# THE MACRO IMPLICATIONS OF A COMPLETE TRANSFORMATION OF U.S. AGRICULTURAL PRODUCTION TO ORGANIC FARMING PRACTICES

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# THE MACRO IMPLICATIONS OF A COMPLETE TRANSFORMATION OF U.S. AGRICULTURAL PRODUCTION TO ORGANIC FARMING PRACTICES

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## ABSTRACT

A national interregional linear programming model of U.S. agriculture is used to evaluate and compare two conventional and three organic production alternatives. The objective is to estimate the effects on production, supply prices, land use, farm income, and export potential, of a complete transformation of U.S. agriculture to organic practices. Crop yields and production costs are estimated for 150 producing regions for seven crops under both conventional and organic methods. Results indicate that compared to conventional methods, widespread organic farming leads to a decrease in total production, lower export potential, higher supply prices, higher value of production, lower costs of production, and higher net farm income. U.S. domestic crop demand can be met with organic methods, but would be more expensive. Some interregional shifts in crop production would also occur.

INTRODUCTION

Recently there has been a renewed interest in organic farming as a method that can both reduce agriculture's dependence on purchased inputs, and, help alleviate potential environmental and health hazards from the use of chemical fertilizers and pesticides (CAST, 1980; USDA, 1980). Studies of the micro, farm-level effects of organic farming have found that lower production costs allow individual farms to remain economically competitive as measured by income per unit area, even though crop yields were lower for the organic farms (Klepper et al., 1977). The objective of this study is to quantitatively estimate how a complete transformation of U.S. agriculture to organic practices would affect production, supply prices, land use, farm income, and export potential.

This analysis is macro in the sense that it deals with the agricultural sector of the United States and broad regions of production. It does not deal with individual farms. Whereas an individual farm could import enough feed so that the level of manure generated could offset the need to purchase fertilizers to maintain yields, an entire nation or region cannot. Hence, the results of this study for the entire United States may differ from those for individual farms.

Conventional farming is defined in this study as the predominate practices currently utilized in U.S. agriculture, i.e., the use of chemical fertilizers and pesticides. Organic farming is broadly defined as that farming method which uses neither chemical or chemically processed fertilizers nor pesticides, but does use unprocessed fertilizers (e.g., potash, rock phosphate, and lime), rotations for nutrient supply, and natural pesticides.

## METHODOLOGY

A linear programming model of U.S. agriculture estimated for 1980 is used in this study to estimate the national and interregional effects of switching from conventional to organic farming methods under five alternatives. The first two alternatives use conventional farming: Alternative I incorporates trend-level exports and Alternative II incorporates a level of exports that requires almost all available cropland to be used. There are three organic alternatives, all of which incorporate a level of exports that uses almost all available cropland. The organic alternatives (III, IV, V) assume different levels of simulated organic crop yields, and are discussed later. For each alternative, the model minimizes total production plus transportation costs for production levels that satisfy the estimated domestic and export demands without exceeding the available cropland.

The interregional aspects of this study are based upon 150 spatially delineated agricultural producing areas of the United States (Figure 1). Agricultural production within an individual producing area is reasonably homogeneous with respect to soil type, climate, historical yields, and production costs. The results of the five alternatives are reported on the basis of 10 major producing regions, which are aggregations of producing areas (Figure 2).

Crop and livestock demands are exogenously defined on the basis of 31 consuming regions. These demands are based on population, per capita income, and export projections from government sources and our own analysis. Domestic crop demands include the demand for livestock feeds. Transportation activities allow the supply of a commodity produced in one consuming region to satisfy the demand in another region. Wheat can be substituted for other feed grains up to a level of 50% of the total feed grains fed to livestock in a given region.

No government supply control programs are assumed; hence, the land base for each alternative includes land formerly retired under previous wheat and feed grain programs. The land base for the organic alternatives (III, IV, V) include legume and meadow crops, since some organic production activities include these crops.

