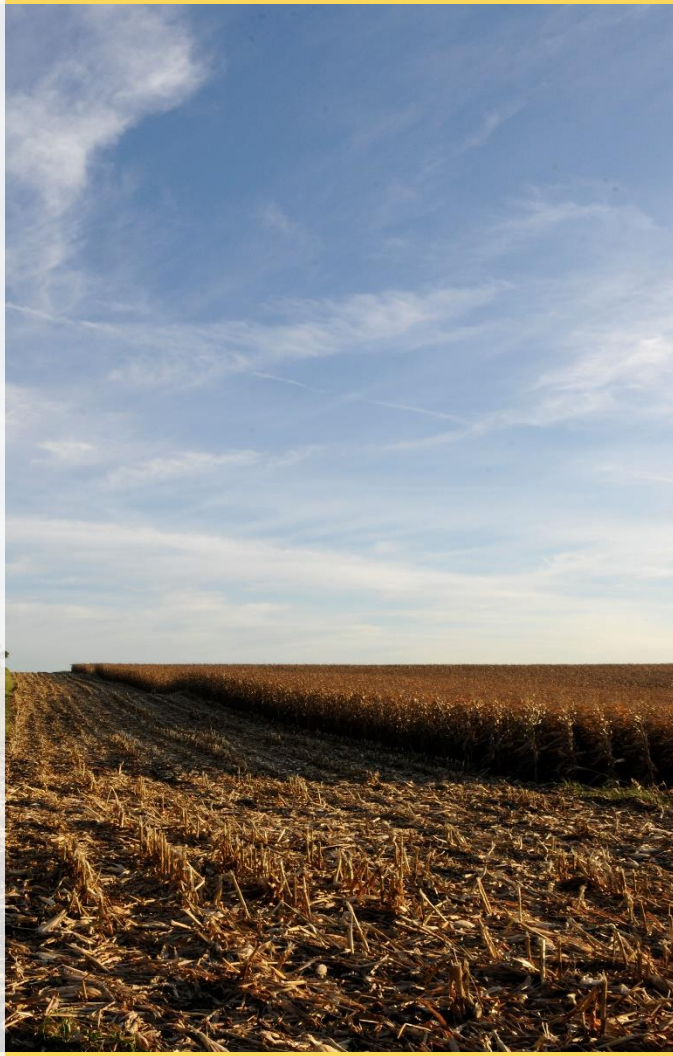
SOIL SOLUTIONS

Climate-Smart Farming in the Show Me State



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SUMMARY

Agriculture is vital to the state of Missouri. Between its anchor cities of St. Louis to the east and Kansas City to the west, the Show Me State is home to 100,000 farms, nearly all of them owned by individuals and families. In 2016, Missouri agriculture, forestry and related industries put nearly 400,000 people to work and contributed more than $88 billion to the economy.[1]

Farming has never been an easy business. With the increase in extreme weather events powered by a warming planet the challenges facing today's farmers are even greater than they have been in the past. Data from the state climatologist show that since the 1950s, there has been an upward trend in the number of downpours with at least three inches of rain in one storm.[2] These more frequent heavy rains and subsequent floods contribute to eroding the very foundation that agriculture relies upon — the soil. Coming out of the 1930s Dustbowl, Missouri was losing topsoil faster than any state in the nation,[3] and by one estimate,[4] Missouri has lost half of its topsoil in the past century.

But through conservation practices, Missouri's farmers are finding ways to battle erosion and benefit the soil. Missouri has saved more than 177 million tons of soil in the past 30 years and currently boasts the highest rate of reduction in soil erosion of any state having more than 10 million acres of cultivated cropland.[3] Many of the conservation practices also lead to soil storage of carbon, thereby helping to reduce the carbon pollution that is accelerating the worsening extreme weather events. Instead of fueling damaging climate change, the carbon enriches the soil.

This report analyzes the extent to which use of conservation farming practices — ones that are well known, but not always widely applied — can reduce carbon pollution and yield carbon savings in Missouri. We examine the potential benefits of various individual conservation farming practices, and we also look at total potential savings county-by-county if practices were to be adopted statewide.

