0 | 715 | 0 | 0 |
| Utah | 1,000 | 0 | 0 | 22,000 | 0 | 0 | 355 | 0 | 0 |
|  | 345 | 238 | 0 | 8,600 | 0 | 0 | 100 | 0 | 100 |

Bulls were included with the number varying across the region to service of about 18 cows per bull (Asem – Hiablie *et al.,* 2016).

2 Hectares of perennial grassland harvested as hay in a spring harvest and grazed the remainder of the year and grassland not grazed at any time of the year.

**Table S2.** Important characteristics of representative finishing facilities simulated in seven regions of the U.S.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Location | Animal numbers | | | Housing | Final | Crop area, ha | | | Manure |
|  | | Background | Finish |  | weight, kg | Corn | Alfalfa | Grass | export, % |
| **Northeast** | |  |  |  |  |  |  |  |  |
| New York | | 75 | 75 | Barn | 632 | 12 | 17 | 15 | 0 |
| Ohio | | 100 | 99 | Open lot | 613 | 0 | 0 | 72 | 0 |
|  | | 0 | 150 | Barn | 626 | 20 | 0 | 5 | 0 |
| Pennsylvania | | 0 | 500 | Barn | 613 | 64 | 0 | 25 | 0 |
| **Southeast** | |  |  |  |  |  |  |  |  |
| Kentucky | | 1500 | 1470 | Open lot | 564 | 0 | 0 | 1020 | 0 |
|  | | 200 | 196 | Open lot | 564 | 20 | 0 | 0 | 50 |
| Florida | | 0 | 15,000 | Open lot | 616 | 320 | 0 | 400 | 50 |
| **Midwest** | |  |  |  |  |  |  |  |  |
| Minnesota | | 0 | 2,500 | Barn | 632 | 325 | 40 | 0 | 0 |
| Wisconsin | | 0 | 100 | Barn | 630 | 18 | 3 | 0 | 0 |
| Michigan1 | | 700 | 700 | Barn | 615 | 136 | 12 | 0 | 20 |
| Iowa | | 0 | 2,000 | Barn | 630 | 200 | 20 | 20 | 0 |
|  | | 0 | 10,000 | Open lot | 640 | 1,200 | 200 | 0 | 0 |
|  | | 2,000 | 0 | Open lot | 300 | 62 | 62 | 62 | 0 |
| Illinois | | 1,500 | 1,500 | Barn | 600 | 200 | 50 | 50 | 20 |
| **Northern Plains** | |  |  |  |  |  |  |  |  |
| North Dakota | | 1,200 | 0 | Open lot | 363 | 55 | 0 | 130 | 0 |
|  | | 203 | 200 | Open lot | 612 | 43 | 29 | 0 | 15 |
| South Dakota | | 305 | 300 | Open lot | 600 | 57 | 8 | 442 | 0 |
| Nebraska | | 0 | 12,000 | Open lot | 612 | 1,275 | 0 | 0 | 0 |
|  | | 0 | 50,000 | Open lot | 612 | 4,435 | 0 | 0 | 80 |
| **Southern Plains** | |  |  |  |  |  |  |  |  |
| Kansas | |  |  |  |  |  |  |  |  |
| Eastern | | 10000 | 10000 | Open lot | 580 | 0 | 0 | 100 | 75 |
| Central | | 59600 | 59000 | Open lot | 581 | 7300 | 340 | 570 | 0 |
| Western | | 0 | 180000 | Open lot | 610 | 2000 | 0 | 0 | 70 |
| Oklahoma | | 9000 | 74000 | Open lot | 610 | 200 | 0 | 0 | 89 |
| Texas | |  |  |  |  |  |  |  |  |
| Western | | 3000 | 30000 | Open lot | 570 | 60 | 0 | 14340 | 80 |
| Western | | 0 | 150000 | Open lot | 608 | 200 | 0 | 200 | 80 |

Holstein finishing operation raising cattle from 4 months to finish at 16 months of age.

**Table S2**. Continued.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Location | | Animal numbers | | | | | | Housing | | Final | | | Crop area, ha | | | | | | | | | Manure | |
|  | | | Background | | | Finish | |  | | weight, kg | | | Corn | | | Alfalfa | | | Grass | | | export, % | |
| **Northwest** |  | | | |  | |  | |  | | |  | | |  | | |  | | |  | | |
| Oregon | | | | 10000 | | 0 | | Open lot | | | 393 | | | 0 | | | 0 | | | 0 | | | 100 | |
| Idaho | | | | 25300 | | 25,000 | | Open lot | | | 632 | | | 500 | | | 250 | | | 0 | | | 60 | |
| Washington | | | | 0 | | 100,000 | | Open lot | | | 632 | | | 500 | | | 0 | | | 0 | | | 80 | |
| Idaho | | | | 0 | | 10,000 | | Open lot | | | 632 | | | 0 | | | 0 | | | 0 | | | 100 | |
| **Southwest** |  | | | |  | |  | |  | | |  | | |  | | |  | | |  | | |
| Nevada | 650 | | | | | 0 | | Open lot | | | 613 | | | 0 | | | 0 | | | 77 | | | 0 | |
| Colorado | 200 | | | | | 0 | | Open lot | | | 613 | | | 0 | | | 0 | | | 0 | | | 100 | |
|  | 0 | | | | | 200,000 | | Open lot | | | 613 | | | 500 | | | 300 | | | 0 | | | 90 | |
| Utah | 15,190 | | | | | 15,000 | | Open lot | | | 613 | | | 600 | | | 0 | | | 500 | | | 0 | |
| Arizona | 0 | | | | | 100,000 | | Open lot | | | 613 | | | 0 | | | 0 | | | 0 | | | 100 | |
| California1 | 0 | | | | | 35,000 | | Open lot | | | 615 | | | 0 | | | 0 | | | 0 | | | 100 | |

Holstein finishing operation raising cattle from 4 months to finish at 16 months of age.