Crop production activities are defined for wheat, feed grains (corn, sorghum, oats, and barley), soybeans, and cotton, for each producing area where such activities are feasible. The yields for conventional farming are calculated by Thomas and Heady (1977) from Spillman functions developed by Stoecker (1974). The basic production costs for conventional farming are updated from Mayer and Hargrove (1971).

Adequate data as to what crop yields would be under widespread organic farming conditions do not exist. Hence, yields for organic farming are simulated by starting with 1944 census data (U.S. Department of Commerce, 1949) and adjusting, if necessary, by a three-year average yield to even out good and bad years. Discussions with faculty members in the Agronomy, Botany and Plant Pathology, and Entomology departments at Iowa State University indicated that in 1944-46 yields were relatively free from the widespread effects of nitrogen fertilizers and chemical pesticides. Except for cotton, the organic alternatives do not assume the use of nitrogen fertilizers. Untreated potash and rock phosphate were being applied in 1944; hence, the analysis includes them in the organic farming alternatives.

Several factors other than chemicals have been responsible for improvements in crop yields since 1944. This study includes quantitative adjustments for two of the more important factors--crop variety improvements and irrigation development. The 1944 yields for each crop for each of the approximately 3,020 counties in the United States are adjusted for crop variety improvement using indexes calculated by Auer (1963). Auer's indexes are based upon equation (1)

$$v_j = \sum_{i=1}^{n} r_{ij} \left[ \sum_{j'=1}^{m} \sum_{k=1}^{p} (y_{ij'k} / y^*_{j'k}) \right] / (mp) \qquad (1)$$

where: $v_j$ = crop variety improvement index for year j (j = 1,m); $r_{ij}$ = the relative amount of cropland planted to variety i in year j; $y_{ijk}$ = yield of variety i (i=1,n) in year j at location k (k = 1,p); and, $y^*_{jk}$ = yield of the check variety in year j at location k. Crop yields for each producing area are obtained by a weighted average of the relevant adjusted crop yields for each county included in the particular producing area.

Auer lists indexes for the seven endogenous crops for 1944-60. The data necessary for calculating indexes for 1961-80 are not readily available; hence, the crop variety improvement indexes for 1961-80 are projected. The three organic alternatives (III, IV, V) involve different projected levels of the rate of improvement in crop yields due to variety for 1961-80. Alternative III, or constant case, assumes a constant annual rate of improvement in crop yields due to variety improvement for 1944-80 based upon the 1944-60 average. Alternative IV, or pessimistic case, assumes that crop variety improvements are 10% less than in the constant case. Finally, Alternative V, or optimistic case, assumes that crop variety improvements are 10% greater than in the constant case. As indicated above, each organic alternative incorporates an export level that requires almost all available land.

In addition to increased yields due to crop variety improvement, yields for corn, grain sorghum, and cotton, in the Western United States (producing areas 80-150) are adjusted due to irrigation development. The irrigation indexes estimate the relative yield between irrigated and nonirrigated crop yields, weighted by the proportion of land irrigated in the state.

The 1944 census yield data are county-specific, while the variety and irrigation indexes are state-specific. The adjusted county organic crop yields are aggregated to obtain a weighted average yield for each relevant crop for each producing area.

State and national average crop yields are generally below those obtained in yield contests or experimental plots. The approach taken in this study to analyze a complete transformation of U.S. agriculture to organic farming practices necessarily assumes that average managerial skills are employed. This implies that the assumed organic yields are probably below those obtained in experiments or on farms with a high level of managerial ability.