Findings in this report include:

- The potential to save carbon by applying individual conservation practices in Missouri is significant.
    - Using cover crops like ryegrass or clover on post-harvest fields could offset more than the estimated annual carbon pollution from all cars belonging to residents of the cities of St. Louis and Kansas City, Missouri, combined.
    - Switching from conventional- to no-till farming would annually save six times the carbon pollution from the energy used by all households in Jefferson City, Missouri's capital city.
    - Modifying the way nitrogen fertilizer is used could avoid nearly half-a-million tons of air pollution that causes climate change, or the equivalent savings provided each year by 115 wind turbine electricity generators.
    - Practicing rotational grazing could offset the annual carbon pollution generated by more than 400,000 cars.
- The above estimates are technical potentials made assuming 100 percent adoption rates that would typically not be achieved in practice. Moreover, the above estimates cannot be simply added together to estimate the technical potential of applying multiple practices, as that would involve some double counting. But when considering realistic adoption rates and correcting for double counting, the estimated total annual carbon storage potential for the state as a whole is equivalent to more than twice the annual total of climate change causing air pollution released by the city of Columbia, home to the University of Missouri, the state's flagship land-grant university.
- At the county level, New Madrid shows the highest potential for carbon savings. The county is in the southeast "Bootheel" region. The five counties with the highest potential carbon savings are in or adjacent to the Bootheel.

Some farmers in Missouri already are putting conservation farming into practice and offsetting emissions. Although agricultural activity is the fifth largest source of greenhouse gas emissions in the United States[5], opportunities exist for the sector to take carbon out of the atmosphere and sequester it in the soil. Farmers and ranchers in Missouri are demonstrating that conservation practices provide a win-win-win outcome, improving soil health, financial health and overall health of the planet.

Photo: Bill Hankins

There can be no life without soil and no soil without life.
Charles E. Kellogg, USDA Yearbook of Agriculture, 1938

SHOW ME THE CLIMATE

Agriculture, weather and climate are inextricable. From the extreme drought of the Dust Bowl in the 1930s to the record rains in parts of Missouri last year, and the countless heat waves in between, farmers have always had to deal with fickle Missouri weather. Just this year, an unusually frigid March and April delayed spring planting. But digging into the data, we see patterns to the erratic precipitation and temperature whiplashes. Extreme weather events are coming more frequently and often are more severe. These extremes of temperature and precipitation — too much or too little — can damage or decimate crops. Examining trends in temperature and precipitation data can help make sense of the risks that a changing climate poses for Missouri's farmers.

Fig 1

Located in the center of the United States, Missouri has a continental climate: cold winters, hot summers and transitional weather during spring and fall. Without mountains or oceans nearby to moderate temperatures, the summer highs can reach three digits. Temperatures above 100°F occur in every region of the state. In the winter, the temperatures occasionally dip below 0°F. It rains or snows an average of about 100 days a year.[2]

The heat is on

Since the beginning of the 20th century, temperatures in Missouri have risen approximately 0.5°F.[6] In recent decades, this warming has been accelerating across the state. The Missouri Climate Center found that 15 out of the past 20 years have had temperatures above the 30-year normal, with 2012 as the hottest year on record for the state.[2]

Temperatures will continue to rise as the climate changes due to greenhouse gas emissions, which trap heat in the atmosphere. And the number of miserably hot days in Missouri is projected to soar. For example, Kansas City averaged nine days above 95°F annually between 1990 and 2010. By 2060, that number is projected to increase to 50 days above 95°F each year. And by the end of the century, a quarter of all days are expected to be above 95°F.[7]

Extreme heat affects the state's cattle and commodity crops. University of Missouri Extension researchers found that at temperatures above 80°F cattle eat less, which can consequently limit their weight gain. Above 90°F, milk production from dairy cows can decrease between three and 20 percent.[8]

Temperatures in the 90s and above can damage soybeans, corn and other Missouri crops, resulting in reduced yields. And it's not just the extreme daytime highs that can harm crops. High nighttime temperatures can affect pollination and the respiration process, which may cut yields dramatically. Overnight lows in the summer months in the state are increasing, and at a rate higher than daytime highs.