**Table S3**. Important characteristics of dairy farms simulated throughout seven regions of the U.S.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Location | Animal numbers1 | | Cow weight, kg | Milk prod., kg/cow/yr | Replacement rate, % | Crop area, ha | | |
|  | Cows | Heifers | Alfalfa | Corn | Other2 |
| New York | 1000 | 820 | 602 | 10480 | 38 | 300 | 530 | 80 |
| Pennsylvania | 100 | 80 | 593 | 8844 | 35 | 32 | 49 | 8 |
| Georgia | 500 | 350 | 612 | 9600 | 33 | 0 | 90 | 60 |
| Wisconsin | 250 | 190 | 632 | 9400 | 35 | 70 | 190 | 0 |
| Nebraska | 85 | 76 | 645 | 9056 | 40 | 35 | 45 | 0 |
| Texas | 1000 | 0 | 600 | 9368 | 38 | 0 | 250 | 250 |
| Idaho | 7000 | 5700 | 651 | 9638 | 35 | 2218 | 1473 | 0 |
| California | 2000 | 1650 | 678 | 11055 | 40 | 0 | 300 | 300 |

1 All cattle are Holstein breed.

2 Small grain forage for NY, PA, and CA and perennial grass for GA and TX.

**Table S4.** Summary of 25 years of weather data (daily solar radiation, daily mean temperature, annual precipitation and daily wind speed)1 used to simulate beef cattle operations in each area of the eastern regions.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | | Solar, MJ/m2 | | | | Temperature, °C | | | Precipitation, mm | | Wind, m/s | |
| Location | | | | Mean | | St. dev. | | Mean | St. dev. | Mean | St. dev. | Mean | St. dev. |
| **Northeast** | | | |  | |  | |  |  |  |  |  |  |
| Maine | |  | | 13.9 | | 0.2 | | 8.1 | 0.6 | 1010 | 277 | 3.7 | 0.3 |
| Maryland | |  | | 14.1 | | 0.4 | | 12.1 | 0.5 | 1019 | 166 | 3.0 | 0.3 |
| New Jersey | |  | | 14.0 | | 0.2 | | 12.9 | 0.6 | 1088 | 216 | 4.5 | 0.2 |
| New York | |  | | 13.3 | | 0.2 | | 9.1 | 0.7 | 752 | 128 | 4.1 | 0.3 |
| Ohio | | Western | | 13.7 | | 0.6 | | 11.3 | 0.7 | 1048 | 204 | 4.2 | 0.3 |
|  | | Eastern | | 13.5 | | 0.3 | | 10.1 | 0.7 | 907 | 198 | 4.2 | 0.2 |
| Pennsylvania | | Eastern | | 13.0 | | 1.0 | | 12.4 | 0.8 | 1071 | 194 | 3.9 | 0.3 |
|  | | Central | | 13,4 | | 0.7 | | 10.2 | 0.8 | 1006 | 197 | 2.8 | 0.3 |
|  | | Western | | 13.8 | | 0.3 | | 10.9 | 0.7 | 897 | 166 | 3.7 | 0.4 |
| Vermont | |  | | 13.3 | | 0.3 | | 7.9 | 0.6 | 804 | 182 | 3.9 | 0.4 |
| West Virginia | | Western | | 14.2 | | 0.3 | | 13.1 | 0.6 | 996 | 182 | 2.8 | 0.3 |
|  | | Southern | | 14.3 | | 0.3 | | 12.9 | 0.6 | 1041 | 162 | 2.1 | 0.5 |
| **Southeast** | |  | |  | |  | |  |  |  |  |  |  |
| Alabama | |  | | 16.6 | | 0.5 | | 18.2 | 0.5 | 1310 | 289 | 2.8 | 0.2 |
| Arkansas | |  | | 16.3 | | 0.3 | | 16.8 | 0.6 | 1217 | 235 | 3.2 | 0.1 |
| Florida | | Northern | | 16.6 | | 0.4 | | 19.5 | 0.5 | 1459 | 260 | 2.5 | 0.1 |
|  | | Central | | 15.5 | | 0.9 | | 22.2 | 0.5 | 1300 | 245 | 3.8 | 0.2 |
| Georgia | |  | | 16.7 | | 0.4 | | 17.9 | 0.5 | 1093 | 173 | 2.8 | 0.3 |
| Kentucky | |  | | 16.3 | | 0.3 | | 16.8 | 0.6 | 1188 | 236 | 3.2 | 0.1 |
| Louisiana | |  | | 16.3 | | 0.2 | | 20.5 | 0.6 | 1575 | 368 | 3.6 | 0.2 |
| Mississippi | |  | | 16.5 | | 0.3 | | 17.9 | 0.5 | 1278 | 260 | 2.9 | 0.5 |
| North Carolina | |  | | 15.7 | | 0.3 | | 14.6 | 0.6 | 999 | 180 | 3.2 | 0.2 |
| South Carolina | |  | | 16.3 | | 0.3 | | 17.4 | 0.6 | 1083 | 202 | 2.9 | 0.2 |
| Tennessee | |  | | 15.8 | | 0.3 | | 15.4 | 0.6 | 1135 | 214 | 3.4 | 0.3 |
| Virginia | |  | | 15.2 | | 0.3 | | 14.6 | 0.6 | 1010 | 160 | 3.6 | 0.2 |
| **Midwest** | |  | |  | |  | |  |  |  |  |  |  |
| Minnesota | |  | | 13.8 | | 0.3 | | 6.9 | 0.9 | 710 | 151 | 5.7 | 0.5 |
| Wisconsin | |  | | 13.8 | | 0.6 | | 8.4 | 0.8 | 767 | 140 | 4.0 | 0.5 |
| Michigan | |  | | 13.3 | | 0.2 | | 9.0 | 0.7 | 694 | 157 | 4.2 | 0.3 |
| Iowa | |  | | 14.9 | | 0.4 | | 10.3 | 0.8 | 813 | 202 | 4.5 | 0.3 |
| Illinois | |  | | 15.1 | | 0.4 | | 11.8 | 0.7 | 850 | 198 | 4.4 | 0.3 |
| Indiana | |  | | 14.8 | | 0.3 | | 11.7 | 0.6 | 994 | 175 | 4.3 | 0.2 |
| Missouri | |  | | 15.5 | | 0.3 | | 12.4 | 0.7 | 1007 | 214 | 4.4 | 0.2 |
|  |  | |  | |  | |  | |  |  |  |  |  |

1Obtained from the Integrated Surface Database of the National Climatic Data Center, National Oceanic and Atmospheric Administration (NOAA, 2016).