Production costs for organic farming are based on those costs for conventional farming, adjusted using data from Berg et al (1975) and Stoneberg et al (1975). For corn and grain sorghum under organic farming, manure is applied, no nitrogen fertilizer is used, one-half the conventional phosphorus and potassium rates are applied (in the form of untreated rock phosphate and potash), and two cultivations instead of one are used. An additional tillage operation before planting is assumed to be used for weed control in small grains. Two cultivations are also assumed for soybeans. The organic farming activities in the interregional linear programming model differ from those in the conventional activities with respect to tillage methods and the crop rotations defined, and the organic production costs reflect extra labor and machinery expenses for manure spreading and the additional tillage operations.

## RESULTS

The reason for incorporating a level of export which uses most available cropland in Alternatives II-V is to evaluate and compare export potential under conventional and organic farming practices. Compared to the conventional high export alternative (II), organic farming leads to a loss in export potential for each crop (Table 1). The estimated export potential for the organic farming constant case (III) is 25% of the conventional level (II) for wheat, 58% for feed grains, 37% for soybeans, and 66% for cotton.

Compared to the conventional, wheat export potential declines the most under organic conditions. One explanation for the relatively low export of wheat is the increased domestic demand for wheat in the form of livestock feed. The constant organic alternative has a 49% increase in wheat substitution for feed grains used for domestic livestock feed, thus, freeing more feed grains for export.

Overall, the main reason for the lowered export potential under organic farming is the lower estimated crop yields as compared to conventional farming (Table 2). The organic farming yields decline due to lower fertilization levels and the use of less productive farmland. Almost 99% of the available cropland is used in the organic alternatives, compared to approximately 66% of available cropland used in the conventional trend-level alternative (I). Soybean yields in the organic alternatives decline primarily because the other crops compete for the most productive land, and since soybeans are a legume, they have a relative yield advantage on less productive land.

Compared to the conventional trend-export alternative (I), crop production increases in the conventional high export alternative (II) for all crops and decreases in the constant organic alternative (III) for all crops except wheat (Table 3). Basically the same pattern is found in the pessimistic and optimistic organic alternatives (IV and V, respectively).

National wheat production increases to 82 million metric tons (MMT) in alternative II and drops to 64 MMT in alternative III as compared to 50 MMT in alternative I. Feed grain production increases to 187 MMT in II and falls to 121 MMT in III, compared to 157 MMT in I. Similarly, national soybean production is 32 MMT, 69 MMT, and 27 MMT in alternatives I, II, and III, respectively.

Regional changes in comparative advantage for crops due to a complete transformation of U.S. agriculture to organic methods are indicated by shifts in crop production patterns among the alternatives. This transformation significantly increases wheat production along the