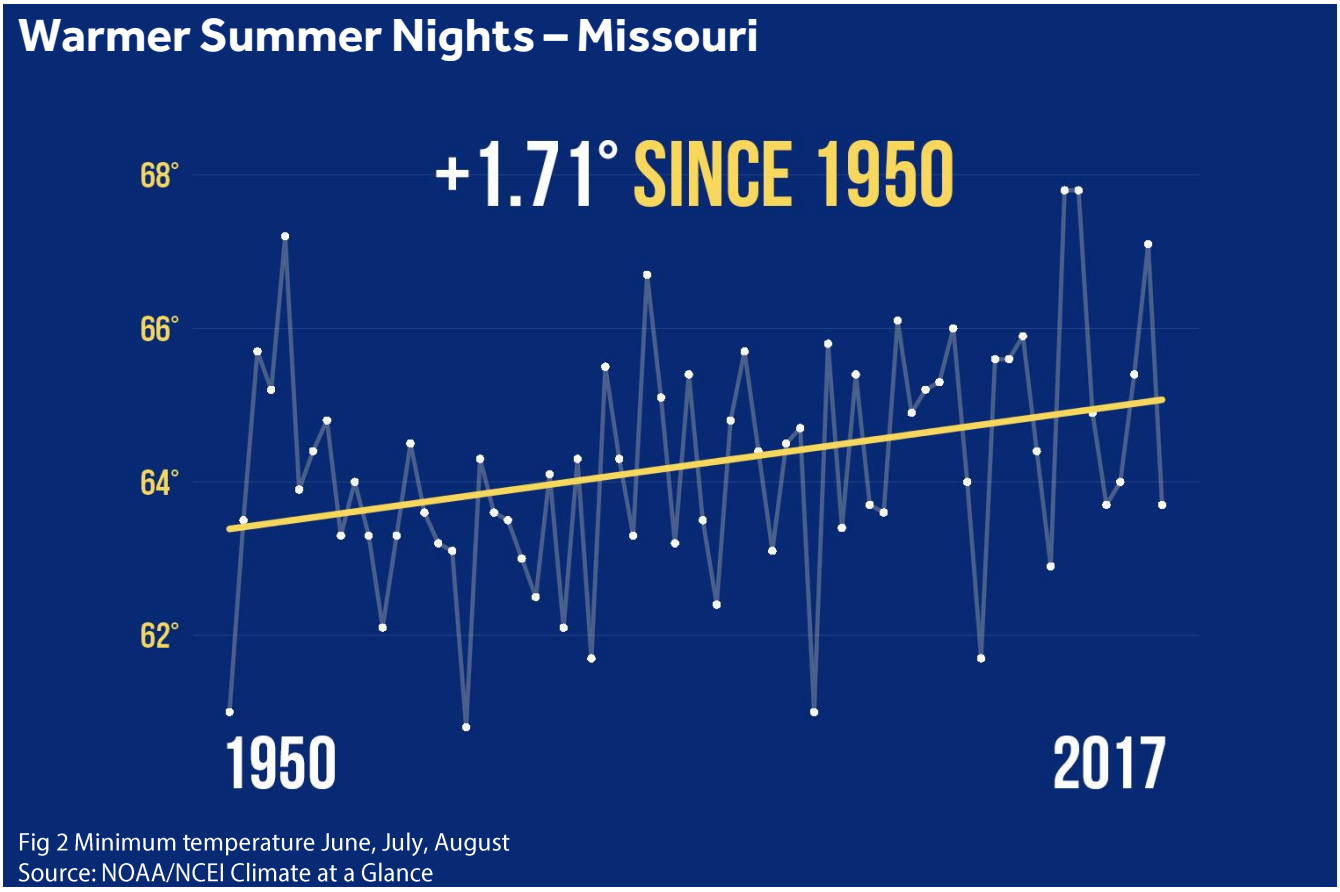

Fig 2 Minimum temperature June, July, August
Source: NOAA/NCEI Climate at a Glance

When it rains it pours

Missouri is no stranger to downpours. On June 22, 1947, heavy rains pummeled Holt, dumping a foot of water on the small northwestern Missouri town in just 42 minutes and setting a world record for rainfall intensity. And while no one place has ever again experienced so much rain in so little time, the overall trend in Missouri for the number of days with heavy downpours has increased dramatically since the deluge in Holt.

