USDA Natural Resources Conservation Service
U.S. DEPARTMENT OF AGRICULTURE

Reduction in Annual Fuel Use from Conservation Tillage

Conservation Effects Assessment Project (CEAP)
Conservation Insight

Background

Conservation tillage, meaning at least one of a field's rotated crops is produced with reduced tillage, is one of the most widely adopted conservation practices in the United States. The CEAP II survey of farmers from 2013 through 2016 indicates that nearly 87 percent of the Nation's cultivated cropland acres use some form of conservation tillage for at least one crop in the crop rotation. In addition to the more commonly recognized environmental benefit of reduced soil disturbance, conservation tillage significantly reduces fuel consumption and therefore emissions from operations. Compared to a scenario where all cropland fields are managed using continuous conventional tillage, this widespread adoption of conservation tillage has resulted in:

- Potential fuel use has been reduced by 763 million gallons of diesel equivalents annually, roughly the amount of energy used annually by 2.8 million average households.
- Potential emissions have been reduced by 8.5 million tons of CO_2 equivalents annually, enough to offset the annual CO_2 emissions of nearly 1.7 million passenger cars.
- Continuous no-till has been adopted on 33 percent of acres and accounts for 48 percent of the reductions in fuel use and emissions.
- North Central and Midwest, Northern Plains, and Southern and Central Plains Production Regions account for 80 percent of the fuel and emission reductions.

The Soil Tillage Intensity Rating (STIR) was used to calculate the soil disturbance intensity for each crop grown in each of the previous 3 years of management at each sample point of the NRI-CEAP-Cropland farmer survey period (2013–16). STIR is a function of the kinds, frequency, and depths of tillage. Tillage management and conservation tillage adoption was assessed on a crop-by-crop basis for each cropping system. Management of each crop was classified according to the average annual STIR values for the implements used to produce the crop. For each implement used, fuel consumption was estimated assuming the same moisture conditions, recommended speed, and tractor horsepower. The fuel use in diesel equivalents was averaged for the rotation within each tillage classification. The fuel consumption requirements for each implement used were based on a standard developed by the Nebraska Tractor Test Laboratory (NTTL) and available at: tractortestlab.unl.edu/nebraskatractortestlabpublications and through ASAE (ASAE Standards, 2002a, 2002b). Emission reductions from fuel savings are based on the U.S. Department of Energy (DOE) Energy Information Administration's estimate that a gallon of diesel fuel emits the equivalent of 22.4 pounds of CO_2 emissions (eia.gov/tools/faqs/faq.cfm?id=307&t=11).

No-till soybeans in stubble.
Photo by Creston Shrum, USDA.

Derivation of Estimates

First, a subset of nearly 12,000 (about 7 percent) National Resources Inventory (NRI) sample points was selected to serve as "representative fields." These NRI sample points, which are located on cultivated cropland, provide the statistical framework for the model and information on soils, climate, and topography. The link to NRI's statistical framework methodology is provided in the reference section. The survey was designed to have statistical accuracy at the U.S. Geological Survey's four-digit hydrologic unit (HUC4) for the majority of HUC4 basins that contain cultivated cropland in the United States.

Second, USDA developed and implemented CEAP-Cropland Farmer Surveys to collect the information needed at the selected NRI sample points to run field-level process models and assess the effects of conservation practices. The farmer surveys are conducted by the National Agricultural Statistics Service (NASS), which interviews cooperating farmers to obtain accurate information on farming practices (crops grown, tillage practices used, nutrient and pesticide application made, and conservation practices used, etc.). A link to the NASS survey methodology and statistical framework is provided in the reference section.

From this dataset the tillage implement type and frequency of use for each crop grown in rotation at each statistically weighted survey point was determined. The STIR rating for each crop in a rotation was calculated by summing the STIR ratings for each implement used and the number of times it was used for that crop. Table 1 contains a subset of the over 350 different field operation implements collected by the farmer surveys. For example, if a farmer growing a crop uses a subsoiler followed by a tandem disk prior to planting with a conventional planter, and then cultivates the field twice before the canopy closes, and then uses a moldboard plow and tandem disk after harvest to incorporate crop residue, those implements (using the values specified in table 1) would produce a STIR rating of 55+53+2+22+22+87+53 = 294 and use an estimated 2.1+0.45+0.44+0.74+0.74+1.87+0.45 = 6.79 gallons of diesel equivalents per acre per year. Another operator, using only a no-till planter for the same crop, would produce a STIR of around 2 and a fuel use of just 0.35 gallons per acre. For this fuel reduction comparison, the fuel use of common actions for tillage systems, such as fertilizer and pesticide applications and harvest, were identical and therefore not listed.