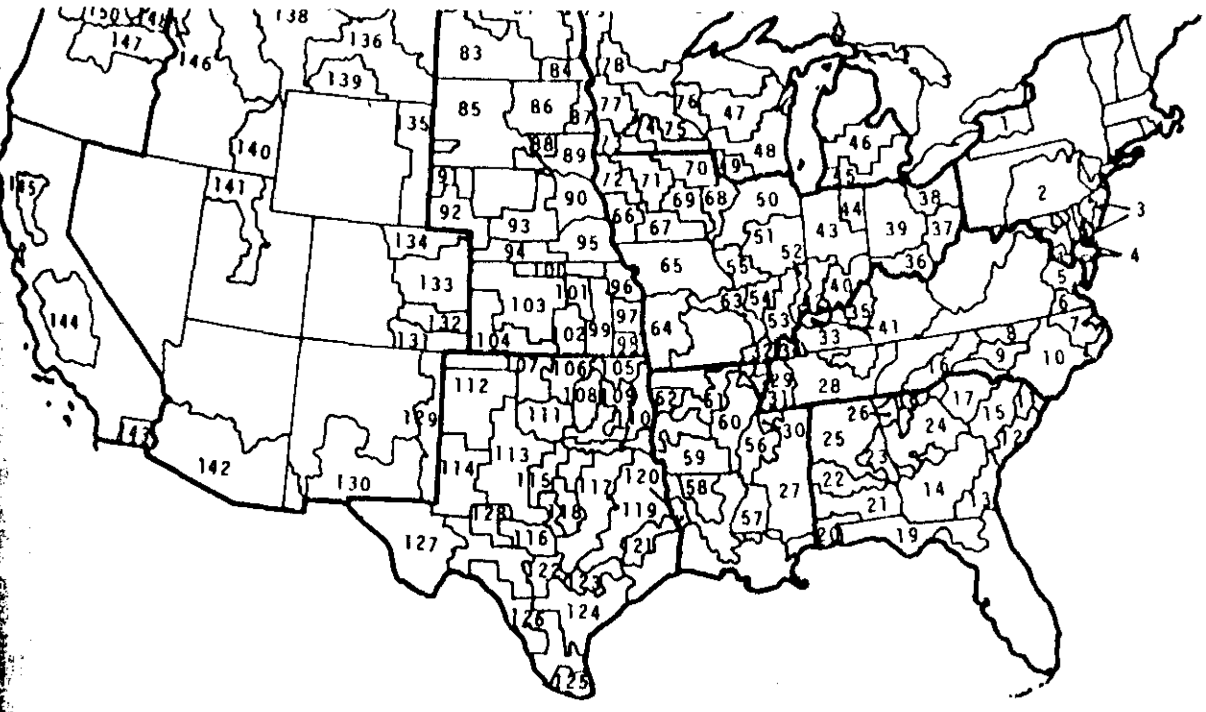

**Figure 1. The 150 producing areas**

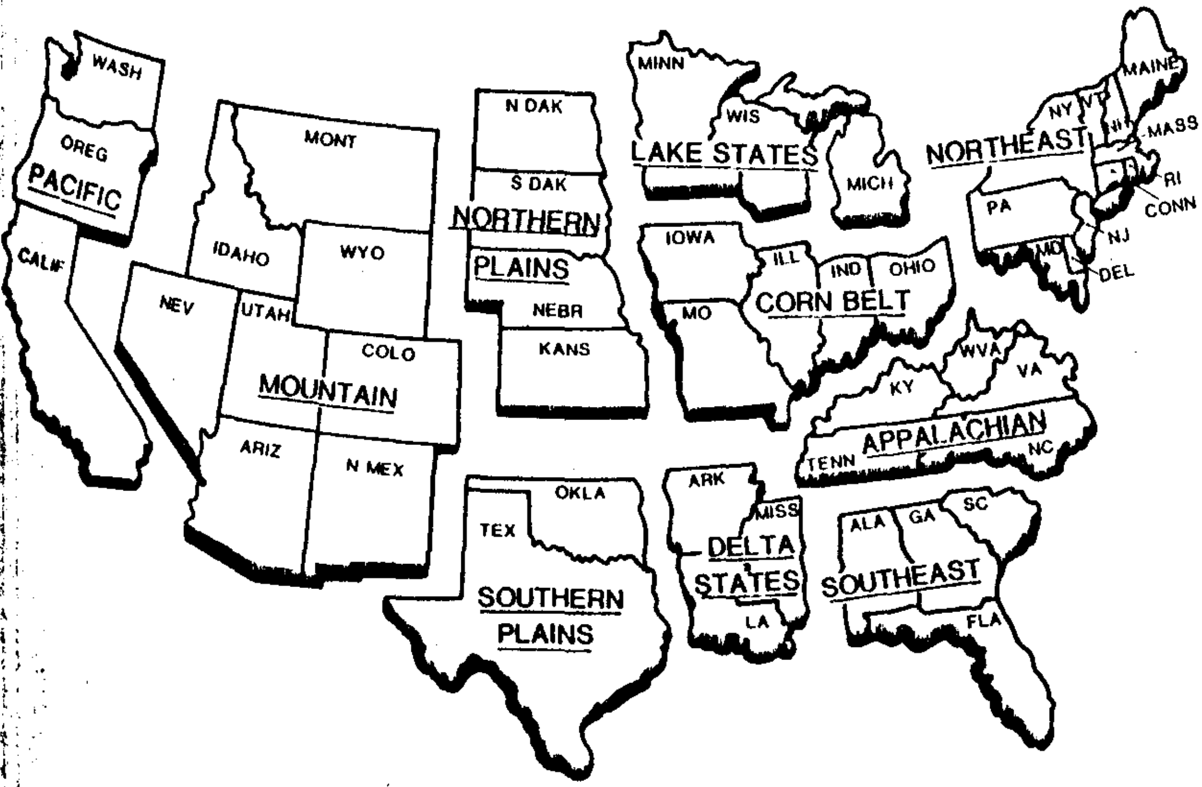


**Figure 2. The 10 farm production regions**

Altantic Coast and in the Southeastern United States, and substantially decreases it in the Southern Plains. Feed grain production declines along the Atlantic Coast and in the North Central states, while the most significant increases occur in the Northern Plains. For soybean production, organic farming practices do not significantly change the comparative advantage among the producing regions.

Supply prices, determined endogenously in the linear programming model, indicate the level of prices necessary to produce the last unit of production to meet the specified demand levels. Supply prices increase in the constant organic case (III) over the high export conventional alternative (II) by 77% for wheat, 99% for feed grains, 2% for soybeans, and 36% for cotton.

Value of production is defined here as the supply price for a particular crop in a producing region times the production level within that region. Data on production costs are obtained as described above. The difference between value and cost of production is defined to be net income. Estimates for value and cost of production and net income are available by individual crops (i.e., for wheat, feed grains, soybeans, and cotton); however, only the total for all crops is presented in Table 4.

Total value of production increases from $26 billion in the conventional alternative (II) to $30 billion in the organic alternative (III). Hence, even though total production is lower for the organic alternative, the higher supply prices bring about a higher national value of production. This is to be expected since the endogenous crops have relatively inelastic demands, resulting in prices increasing by a greater proportional change than production decreases.

Total cost of production for organic farming ($17 billion) are less than for the conventional ($20 billion) for a variety of reasons. The extra cost of chemical fertilizers and pesticides are included in the conventional alternative. Also, for organic farming, there is a more intensive utilization of land in the eastern states, where irrigation costs are not a factor.