More Heavy Downpours

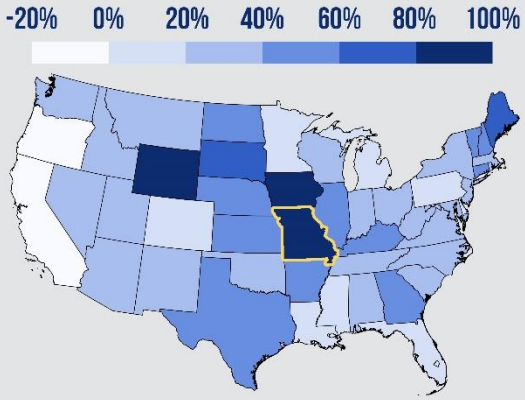

Fig 3 Percent change in top 1% of events between 1950-1959 and 2007-2016
Source: Applied Climate Information System (rcc-acis.org)

Changes in Frequency of Heaviest MO Downpours

Fig 4 Heaviest downpours defined as top 1% of events. Shown as departure from 1950-2017 average
Each bar represents a 5-year average except for the last three which show the average for 2015, 2016 and 2017
Source: Applied Climate Information System (rcc-acis.org)

Heavier precipitation is a signature of a changing climate. For every 1°F of temperature increase, the atmosphere can hold four percent more water vapor. So as the world warms from the increase in greenhouse gases, the amount of evaporation also increases from oceans, lakes, rivers and soils. The extra water vapor is available to produce additional precipitation, creating an environment ripe for heavy rainfall events. For Missouri, projections are for continued increases in heavy precipitation during the winter and spring. Future increases in winter precipitation will in particular contribute to increased flooding along rivers and streams.

Extreme rainfall in the spring and summer can have negative effects on agriculture, both in the longer term by washing away valuable topsoil, and in the shorter term by delaying planting in a given year. University of Missouri Extension researchers estimate a yield drop of one bushel per acre of soybeans for every week that planting is delayed in June and three times that if delayed into July.[9]

Hot and dry

Although Missouri is experiencing more heavy rainfall days on average, overall seasonal and annual rainfall is not increasing across the state. During the summer, the agriculturally intensive Bootheel region has experienced less rain over the past 50 years, while northern regions have experienced an increase in total rainfall.[10]

When low precipitation levels are sustained, particularly when combined with high temperatures, the result is drought. Missouri, like much of the Midwest, suffered through a rapidly developed and crippling flash drought in 2012.[11] Sunny, abnormally hot days in May and June, paired with below-normal humidity, triggered high evaporation loss from the soil, plants and water sources. This, in combination with little or no spring rain, left the Show Me State with the worst drought in a generation.[12]

A global changing climate is expected to produce warmer droughts that last longer and happen more often.[13]