**Table S4**. Continued.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Solar, MJ/m2 | | Temperature, °C | | Precipitation, mm | | Wind, m/s | |
| Location | | Mean | St. dev. | Mean | St. dev. | Mean | St. dev. | Mean | St. dev. |
| **Northern Plains** | |  |  |  |  |  |  |  |  |
| North Dakota | Eastern | 12.1 | 1.7 | 5.0 | 1.1 | 553 | 107 | 5.2 | 0.3 |
|  | Central | 14.2 | 0.4 | 6.2 | 1.0 | 381 | 111 | 4.3 | 0.2 |
|  | Western | 12.3 | 1.8 | 6.0 | 1.1 | 402 | 98 | 5.6 | 0.4 |
| South Dakota | Eastern | 13.1 | 1.5 | 6.3 | 1.1 | 556 | 108 | 5.1 | 0.2 |
|  | Western | 14.8 | 0.4 | 8.7 | 1.0 | 418 | 121 | 4.9 | 0.2 |
| Nebraska | Eastern | 15.7 | 0.4 | 10.3 | 0.8 | 572 | 166 | 5.0 | 0.2 |
|  | Central | 15.5 | 0.9 | 9.4 | 0.7 | 523 | 128 | 4.5 | 0.1 |
|  | Western | 14.4 | 1.9 | 8.4 | 0.7 | 348 | 101 | 5.2 | 0.2 |
| **Southern Plains** |  |  |  |  |  |  |  |  |  |
| Kansas | Eastern | 15.7 | 8.5 | 13.0 | 10.8 | 828 | 160 | 4.15 | 1.35 |
|  | Central | 15.1 | 8.3 | 13.4 | 11.1 | 653 | 196 | 5.05 | 1.80 |
|  | Western | 17.9 | 7.8 | 12.7 | 10.7 | 450 | 121 | 5.92 | 1.89 |
| Oklahoma | Eastern | 16.1 | 8.3 | 15.9 | 9.7 | 954 | 183 | 4.35 | 1.50 |
|  | Central | 17.1 | 6.4 | 15.6 | 9.7 | 811 | 165 | 5.09 | 1.80 |
|  | Western | 17.3 | 8.0 | 16.1 | 10.9 | 464 | 152 | 5.93 | 1.96 |
| Texas | Eastern | 16.6 | 7.7 | 20.4 | 7.0 | 1386 | 333 | 4.15 | 1.34 |
|  | Central | 15.6 | 7.7 | 17.7 | 9.6 | 637 | 179 | 5.13 | 1.68 |
|  | Western | 18.5 | 5.9 | 18.3 | 8.6 | 497 | 140 | 4.43 | 1.50 |
| **Northwest** |  |  |  |  |  |  |  |  |  |
| Idaho |  | 31.7 | 1.36 | 11.5 | 1.08 | 260 | 61 | 3.8 | 0.13 |
| Montana | Eastern | 27.7 | 1.21 | 8.9 | 0.82 | 276 | 85 | 4.9 | 0.18 |
|  | Western | 14.3 | 0.27 | 7.0 | 1.0 | 242 | 71 | 3.2 | 0.21 |
| Oregon |  | 13.7 | 0.22 | 9.2 | 0.64 | 864 | 156 | 3.7 | 0.29 |
| Washington | Eastern | 13.9 | 0.30 | 8.7 | 0.76 | 362 | 89 | 4.1 | 0.28 |
|  | Western | 11.9 | 0.26 | 11.2 | 0.54 | 842 | 150 | 3.6 | 0.34 |
| Wyoming |  | 16.4 | 0.26 | 7.5 | 0.81 | 222 | 60 | 2.9 | 0.17 |
| **Southwest** |  |  |  |  |  |  |  |  |  |
| Arizona |  | 20.5 | 0.47 | 23.9 | 0.52 | 200 | 75 | 2.7 | 0.28 |
| California | North | 17.7 | 0.56 | 15.9 | 0.48 | 574 | 207 | 2.6 | 0.10 |
|  | Central | 18.8 | 0.67 | 18.2 | 0.52 | 244 | 177 | 1.9 | 0.14 |
| Colorado | Eastern | 15.9 | 1.40 | 9.7 | 0.84 | 373 | 88 | 5.3 | 0.41 |
|  | Western | 17.9 | 0.65 | 11.8 | 0.56 | 230 | 44 | 3.5 | 0.23 |
| Nevada |  | 17.9 | 0.47 | 10.2 | 0.57 | 195 | 63 | 3.0 | 0.21 |
| Utah |  | 16.4 | 0.62 | 11.6 | 0.66 | 359 | 107 | 3.9 | 0.21 |
| Hawaii |  | 19.6 | 0.57 | 24.2 | 0.38 | 432 | 228 | 5.7 | 0.28 |

1Obtained from the Integrated Surface Database of the National Climatic Data Center, National Oceanic and Atmospheric Administration (NOAA, 2014). These meteorological data sets were processed using AERMET, a meteorological processor (USEPA, 2004).