The STIR values for each crop in a crop rotation were used to determine to which tillage consistency class the survey point and its weighted acres belong (the classification definitions are provided on the next page); the national weighted average for each tillage classification is presented in Table 2. Fuel savings and emission reductions by tillage classification (see table below and maps on next two pages) were determined by subtracting the mean of the reduced tillage class from the fuel use of continuously conventionally tilled crop rotations and then multiplying by the acres of the specific tillage type. For example, table 2 estimates for fuel savings and emissions reductions from seasonal conventional were calculated as follows: Continuous Conventional 5.4 gallons minus Seasonal Conventional 3.6 gallons = 1.8 gallons x 62.7 million acres = 113 million gallons saved and 1.3 million tons fewer CO_2 equivalents emitted. Emission estimates (see table below and map on the last page) were developed by multiplying the reduction in fuel use by 22.4 pounds of CO_2 equivalents per gallon of diesel equivalents saved.

Tilling disturbs soil and is time consuming and expensive. During the process, tractors burn fuel and emit carbon dioxide (CO_2) and other greenhouse gases and pollutants. Conservation tillage used in 2013–2016 is estimated to have saved the CO_2 equivalent emissions of nearly 1.7 million cars. USDA Photo.

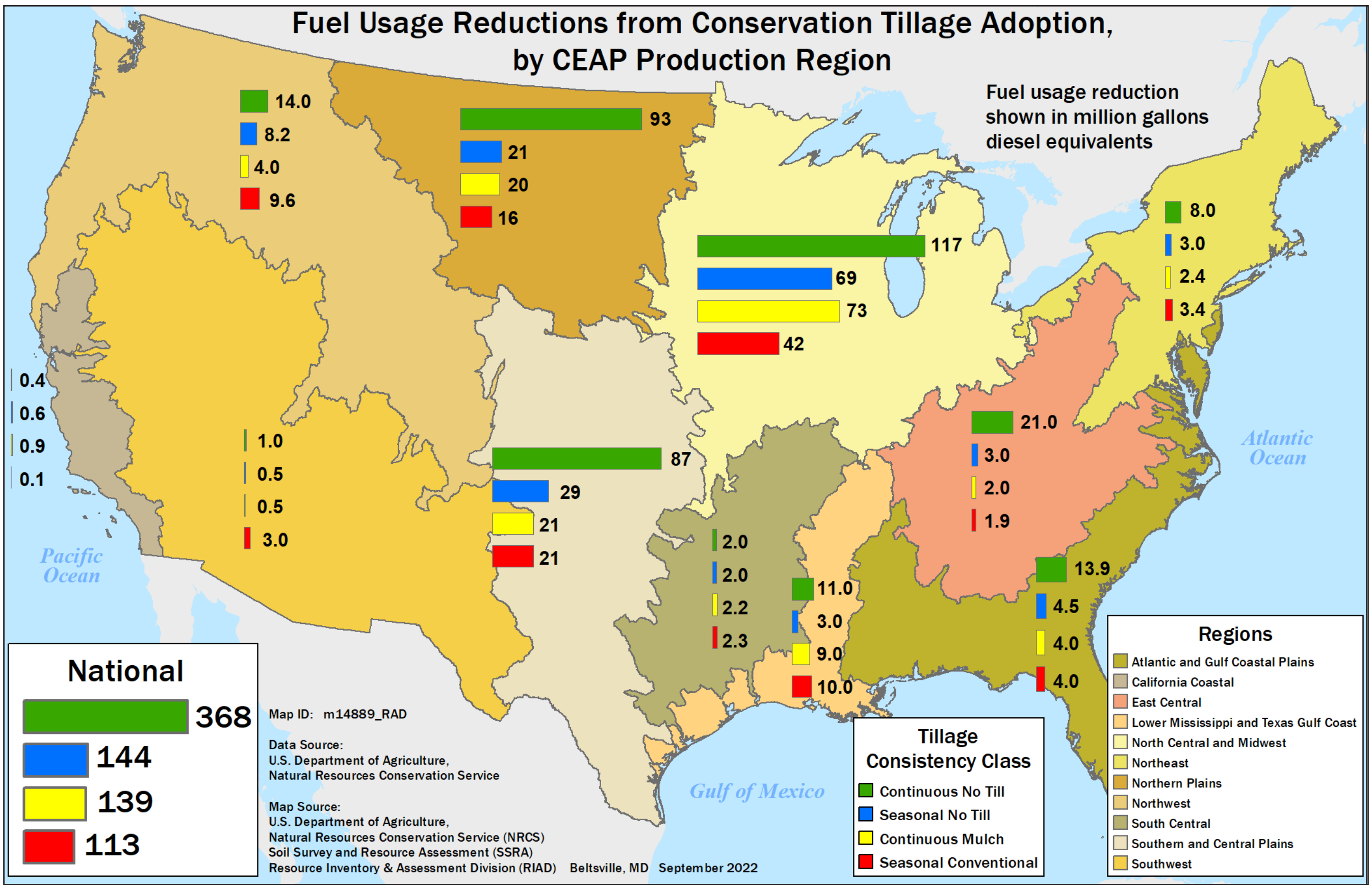
Table 1. STIR rating and estimated fuel-use requirements resulting from the use of selected implements.