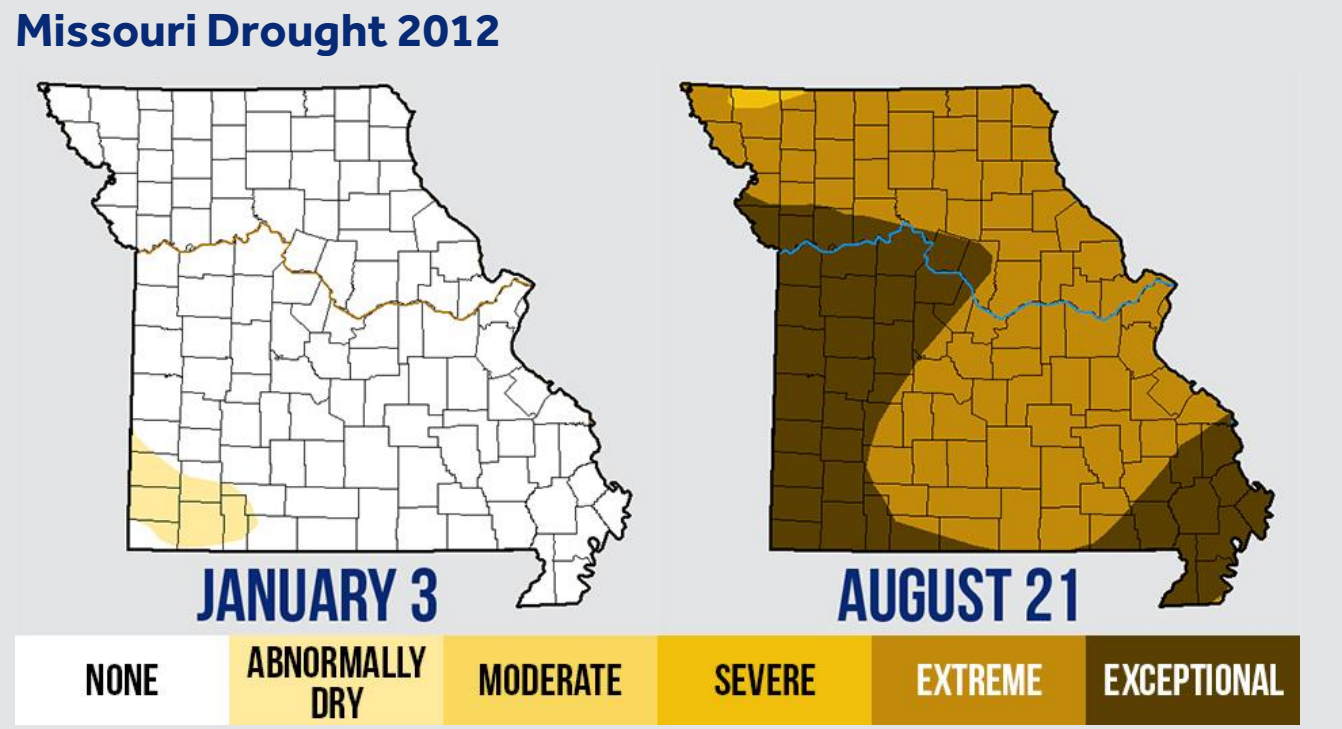

Fig 5
Source: US Drought Monitor

During the 2012 drought farm income was reduced in Missouri by more than $1 billion initially and then by an additional $700 million in 2013 from impacts to both crops and livestock.[14]

Temperature and precipitation extremes generally reduce crop yields, although the overall impact may be partly offset as higher carbon dioxide concentrations can stimulate plant growth in some species. If current climate change trends continue, by the end of the century, 95 of Missouri's 115 counties are projected to see at least a 20-percent reduction in average crop yields of maize, wheat, soybeans and cotton from today. Ten counties are projected to have yield reductions of nearly 50 percent.[15]

HEALTHY SOIL, CARBON SINK

In addition to directly reducing livestock and crop yields, more extreme weather events affect the soil, which itself is vital to agricultural productivity. Extreme heat dries out the soil; heavy rains can wash it and its nutrients away. But farmers can fight back. They can build healthier soils more resilient to weather extremes through the use of conservation farming practices that leave the soil largely intact and promote biodiversity. These practices help improve the soil's nutrients and its moisture-retention capacity, with the potential to increase yields. And many conservation farming methods have the added benefit of being climate-smart: they pull carbon dioxide — the gas that's helping fuel the increase in weather extremes — from the atmosphere and then convert the gas to soil carbon and store it in the ground. Sequestering carbon is not only good for the health of the soil, but for the health the planet, too. Healthy soil and carbon savings could benefit farmers' balance sheets as well, by generating revenues from increased crop yields and potentially from carbon offsets.

Photo: Felipe Castro

Carbon: A New Cash Crop?

In addition to corn, soybeans and rice, some farmers can get paid now to "grow" carbon for a small but expanding carbon market. Crop and livestock farmers can earn carbon credits by using conservation practices that sequester carbon in the soil or that reduce carbon emissions. A broker buys the credits from the farmers and then sells the credits to organizations or individuals who wish to offset some or all of their carbon emissions.

It's a simple concept, but not without challenges. Measuring, verifying and reporting the amount of carbon stored in the soil or of avoided emissions can be complicated and costly. And when it comes to customers seeking credits, much of the market is voluntary. The United States still has no federal mandate to require reductions or offsets of carbon emissions. Still, California and some countries are developing protocols and creating demand for carbon credits through carbon pricing programs. That demand could provide a new stream of revenue for farmers looking to improve the health of both their soil and their balance sheets.

Conservation Practices

The USDA Natural Resources Conservation Service (NRCS) promotes many conservation practices[16] and a number of these are listed in Table 1. Conservation practices are proven techniques, some of which are already employed to some extent in Missouri.

Without the benefit of conservation farming, cropland soils are generally depleted in carbon relative to their original (pre-agriculture) state.[17] Those that have been farmed long term typically have lost a third to half of the carbon originally found in the top 12-inch layer of soil. Grazing lands that are heavily grazed are also likely to have significantly depleted soil carbon.[18] Fortunately, conservation farming methods can help return soil to its natural, carbon-rich state. Many of these methods involve less use of diesel-fueled machinery and thus further reduce carbon emissions.