**Table S5.** Soil characteristics used for locations simulated across the U.S.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  | Soil texture1, % | | | | | | | | Density, | | Available water, mm | |
| Location |  | Soil type | Clay | | | | Silt | | Sand | | g/cm3 | |
| **Northeast** |  |  |  | | | |  | |  | |  | |  | |
| Maine |  | Silt loam | | | 17 | 50 | | 33 | | 1.70 | | 225 | |
| Maryland |  | Loam | | | 20 | 50 | | 30 | | 1.45 | | 200 | |
| New Jersey |  | Loam | | | 15 | 30 | | 55 | | 1.50 | | 256 | |
| New York |  | Loam | | | 22 | 54 | | 24 | | 1.35 | | 182 | |
| Ohio | Central | Silt loam | | | 25 | 60 | | 15 | | 1.40 | | 311 | |
|  | Eastern | Silt loam | | | 25 | 60 | | 15 | | 1.50 | | 200 | |
| Pennsylvania | Eastern | Silty clay | | | 45 | 47 | | 8 | | 1.40 | | 260 | |
|  | Central | Silt loam | | | 25 | 50 | | 25 | | 1.45 | | 160 | |
|  | Western | Loam | | | 20 | 50 | | 30 | | 1.45 | | 140 | |
| Vermont |  | Sandy loam | | | 8 | 32 | | 60 | | 1.33 | | 150 | |
| West Virginia | Western | Silt loam | | | 25 | 55 | | 20 | | 1.35 | | 160 | |
|  | Southern | Silt loam | | | 24 | 56 | | 20 | | 1.30 | | 120 | |
| **Southeast** |  |  | |  | |  | |  | |  | |  | | |
| Alabama |  | Silt loam | | 28 | | 64 | | 8 | | 1.40 | | 311 | | |
| Arkansas |  | Silty clay | | 46 | | 48 | | 6 | | 1.48 | | 143 | | |
| Florida | Northern | Sandy clay loam | | 26 | | 9 | | 65 | | 1.55 | | 183 | | |
|  | Central | Loamy sand | | 3 | | 3 | | 94 | | 1.59 | | 102 | | |
| Georgia |  | Sandy clay loam | | 27 | | 8 | | 65 | | 1.51 | | 182 | | |
| Kentucky |  | Silty clay loam | | 34 | | 57 | | 9 | | 1.46 | | 280 | | |
| Louisiana |  | Silt loam | | 28 | | 64 | | 8 | | 1.32 | | 311 | | |
| Mississippi |  | Loam | | 24 | | 50 | | 26 | | 1.52 | | 207 | | |
| North Carolina |  | Clay loam | | 30 | | 33 | | 37 | | 1.47 | | 208 | | |
| South Carolina |  | Sandy clay loam | | 23 | | 16 | | 61 | | 1.58 | | 183 | | |
| Tennessee |  | Clay loam | | 41 | | 33 | | 26 | | 1.41 | | 190 | | |
| Virginia |  | Clay loam | | 35 | | 27 | | 38 | | 1.39 | | 214 | | |
| **Midwest** |  |  | |  | |  | |  | |  | |  | | |
| Minnesota |  | Sandy clay loam | | 26 | | 37 | | 37 | | 1.41 | | 260 | | |
| Wisconsin |  | Silt loam | | 12 | | 56 | | 32 | | 1.40 | | 185 | | |
| Michigan |  | Loam | | 25 | | 40 | | 35 | | 1.45 | | 208 | | |
| Iowa |  | Silt loam | | 27 | | 70 | | 3 | | 1.31 | | 289 | | |
| Illinois |  | Silty clay loam | | 31 | | 61 | | 8 | | 1.30 | | 240 | | |
| Indiana |  | Silt loam | | 20 | | 62 | | 18 | | 1.47 | | 165 | | |  |  |
| Missouri |  | Silt loam | | 28 | | 67 | | 5 | | 1.35 | | 270 | | |

1Soil characteristics based upon common soils found in each area as found in the Web Soil Survey (NRCS, 2016).

**Table S5.** Continued.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  | Soil texture1, % | | | Density,  g/cm3 | Available water, mm |
| Location |  | Soil type | Clay | Silt | Sand |
| **Northern Plains** |  |  |  |  |  |  |  |
| North Dakota | East | Loam | 23 | 37 | 40 | 1.36 | 245 |
|  | Central | Loam | 23 | 37 | 40 | 1.36 | 250 |
|  | West | Loam | 22 | 37 | 41 | 1.28 | 252 |
| South Dakota | East | Loam | 23 | 39 | 38 | 1.30 | 250 |
|  | West | Clay | 45 | 35 | 20 | 1.18 | 100 |
| Nebraska | East | Silt loam | 26 | 63 | 11 | 1.36 | 281 |
|  | Central | Sandy loam | 9 | 22 | 68 | 1.49 | 111 |
|  | West | Loamy sand | 5 | 10 | 85 | 1.70 | 160 |
| **Southern Plains** |  |  |  |  |  |  |  |
| Kansas | East | Clay loam | 40 | 50 | 10 | 1.15 | 150 |
|  | Central | Loam | 20 | 50 | 30 | 1.50 | 160 |
|  | West | Loam | 20 | 60 | 20 | 1.55 | 160 |
| Oklahoma | East | Clay loam | 40 | 50 | 10 | 1.10 | 150 |
|  | Central | Loam | 20 | 50 | 30 | 1.50 | 160 |
|  | West | Loam | 20 | 60 | 20 | 1.45 | 160 |
| Texas | East | Deep loam | 20 | 30 | 50 | 1.70 | 270 |
|  | Central | Clay loam | 35 | 30 | 35 | 1.30 | 150 |
|  | West | Sandy loam | 30 | 20 | 50 | 1.40 | 260 |
| **Northwest** |  |  |  |  |  |  |  |
| Idaho |  | Silt loam | 11 | 69 | 20 | 1.37 | 180 |
| Montana | Eastern | Clay loam | 37 | 35 | 28 | 1.39 | 140 |
| Montana | Western | Clay loam | 36 | 25 | 39 | 1.37 | 130 |
| Oregon | Eastern | Loam | 27 | 38 | 35 | 1.35 | 120 |
| Washington | Eastern | Silt loam | 28 | 65 | 7 | 1.35 | 200 |
| Washington | Western | Clay loam | 31 | 20 | 49 | 1.20 | 259 |
| Wyoming |  | Loam | 23 | 37 | 40 | 1.29 | 180 |
| **Southwest** |  |  |  |  |  |  |  |
| Arizona |  | Loam | 16 | 33 | 51 | 1.43 | 255 |
| California | North | Clay loam | 28 | 35 | 37 | 1.41 | 180 |
|  | Central | Sandy loam | 14 | 16 | 70 | 1.55 | 190 |
| Colorado | Eastern | Sandy clay loam | 24 | 24 | 52 | 1.50 | 207 |
| Colorado | Western | Clay | 38 | 31 | 31 | 1.30 | 245 |
| Nevada |  | Sandy loam | 12 | 14 | 74 | 1.50 | 120 |
| Utah |  | Loam | 22 | 38 | 40 | 1.30 | 240 |
| Hawaii |  | Loam | 23 | 37 | 40 | 1.25 | 200 |

1Soil texture based upon typical soils found in each area as defined by USDA official soil series descriptions (<https://soilseries.sc.egov.usda.gov>).