Implement	STIR	Fuel Use, in Diesel Equivalents (gallons/acre)
Drill-No-till, Minimum till	2	0.35
Conventional, Regular planter	2	0.44
Field Cultivator	22	0.74
Tandem Disk-Regular	53	0.45
Deep Ripper	55	2.1
Subsoiler	55	2.1
Chisel Plow	78	1.1
Moldboard-Regular	87	1.87

Table 2. **Estimated reductions in fuel use and emissions from adoption of conservation tillage.**

Tillage Type	Average Fuel Use/ Acre* (Gallons)	Fuel Use Reduction (Million gallons in Diesel Equivalents)	Emission Reductions, in CO_2 Equivalents (U.S. tons)	Acres	% of Acres
Continuous Conventional	5.4	--	--	42,052,416	13%
Seasonal Conventional	3.6	113	1,265,600	62,718,841	20%
Continuous Mulch	3.1	139	1,556,800	60,212,092	19%
Seasonal No-Till	2.4	144	1,597,128	47,211,285	15%
Continuous No-Till	1.8	368	4,132,800	103,108,466	33%
Total	--	**763**	**8,552,328**	**315,303,100**	**100%**

*Average fuel use per acre does not include all field activities, such as harvest and spraying, which occur in both conservation till and conventional till.



Tillage Consistency Classification

Continuous Conventional Tillage:
All crops in the rotation are conventionally tilled (STIR >80).