Potential Carbon Storage by Conservation Practice

Practice		Increases soil carbon content	Reduces GHG emissions
Croplands			
Modified Tillage	No till	●	●
	Conservation tillage	●	●
Modified Crop Rotaton	Conservation cropping rotations	●	
	Cover cropping	●	
	Stripcropping	●	
Improved Nutrient Management	Change rate/timing of fertilizer application		●
	Mulching	●	
	Replace synthetic N with organic amendments	●	●
Conservation Cover	Cropland conversion to perennial grasses	●	●
Grazing Lands			
	Prescribed grazing	●	
	Rangeland planting	●	

Table 1. Conservation practices that can increase carbon in soils and/or limit agriculture-related emissions

Healthy Soil: A Definition

Soil health, also referred to as soil quality, is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans. This definition speaks to the importance of managing soils so they are sustainable for future generations. To do this, we need to remember that soil contains living organisms that when provided the basic necessities of life — food, shelter, and water — perform functions required to produce food and fiber.[19] USDA Natural Resources Conservation Service

CROPLANDS

Modified tilling

Farmers use tractors and other mechanized tools to plow, or till, their fields in preparation for planting. This practice helps control weeds and can help incorporate manure or plant residues into the soil. But tilling has its disadvantages. Disturbing the soil makes it more vulnerable to erosion. No-till farming reduces soil erosion as much as 90 percent compared to conventional tilling.

Additionally, no-till or reduced-till farming can allow carbon in harvest residues to be absorbed into the soil. In contrast, tilling exposes carbon that was below the surface to the air and converts it to carbon dioxide in the atmosphere.

Modified crop rotations

Conservation crop rotations use a planned sequence of growing different crops on the same land. These practices can improve productivity of the land, provide feed and forage for livestock, and food and cover habitat for wildlife. They typically reduce soil erosion and increase soil health by building up carbon in the soil. Conservation rotation can include cover cropping, a practice where farmers plant grasses, legumes or herbaceous flowering plants called forbs, as seasonal ground cover, generally after a harvest. Conservation rotation practices also can include stripcropping. This involves growing planned rotations of row crops, forages, small grains or fallow in a systematic arrangement of strips across a field.

Improved nitrogen management

Nitrogen is a key added nutrient for productive agriculture, and is a principal ingredient in fertilizer. But some of the nitrogen applied to the soil as fertilizer is unavoidably converted into nitrous oxide, a potent greenhouse gas that is nearly 300 times more effective in trapping heat than is carbon dioxide. Nitrous oxide emissions can be reduced with different nitrogen management strategies, for example, incorporating nitrogen stabilizers, not over fertilizing, or shifting the timing and placement of fertilizer applications.

Full or partial replacement of synthetic nitrogen fertilizers with organic fertilizers is not practical today for a number of reasons. However, when organic material like manure is applied to the land as a fertilizer, or crop residue is left in the field after combining, soil carbon content typically increases and nitrogen, potassium and phosphorus are returned to the soil.

Conservation cover

Conservation set-asides, where fragile/marginal lands or lands susceptible to flooding are taken out of production and planted with perennial grasses, provide multiple ecosystem services. These include reducing soil erosion, improving water and air quality, enhancing wildlife habitat, protecting crops from wind damage, stabilizing steep slopes, and reducing sediment and contaminants in runoff. Significant carbon build up in the soil can also result.

PROFILE: Richard Oswald

Like most farmers in Missouri, Richard Oswald's roots in agriculture run deep. He's a fifth-generation farmer, growing corn and soybeans on 2000 acres tucked away in the northwestern corner of the state. The 68-year-old Oswald prefers to leave the soil on his fields mainly intact. "I don't like to till; I don't like to disturb the soil," says Oswald. "That leaves the soil better in a lot of ways."

Oswald uses a campfire analogy when describing till and no-till methods. "Stirring up the soil is like poking the coals. Oxygen gets to the fire and burns up the fuel faster, " says Oswald. "No-till is like banking the fire; it cushions and protects, and it holds the carbon for a longer time." And carbon is good for the soil.