**Table S6.** Cattle numbers by state and region as obtained or estimated from NASS (2017).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Dairy | Beef | Estimated | Stockers/ | Finished | Total |
| State | cows | cows | calves | background | cattle | Slaughter |
| Alabama | 8,000 | 680,000 | 457,970 | 460,186 | 85,449 | 148,505 |
| Alaska | 320 | 4,460 | 2,868 | 1,015 | 792 | 1,290 |
| Arizona | 193,600 | 183,400 | 230,527 | 120,693 | 309,321 | 387,015 |
| Arkansas | 7,400 | 876,600 | 587,497 | 592,133 | 193,630 | 273,993 |
| California | 1,773,000 | 611,000 | 1,484,935 | 663,880 | 780,407 | 1,396,827 |
| Colorado | 144,000 | 742,000 | 609,085 | 339,940 | 1,323,342 | 1,435,028 |
| Connecticut | 18,800 | 5,600 | 14,340 | 11,913 | 2,943 | 9,401 |
| Delaware | 4,840 | 2,860 | 4,626 | 4,112 | 2,578 | 4,366 |
| Florida | 123,400 | 920,600 | 624,505 | 665,527 | 54,801 | 175,852 |
| Georgia | 81,800 | 494,200 | 373,161 | 363,146 | 73,474 | 143,388 |
| Hawaii | 2,240 | 71,760 | 45,334 | 30,164 | 14,106 | 21,203 |
| Idaho | 582,200 | 485,800 | 726,276 | 177,777 | 485,090 | 712,884 |
| Illinois | 94,800 | 373,200 | 313,024 | 431,789 | 324,747 | 388,013 |
| Indiana | 180,400 | 197,600 | 256,741 | 302,685 | 161,155 | 235,929 |
| Iowa | 209,000 | 925,000 | 817,254 | 751,478 | 1,934,272 | 2,082,850 |
| Kansas | 140,600 | 1,445,400 | 1,048,552 | 3,704,265 | 3,413,898 | 3,587,109 |
| Kentucky | 63,800 | 1,010,200 | 744,780 | 703,255 | 326,776 | 436,909 |
| Louisiana | 14,000 | 453,000 | 276,016 | 309,840 | 45,262 | 90,017 |
| Maine | 30,400 | 10,800 | 24,055 | 20,549 | 7,002 | 17,600 |
| Maryland | 49,200 | 41,000 | 53,970 | 50,595 | 22,834 | 42,079 |
| Massachusetts | 12,100 | 6,100 | 13,261 | 9,507 | 2,943 | 7,322 |
| Michigan | 399,600 | 113,400 | 306,856 | 342,118 | 212,506 | 349,272 |
| Minnesota | 461,000 | 355,000 | 602,917 | 621,664 | 675,879 | 853,611 |
| Mississippi | 11,600 | 483,400 | 301,459 | 329,371 | 88,088 | 134,787 |
| Missouri | 89,600 | 1,868,400 | 1,403,209 | 1,274,425 | 645,434 | 840,125 |
| Montana | 14,000 | 1,484,000 | 1,131,819 | 326,271 | 449,571 | 586,085 |
| Nebraska | 56,000 | 1,830,000 | 1,281,392 | 784,047 | 3,769,090 | 3,949,712 |
| Nevada | 28,800 | 222,200 | 157,283 | 98,475 | 73,474 | 102,379 |
| New Hampshire | 13,700 | 3,800 | 10,408 | 8,474 | 2,131 | 6,812 |
| New Jersey | 6,900 | 7,700 | 7,324 | 8,533 | 3,126 | 5,998 |
| New Mexico | 321,200 | 430,800 | 448,719 | 252,507 | 193,833 | 333,995 |
| New York | 616,000 | 104,000 | 413,253 | 331,745 | 84,637 | 289,165 |
| North Carolina | 46,000 | 362,000 | 279,871 | 260,747 | 64,340 | 111,140 |
| North Dakota | 16,600 | 919,400 | 683,101 | 308,430 | 462,764 | 549,853 |
| Ohio | 266,600 | 287,400 | 365,451 | 322,242 | 263,654 | 373,744 |
| Oklahoma | 40,600 | 1,877,400 | 1,384,705 | 1,000,460 | 1,359,876 | 1,539,835 |
| Oregon | 124,400 | 527,600 | 484,184 | 130,671 | 270,960 | 357,352 |
| Pennsylvania | 530,000 | 164,000 | 434,841 | 340,358 | 215,145 | 397,751 |
| Rhode Island | 920 | 1,480 | 1,696 | 1,472 | 710 | 1,134 |
| South Carolina | 15,400 | 170,600 | 114,107 | 120,511 | 21,920 | 41,986 |
| South Dakota | 102,400 | 1,655,600 | 1,306,064 | 610,559 | 1,244,185 | 1,423,994 |
| Tennessee | 45,200 | 888,800 | 647,635 | 614,612 | 222,857 | 316,289 |
| Texas | 459,000 | 4,201,000 | 3,153,366 | 6,501,025 | 3,953,789 | 4,473,181 |
| Utah | 94,600 | 338,400 | 294,520 | 161,748 | 150,398 | 210,504 |
| Vermont | 131,600 | 12,600 | 83,422 | 63,783 | 9,742 | 52,581 |
| Virginia | 91,600 | 648,400 | 498,062 | 470,516 | 227,323 | 314,067 |
| Washington | 271,800 | 215,200 | 326,901 | 80,459 | 306,885 | 412,199 |
| West Virginia | 9,000 | 196,800 | 145,718 | 148,788 | 61,296 | 81,664 |
| Wisconsin | 1,275,000 | 269,000 | 1,076,308 | 997,608 | 441,452 | 869,568 |
| Wyoming | 6,000 | 700,000 | 505,772 | 153,827 | 285,777 | 349,979 |
|  |  |  |  |  |  |  |
| **Regional totals** |  |  |  |  |  |  |
| Southern Plains | 640,200 | 7,523,800 | 5,586,623 | 11,205,750 | 8,727,563 | 9,600,125 |
| Northern Plains | 175,000 | 4,405,000 | 3,270,557 | 1,703,036 | 5,476,039 | 5,923,559 |
| Midwest | 2,709,400 | 4,101,600 | 4,776,308 | 4,721,767 | 4,395,445 | 5,619,367 |
| Northwest | 998,720 | 3,417,060 | 3,177,822 | 870,019 | 1,799,076 | 2,419,788 |
| Southwest | 2,557,440 | 2,599,560 | 3,270,403 | 1,667,405 | 2,844,881 | 3,886,951 |
| Southeast | 508,200 | 6,987,800 | 4,905,064 | 4,889,843 | 1,403,920 | 2,186,934 |
| Northeast | 1,690,060 | 844,140 | 1,572,365 | 1,322,071 | 678,741 | 1,289,618 |
|  |  |  |  |  |  |  |
| **National totals** | 9,279,020 | 29,878,960 | 26,559,143 | 26,379,892 | 25,325,664 | 30,926,341 |