Since a complete transformation of U.S. agriculture to organic farming from conventional methods leads to an increase in total value of production and a decrease in total costs of production, net income also is higher. Total net income is $13 billion and $6 billion (1975 Dollars) for the organic and conventional alternatives, respectively.

## CONCLUSIONS

Based on our assumptions, definitions, and analysis, it is concluded that a complete transformation of U.S. agriculture to organic methods would allow the nation to readily produce enough crops for domestic consumption; however, it would also be necessary to reduce U.S. export potential. Net income of the U.S. farm sector would be higher under organic farming because of lower costs of production and higher crop supply prices, but these prices would cause the domestic food supply to be more expensive. The lower level of production with organic farming methods also tends to imply that the nation's productive reserve would be reduced, which could lead to some shortages in years of relatively poor growing conditions either domestically or abroad.

Using net income as a criteria for judging the total gains and losses to each major producing region, the results indicate that only the Southeast and Southern Plains would encounter losses with the adoption of organic farming. Although this study compares both conventional and organic methods, no attempt is made to determine a "best" farming technique for the nation.

Possible extentions of the model and analysis presented here include the following. As more research is completed in the area of organic farming practices, the yield estimates and activities of the linear programming model could be revised to better reflect the full range of improved practices now available to organic farmers. Modifications of the "all-or-nothing" approach taken here could be incorporated into the model to determine an optimal mix of conventional and organic methods. Also, a more explicit incorporation of livestock should be included in future analyses to account for the impacts of changes in regional comparative advantages in crop production on the livestock sector. The modelling framework presented here is flexible enough to allow several other extentions.