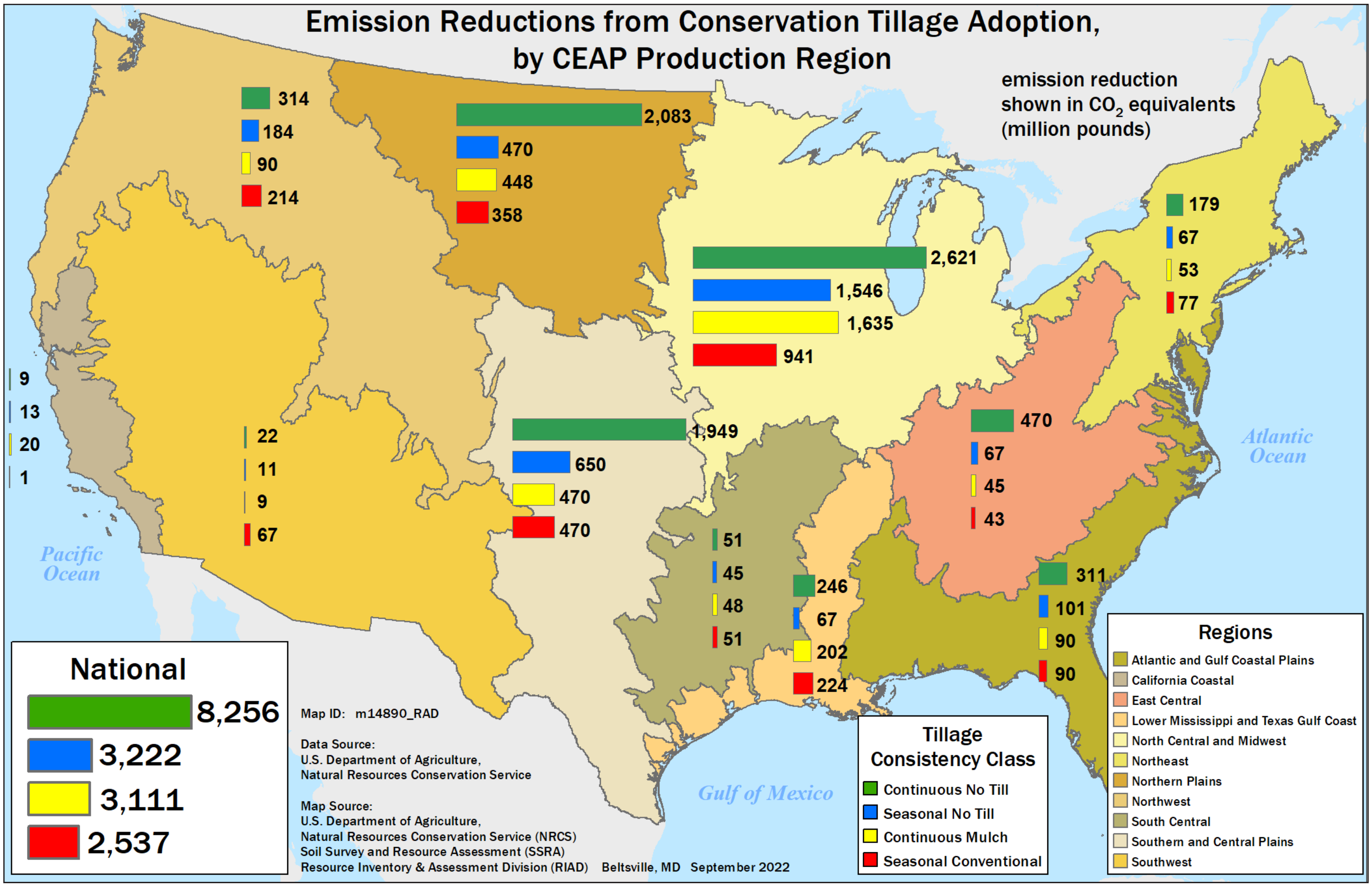
Seasonal Conventional Tillage:
At least one crop in the rotation is conventionally tilled (STIR>80) and at least one crop is conservation tilled (STIR<80).

Continuous Mulch Tillage:
All crops in the rotation are produced under tillage with STIR values for each crop between 20 and 80.

Seasonal No-till:
At least one crop is produced with no-till (STIR <20) and no crop in the rotation is conventionally tilled (STIR>80).

Continuous No-till:
All crops in rotation are produced with practices having STIR values <20.

Corn planted into no-till corn residue. USDA Photo



References

ASAE Standards, 49th Ed. 2002a. EP496.2. Agricultural machinery management. St. Joseph, Michigan. ASAE Standards, 49th Ed. 2002b. D497.4 JAN98. Agricultural machinery management data. St. Joseph, Michigan.

STIR: Soil Tillage Intensity Rating: https://www.nrcs.usda.gov/sites/default/files/2022-11/CEAP-Croplands-2008-Methodology-SoilTillageIntensityRating.pdf

Statistical Methodology for the NRI-CEAP Cropland Survey: https://www.nrcs.usda.gov/sites/default/files/2022-11/CEAP-Croplands-2021-Methodology-NationalFarmerSurveys.pdf

NASS Survey Information: https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Conservation_Effects_Assessment_Project/index.php