**Table S7.** Cattle numbers by state and region divided between traditional beef and dairy breeds as obtained or estimated from NASS (2017).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Beef breed cattle | | | Dairy breed cattle | | |
| State | Calves | Stockers / Background | Finished | Cows | Finished | Finished portion, % |
| Alabama | 522,073 | 457,164 | 84,888 | 2,544 | 561 | 2.1 |
| Alaska | 3,424 | 975 | 761 | 102 | 31 | 10.3 |
| Arizona | 140,806 | 75,763 | 194,170 | 61,565 | 115,151 | 45.7 |
| Arkansas | 673,014 | 589,338 | 192,716 | 2,353 | 914 | 1.2 |
| California | 469,098 | 252,404 | 296,707 | 563,814 | 483,699 | 75.0 |
| Colorado | 569,674 | 306,520 | 1,193,245 | 45,792 | 130,097 | 12.3 |
| Connecticut | 4,299 | 4,128 | 1,020 | 5,978 | 1,923 | 84.1 |
| Delaware | 2,196 | 2,108 | 1,321 | 1,539 | 1,256 | 64.0 |
| Florida | 706,795 | 618,919 | 50,963 | 39,241 | 3,838 | 24.5 |
| Georgia | 379,425 | 332,251 | 67,223 | 26,012 | 6,251 | 22.5 |
| Hawaii | 55,094 | 29,644 | 13,863 | 712 | 243 | 4.5 |
| Idaho | 372,975 | 106,244 | 289,904 | 185,140 | 195,186 | 53.4 |
| Illinois | 286,526 | 377,865 | 284,190 | 30,146 | 40,556 | 18.2 |
| Indiana | 151,708 | 200,070 | 106,521 | 57,367 | 54,634 | 47.5 |
| Iowa | 710,173 | 666,833 | 1,716,399 | 66,462 | 217,873 | 13.7 |
| Kansas | 1,109,713 | 3,512,322 | 3,237,001 | 44,711 | 176,897 | 6.2 |
| Kentucky | 775,586 | 679,157 | 315,579 | 20,288 | 11,197 | 7.2 |
| Louisiana | 347,793 | 304,552 | 44,489 | 4,452 | 772 | 5.8 |
| Maine | 8,292 | 7,961 | 2,713 | 9,667 | 4,290 | 79.3 |
| Maryland | 31,478 | 30,221 | 13,639 | 15,646 | 9,195 | 59.0 |
| Massachusetts | 4,683 | 4,496 | 1,392 | 3,848 | 1,551 | 73.7 |
| Michigan | 87,063 | 114,818 | 71,319 | 127,073 | 141,187 | 76.8 |
| Minnesota | 272,553 | 359,438 | 390,784 | 146,598 | 285,095 | 50.6 |
| Mississippi | 371,133 | 324,990 | 86,916 | 3,689 | 1,172 | 3.6 |
| Missouri | 1,434,474 | 1,240,991 | 628,501 | 28,493 | 16,933 | 5.4 |
| Montana | 1,139,349 | 324,551 | 447,201 | 4,452 | 2,370 | 1.2 |
| Nebraska | 1,404,992 | 770,796 | 3,705,388 | 17,808 | 63,702 | 2.1 |
| Nevada | 170,595 | 91,791 | 68,487 | 9,158 | 4,987 | 13.8 |
| New Hampshire | 2,917 | 2,801 | 704 | 4,357 | 1,427 | 84.9 |
| New Jersey | 5,912 | 5,676 | 2,079 | 2,194 | 1,047 | 54.0 |
| New Mexico | 330,749 | 177,963 | 136,611 | 102,142 | 57,222 | 47.7 |
| New York | 79,847 | 76,658 | 19,558 | 195,888 | 65,079 | 90.2 |
| North Carolina | 277,927 | 243,373 | 60,053 | 14,628 | 4,287 | 17.0 |
| North Dakota | 705,874 | 305,333 | 458,117 | 5,279 | 4,647 | 1.8 |
| Ohio | 220,653 | 211,843 | 173,326 | 84,779 | 90,327 | 46.9 |
| Oklahoma | 1,441,383 | 988,451 | 1,343,553 | 12,911 | 16,323 | 1.9 |
| Oregon | 405,068 | 115,386 | 239,266 | 39,559 | 31,694 | 19.9 |
| Pennsylvania | 125,912 | 120,884 | 76,413 | 168,540 | 138,732 | 77.3 |
| Rhode Island | 1,136 | 1,091 | 527 | 293 | 184 | 42.0 |
| South Carolina | 130,979 | 114,694 | 20,862 | 4,897 | 1,058 | 14.2 |
| South Dakota | 1,271,095 | 590,056 | 1,202,405 | 32,563 | 41,781 | 5.2 |
| Tennessee | 682,381 | 597,540 | 216,667 | 14,374 | 6,190 | 6.5 |
| Texas | 3,225,339 | 6,125,058 | 3,725,134 | 145,962 | 228,656 | 8.4 |
| Utah | 259,808 | 139,793 | 129,984 | 30,083 | 20,414 | 24.0 |
| Vermont | 9,674 | 9,287 | 1,419 | 41,849 | 8,324 | 95.4 |
| Virginia | 497,812 | 435,919 | 210,608 | 29,129 | 16,715 | 14.6 |
| Washington | 165,221 | 47,064 | 179,512 | 86,432 | 127,374 | 51.9 |
| West Virginia | 151,094 | 145,061 | 59,761 | 2,862 | 1,535 | 5.4 |
| Wisconsin | 206,526 | 272,363 | 120,523 | 405,450 | 320,929 | 83.5 |
| Wyoming | 537,429 | 153,090 | 284,407 | 1,908 | 1,370 | 0.9 |
| **Regional totals** |  |  |  |  |  |  |
| Southern Plains | 5,776,436 | 10,625,831 | 8,305,688 | 203,584 | 421,876 | 6.5 |
| Northern Plains | 3,381,961 | 1,666,185 | 5,365,910 | 55,650 | 110,129 | 2.8 |
| Midwest | 3,149,024 | 3,232,376 | 3,318,238 | 861,589 | 1,077,207 | 34.5 |
| Northwest | 2,623,465 | 747,311 | 1,441,051 | 317,593 | 358,024 | 27.9 |
| Southwest | 1,995,825 | 1,073,878 | 2,033,067 | 813,266 | 811,814 | 41.8 |
| Southeast | 5,364,919 | 4,697,898 | 1,350,965 | 161,608 | 52,955 | 9.8 |
| Northeast | 648,093 | 622,216 | 353,870 | 537,439 | 324,870 | 66.9 |
|  |  |  |  |  |  |  |
| **National totals** | 22,939,724 | 22,665,695 | 22,168,788 | 2,950,728 | 3,156,876 | 19.7 |