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Table 1. Estimated net crop exports for the conventional (I, II) and organic (III, IV, V) farming alternatives compared to actual 1968-70 and 1972-74 average net exports

| Crop | Alternatives | | | | | 1968-70[a] Average | 1972-74[a] Average |
|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | | |
| | (million metric tons) | | | | | | |
| Wheat | 33 | 63 | 16 | 13 | 20 | 17 | 31 |
| Feed Grains[2] | 38 | 67 | 39 | 32 | 48 | 18 | 38 |
| Soybeans | 19 | 41 | 15 | 12 | 18 | 10 | 13 |
| Cotton | 1.11 | 1.36 | 0.89 | 0.73 | 1.10 | 0.66 | 1.04 |

[a]Source: U.S. Department of Agriculture, 1976.

[b]Feed grains includes corn, grain sorghum, oats, and barley.

Table 2. Estimated national average crop yields under conventional (I, II) and organic (III, IV, V) farming alternatives

| Crop | Alternative I | Alternative II | Alternative III | Alternative IV | Alternative V |
|---|---|---|---|---|---|
| | (t/ha) | | | | |
| Wheat | 3.09 | 2.90 | 1.73 | 1.63 | 1.86 |
| Feed Grains[a] | 5.28 | 5.39 | 2.92 | 2.75 | 3.20 |
| Soybeans | 2.78 | 2.71 | 1.81 | 1.67 | 1.94 |
| Cotton | 0.84 | 1.40 | 0.84 | 0.73 | 0.90 |

[a]Feed grains include corn, grain, sorghum, oats, and barley.

ble 3. Estimated area and production of wheat, feed grains, soybeans under conventional (I, II) and organic (III) farming practices by producing region

| oducing Region | Alternative I | | Alternative II | | Alternative III | |
|---|---|---|---|---|---|---|
| | Area | Production | Area | Production | Area | Production |
| | (million hectares, million metric tons) | | | | | |
| | | | **Wheat** | | | |
| rtheast | 0.41 | 1.34 | 0.76 | 2.40 | 0.30 | 0.63 |
| ppalachian | 0.38 | 1.91 | 0.35 | 1.91 | 1.60 | 2.94 |
| otheast | 0.13 | 0.46 | 0.13 | 0.47 | 2.56 | 4.47 |
| ke States | 0.95 | 2.57 | 2.23 | 5.65 | 4.47 | 9.87 |
| rn Belt | 1.20 | 5.45 | 1.16 | 3.94 | 4.38 | 10.72 |
| lta | 0.06 | 0.19 | 0.57 | 1.79 | 0.96 | 1.96 |
| rthern Plains | 5.67 | 15.88 | 12.54 | 26.80 | 14.18 | 19.39 |
| uthern Plains | 2.88 | 9.86 | 4.91 | 15.52 | 2.15 | 3.10 |
| untain | 2.40 | 6.73 | 3.92 | 11.50 | 3.96 | 6.28 |
| cific | 1.66 | 5.53 | 1.62 | 5.44 | 2.31 | 4.52 |
| ited States[a] | 16.13 | 49.91 | 28.20 | 81.78 | 36.85 | 63.86 |
| | | | **Feed Grains[b]** | | | |
| rtheast | 0.48 | 2.34 | 0.68 | 3.26 | 1.08 | 2.72 |
| ppalachian | 1.37 | 5.64 | 1.76 | 8.77 | 0.91 | 2.09 |
| utheast | 0.69 | 2.28 | 1.27 | 4.18 | 0.33 | 0.43 |
| ke States | 3.63 | 16.35 | 4.46 | 20.74 | 4.55 | 14.42 |
| rn Belt | 13.75 | 84.36 | 14.59 | 92.84 | 15.89 | 46.89 |
| lta | 0.21 | 1.26 | 0.26 | 1.70 | 1.82 | 3.49 |
| rthern Plains | 4.32 | 20.56 | 5.38 | 27.58 | 8.87 | 29.48 |
| uthern Plains | 3.46 | 14.38 | 4.22 | 17.24 | 7.73 | 14.74 |
| untain | 1.11 | 4.97 | 1.26 | 5.95 | 2.16 | 5.85 |
| cific | 0.74 | 4.16 | 0.78 | 4.44 | 0.27 | 0.61 |
| ited States[a] | 29.75 | 157.20 | 34.65 | 186.75 | 41.34 | 120.71 |
| | | | **Soybeans** | | | |
| rtheast | 0.08 | 0.13 | 0.08 | 0.13 | 0.00 | 0.00 |
| ppalachian | 0.49 | 1.30 | 1.19 | 3.24 | 0.81 | 1.55 |
| utheast | 0.37 | 0.73 | 1.87 | 3.94 | 0.07 | 0.16 |
| ke States | 0.90 | 1.76 | 1.61 | 3.73 | 0.72 | 1.33 |
| rn Belt | 6.66 | 18.39 | 12.13 | 33.60 | 9.72 | 18.17 |
| lta | 1.56 | 3.20 | 2.62 | 5.36 | 1.31 | 2.19 |
| rthern Plains | 1.03 | 5.31 | 4.88 | 16.43 | 2.00 | 3.09 |
| uthern Plains | 0.38 | 0.84 | 1.01 | 2.29 | 0.00 | 0.00 |
| ited States[a] | 11.39 | 31.65 | 25.39 | 68.72 | 14.63 | 26.48 |