**Table S8.** Important resource inputs and emissions from representative cow-calf, stocker / background and feedlot operations expressed per unit of final carcass weight (CW)1 produced.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Resource use or emission | Units | Cow-calf | Background | | Feedlot | | Total |
| **Northeast** |  |  |  |  | |  | |
| Total feed intake | kg DM/kg CW | 16.5 | 2.7 | 4.0 | | 23.2 | |
| Drinking water consumed | liter/kg CW | 49.6 | 9.8 | 13.7 | | 73.1 | |
| Fuel use | liter/kg CW | 0.17 | 0.04 | 0.15 | | 0.36 | |
| Natural gas | m3/kg CW | 0.0 | 0.0 | 0.0 | | 0.0 | |
| Electricity use | kWh/kg CW | 0.13 | 0.05 | 0.085 | | 0.26 | |
| Ammonia emission | g/kg CW | 47 | 16 | 28 | | 91 | |
| Carbon dioxide emission | g/kg CW | 474 | 247 | 450 | | 1171 | |
| Methane emission | g/kg CW | 367 | 78.3 | 73.9 | | 519 | |
| Nitrous oxide emission | g/kg CW | 18.5 | 1.9 | 5.7 | | 26.1 | |
| Nitrate leaching and runoff | g /kg CW | 153 | 10 | 41 | | 204 | |
| Greenhouse gas emissions | kg CO2e/kg CW | 17.2 | 3.2 | 5.2 | | 25.7 | |
| Energy use | MJ/kg CW | 28.8 | 5.5 | 23.7 | | 58.0 | |
| Blue water use | liter/kg CW | 86.5 | 14.1 | 93.2 | | 194 | |
| Reactive nitrogen loss | g N/kg CW | 111 | 26.1 | 59.7 | | 197 | |
| **Southeast** |  |  |  |  | |  | |
| Total feed intake | kg DM/kg CW | 16.3 | 2.5 | 2.3 | | 21.1 | |
| Drinking water consumed | liter/kg CW | 55 | 7.6 | 8.5 | | 70.9 | |
| Fuel use | liter/kg CW | 0.22 | 0.06 | 0.01 | | 0.29 | |
| Natural gas | m3/kg CW | 0 | 0 | 0.02 | | 0.02 | |
| Electricity use | kWh/kg CW | 0.14 | 0.04 | 0.04 | | 0.22 | |
| Ammonia emission | g/kg CW | 45.2 | 12.3 | 28.5 | | 86 | |
| Carbon dioxide emission | g/kg CW | 822 | 190 | 90 | | 1,102 | |
| Methane emission | g/kg CW | 356 | 63 | 35 | | 454 | |
| Nitrous oxide emission | g/kg CW | 28.0 | 2.4 | 4.1 | | 34.5 | |
| Nitrate leaching and runoff | g /kg CW | 109 | 87 | 23 | | 219 | |
| Greenhouse gas emissions | kg CO2e/kg CW | 19.6 | 3.0 | 5.3 | | 27.9 | |
| Energy use | MJ/kg CW | 31.3 | 7.3 | 23.9 | | 62.5 | |
| Blue water use | liter/kg CW | 145 | 41 | 45 | | 231 | |
| Reactive nitrogen loss | g N/kg CW | 113 | 36 | 76 | | 225 | |
| **Midwest** |  |  |  |  | |  | |
| Total feed intake | kg DM/kg CW | 15.5 | 1.7 | 3.7 | | 21.0 | |
| Drinking water consumed | liter/kg CW | 43.9 | 5.8 | 12.4 | | 62.1 | |
| Fuel use | liter/kg CW | 0.19 | 0.03 | 0.05 | | 0.27 | |
| Natural gas | m3/kg CW | 0 | 0 | 0.02 | | 0.02 | |
| Electricity use | kWh/kg CW | 0.13 | 0.06 | 0.07 | | 0.25 | |
| Ammonia emission | g/kg CW | 61.3 | 14.6 | 29.8 | | 106 | |
| Carbon dioxide emission | g/kg CW | 898 | 130 | 242 | | 1269 | |
| Methane emission | g/kg CW | 362 | 48.2 | 56.5 | | 467 | |
| Nitrous oxide emission | g/kg CW | 23.0 | 1.9 | 2.6 | | 27.5 | |
| Nitrate leaching and runoff | g /kg CW | 37 | 9.3 | 35 | | 81 | |
| Greenhouse gas emissions | kg CO2e/kg CW | 18.4 | 2.2 | 3.4 | | 24.1 | |
| Energy use | MJ/kg CW | 25.9 | 4.5 | 13.4 | | 43.9 | |
| Blue water use | liter/kg CW | 88.7 | 13.8 | 42.9 | | 145 | |
| Reactive nitrogen loss | g N/kg CW | 97.1 | 21.4 | 46.0 | | 165 | |

1Annual system consumption or emission expressed per unit of total carcass weight produced including finished cattle and cull animals.

**Table S8.** Continued.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Resource use or emission | Units | Cow-calf | | Background | | | | Feedlot | | Total | |
| **Northern Plains** |  |  | |  | |  | | |  | | |
| Total feed intake | kg DM/kg CW | 17.0 | | 2.9 | | 3.3 | | | 23.2 | | |
| Drinking water consumed | liter/kg CW | 30.0 | | 5.1 | | 10.8 | | | 45.9 | | |
| Fuel use | liter/kg CW | 0.15 | | 0.07 | | 0.03 | | | 0.25 | | |
| Natural gas | m3/kg CW | 0.0 | | 0.01 | | 0.03 | | | 0.04 | | |
| Electricity use | kWh/kg CW | 0.37 | | 0.10 | | 0.06 | | | 0.54 | | |
| Ammonia emission | g/kg CW | 43.6 | | 12.8 | | 33.6 | | | 90.0 | | |
| Carbon dioxide emission | g/kg CW | 385 | | 207 | | 153 | | | 745 | | |
| Methane emission | g/kg CW | 386 | | 67 | | 47 | | | 500 | | |
| Nitrous oxide emission | g/kg CW | 6.9 | | 1.4 | | 2.6 | | | 10.9 | | |
| Nitrate leaching and runoff | g N/kg CW | 12.8 | | 5.7 | | 24.4 | | | 43.4 | | |
| Greenhouse gas emissions | kg CO2e/kg CW | 14.2 | | 2.8 | | 3.0 | | | 20.1 | | |
| Energy use | MJ/kg CW | 19.7 | | 7.8 | | 12.0 | | | 39.5 | | |
| Blue water use | liter/kg CW | 415 | | 204 | | 562 | | | 1181 | | |
| Reactive nitrogen loss | g N/kg CW | 57.7 | | 15.0 | | 41.7 | | | 114 | | |
| **Southern Plains** |  |  | |  | |  | | |  | | |
| Total feed intake | kg DM/kg CW | | 14.5 | | 2.8 | | 3.3 | | | | 20.5 | |
| Drinking water consumed | liter/kg CW | | 51.0 | | 8.2 | | 13.3 | | | | 72.5 | |
| Fuel use | liter/kg CW | | 0.19 | | 0.06 | | 0.01 | | | | 0.26 | |
| Natural gas | liter/kg CW | | 0.0 | | 0.0 | | 0.03 | | | | 0.03 | |
| Electricity use | kWh/kg CW | | 0.25 | | 0.09 | | 0.08 | | | | 0.42 | |
| Ammonia emission | g/kg CW | | 40.9 | | 10.6 | | 31.2 | | | | 82.7 | |
| Carbon dioxide emission | g/kg CW | | 1285 | | 163 | | 76.5 | | | | 1524 | |
| Methane emission | g/kg CW | | 362 | | 74.8 | | 35.1 | | | | 472 | |
| Nitrous oxide emission | g/kg CW | | 11.1 | | 2.3 | | 2.3 | | | | 15.7 | |
| Nitrate leaching and runoff | g N/kg CW | | 79.3 | | 19.0 | | 1.3 | | | | 99.6 | |
| Greenhouse gas emissions | kg CO2e/kg CW | | 14.9 | | 3.3 | | 2.9 | | | | 21.1 | |
| Energy use | MJ/kg CW | | 25.5 | | 10.0 | | 12.1 | | | | 47.6 | |
| Blue water use | liter/kg CW | | 532 | | 237 | | 964 | | | | 1733 | |
| Reactive nitrogen loss | g N/kg CW | | 74.6 | | 18.3 | | 3.2 | | | | 126 | |

1Annual system consumption or emission expressed per unit of total carcass weight produced including finished cattle and cull animals.

**Table S8**. Continued.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Resource use or emission | Units | Cow-calf | Background | | Finish | | Total |
| **Northwest** |  |  |  |  | |  | |
| Total feed intake | kg DM/kg CW | 17 | 2.2 | 3.8 | | 23.0 | |
| Drinking water consumed | L/kg CW | 38.5 | 6.0 | 14.8 | | 59.3 | |
| Fuel use | L /kg CW | 0.13 | 0.01 | 0.01 | | 0.16 | |
| Natural gas | m3/kg CW | 0 | 0.01 | 0.03 | | 0.04 | |
| Electricity use | kWh/kg CW | 0.48 | 0.04 | 0.06 | | 0.57 | |
| Ammonia emission | g/kg CW | 35.8 | 33.3 | 49.4 | | 119 | |
| Carbon dioxide emission | g/kg CW | 354 | 59 | 92 | | 505 | |
| Methane emission | g/kg CW | 378 | 55 | 57 | | 490 | |
| Nitrous oxide emission | g/kg CW | 6.2 | 2.0 | 3.5 | | 11.7 | |
| Nitrate leaching and runoff | g N/kg CW | 72.2 | 7.1 | 3.5 | | 82.8 | |
| Greenhouse gas emissions | kg CO2e/kg CW | 13.7 | 2.6 | 3.7 | | 20.1 | |
| Energy use | MJ/kg CW | 24.4 | 6.0 | 12.7 | | 43.1 | |
| Blue water use | L/kg CW | 4016 | 893 | 1186 | | 6095 | |
| Reactive nitrogen loss | g N/kg CW | 60.0 | 35.2 | 57.0 | | 152 | |
| **Southwest** |  |  |  |  | |  | |
| Total feed intake | kg DM/kg CW | 17.2 | 2.6 | 3.2 | | 23.0 | |
| Drinking water consumed | L/kg CW | 48.2 | 6.8 | 10.6 | | 65.7 | |
| Fuel use | L/kg CW | 0.18 | 0.08 | 0.01 | | 0.27 | |
| Natural gas | m3/kg CW | 0.0 | 0.02 | 0.02 | | 0.04 | |
| Electricity use | kWh/kg CW | 0.88 | 0.07 | 0.06 | | 0.102 | |
| Ammonia emission | g/kg CW | 32.6 | 12.8 | 43.1 | | 88.5 | |
| Carbon dioxide emission | g/kg CW | 478 | 240 | 73 | | 791 | |
| Methane emission | g/kg CW | 383 | 57.8 | 47.6 | | 488 | |
| Nitrous oxide emission | g/kg CW | 3.9 | 1.5 | 2.8 | | 8.2 | |
| Nitrate leaching and runoff | g N/kg CW | 3.0 | 0.3 | 2.4 | | 5.7 | |
| Greenhouse gas emissions | kg CO2e/kg CW | 13.6 | 2.7 | 3.3 | | 19.6 | |
| Energy use | MJ/kg CW | 26.2 | 8.5 | 11.6 | | 46.3 | |
| Blue water use | L/kg CW | 3089 | 648 | 1130 | | 4868 | |
| Reactive nitrogen loss | g N/kg CW | 38.8 | 15.3 | 51.2 | | 105 | |

Annual system consumption or emission expressed per unit of total carcass weight produced including finished cattle and cull animals.

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