[a]Total may not equal summations over regions because of rounding.

[b]Feed grains include corn, sorghum, oats, and barley, expressed in corn-equivalent its.

Table 4. Comparison of estimated total value, cost of production and net income for the conventional high expor (II) and the organic farming (III) alternatives, by producing region[a]

| Producing Region | Alternative II | | | Alternative III | | | Alternative III | | |
|---|---|---|---|---|---|---|---|---|---|
| | Value of Production | Cost of Production | Net Income | Value of Production | Cost of Production | Net Income | Value of Production | Cost of Production | Net Income |
| | (Billions 1975 Dollars) | | | | | | (Index, Alternative II = 100) | | |
| Northeast | 0.49 | 0.44 | 0.05 | 0.55 | 0.35 | 0.20 | 112 | 79 | 390 |
| Appalachian | 1.33 | 1.02 | 0.31 | 1.12 | 0.75 | 0.37 | 84 | 73 | 118 |
| Southeast | 1.12 | 0.79 | 0.33 | 0.86 | 0.59 | 0.28 | 77 | 74 | 86 |
| Lake States | 2.63 | 1.84 | 0.79 | 3.46 | 1.74 | 1.72 | 132 | 95 | 217 |
| Corn Belt | 9.17 | 7.12 | 2.05 | 10.70 | 5.57 | 5.13 | 117 | 78 | 250 |
| Delta | 0.99 | 0.74 | 0.25 | 1.44 | 0.97 | 0.47 | 145 | 131 | 184 |
| Northern Plains | 5.28 | 4.30 | 0.98 | 6.73 | 3.49 | 3.25 | 127 | 81 | 332 |
| Southern Plains | 3.03 | 1.96 | 1.04 | 2.32 | 1.37 | 0.95 | 76 | 70 | 92 |
| Mountain | 1.27 | 1.04 | 0.32 | 1.56 | 1.15 | 0.41 | 123 | 111 | 128 |
| Pacific | 0.75 | 0.72 | 0.03 | 1.49 | 1.11 | 0.39 | 199 | 153 | 1,481 |
| United States[b] | 26.06 | 19.92 | 6.15 | 30.23 | 17.08 | 13.16 | 116 | 86 | 214 |

[a]Total includes wheat, feed grains, soybeans, and cotton.

[b]U.S. total may not equal column sum because of rounding.