Few of his neighbors have adopted no-till practices, according to Oswald. North Dakota researchers in the middle of an eight-year study say while many farmers try no-till or reduced-till practices, fewer stick with the conservation farming methods. Researchers say there can be a significant learning curve to no-till, along with a five- to 10-year transition period before the ecosystems adjust to no-till methods.

Oswald is long past the transition phase. He's been no-till farming for more than three decades.

Photo: Richard Oswald

GRAZING LANDS

Conservation practices on grazing lands provide improved and sustainable forage, better soil and water quality, reduced erosion, more shade for livestock, increased cover for wildlife, reduced fire hazards and carbon storage in biomass and soils.

Prescribed grazing, also called rotational or managed grazing, is a management system in which livestock are rotated to different paddocks or pastures to prevent overgrazing and to encourage grass growth. The practice includes built-in manure and nutrient management.

Rangeland planting involves re-establishing vegetation where natural reseeding does not result in desirable levels of vegetation for grazing, or where implementing prescribed grazing to improve vegetation is not possible.

The potential for carbon sequestration with pasture and grazing management improvements is especially high in grazing lands that have been degraded due to long-term overgrazing.

Profile: Felipe Castro

When it comes to raising cattle the past 14 years, Felipe Castro says, "I've tried everything."

The 38-year-old Colombia, South America native runs about 115 head of beef cattle on nearly 300 acres just outside of Holden, Missouri, a town an hour's drive southeast of Kansas City. Castro has experimented with a variety of ways to keep his cows and fields healthy, and his business in the black. He admits that it's not easy. "I guess you could say the grass always seems greener in the other fields," Castro laughs.

Castro has studied grazing methods used around the country, and in Africa and New Zealand. He's settled on a practice he calls "seasonal intensive grazing." He rotates his cattle among 10 different paddocks, moving the herd every four days when the grass is eaten to about a foot high. He supplements with hay when necessary.

The livestock farmer is particularly happy when his cattle consume the abundant ragweed in his fields. The weeds cost nothing and are full of protein. But perhaps best of all, at least for Castro, the cattle serve as a natural suppressant. Castro admits to being allergic to the hardy weed.

Photo: Felipe Castro

CROPS & GRAZING

Profile: Ethan Miller

Ethan Miller farms with his family in the counties of Audrain, Boone and Callaway in central Missouri. The diverse operation includes row crops, hay and livestock. The Millers implement crop rotation, no-till, and occasionally cover crops in their cropping system. "On the home farm, where we keep cattle on part of the property and the crop acres are fenced, grazing of residues, red clover and cover crops provides a biological boost to the soil and decreases the need for stored winter feed," says Miller.

The family also raises beef cattle and hair sheep. Rotational grazing among paddocks on the farms' pasturelands allows for more forage production of a higher quality and has helped the pastures become more resilient to erosion and drought effects. Grazing multiple species increases utilization beyond what a single species of livestock would normally consume, diversifies the enterprise and helps control parasites.

The family believes in doing more than maintaining the land and resources they manage. "We're working to continue improving the land so it can provide for many more generations who want to farm," says Miller. He adds that the benefits of the practices the family utilizes are helping to accomplish their goals by improving the soil's health, increasing carbon content, sequestering nutrients and improving the forage base. This in turn helps improve water and air quality, which benefits everyone.

Photo: Ethan Miller

Show Me the Savings

Individual Conservation Practices

Conservation farming practices help build healthy, resilient soil, and give farmers a tool to help manage the more-intense weather extremes that occur more frequently with our changing climate. These climate-smart farming methods also aid in carbon sequestration, removing some of the excess carbon dioxide from the atmosphere and trapping the soil-enriching carbon in the ground.

But can we put a number on how much potential carbon savings individual conservation farming practices in Missouri may produce?

Yes. This report estimates the technical potential for annual soil-carbon build up and, if applicable, the reduced carbon emissions from farming with adoption of NRCS conservation practices in Missouri. These results are based on estimates of annual per-acre soil-carbon build-up rates or per-acre carbon emissions reduction rates (Figure 6) when applying individual practices.[20] Such rates are useful for making preliminary estimates of greenhouse gas impacts of modified farming practices in the state as a whole, but more precise farm-level estimates can be made when detailed farm-specific information is available.[21] Note that if two or more practices are applied on the same acre, these estimates cannot be added to estimate the carbon impact. That would involve some double counting.

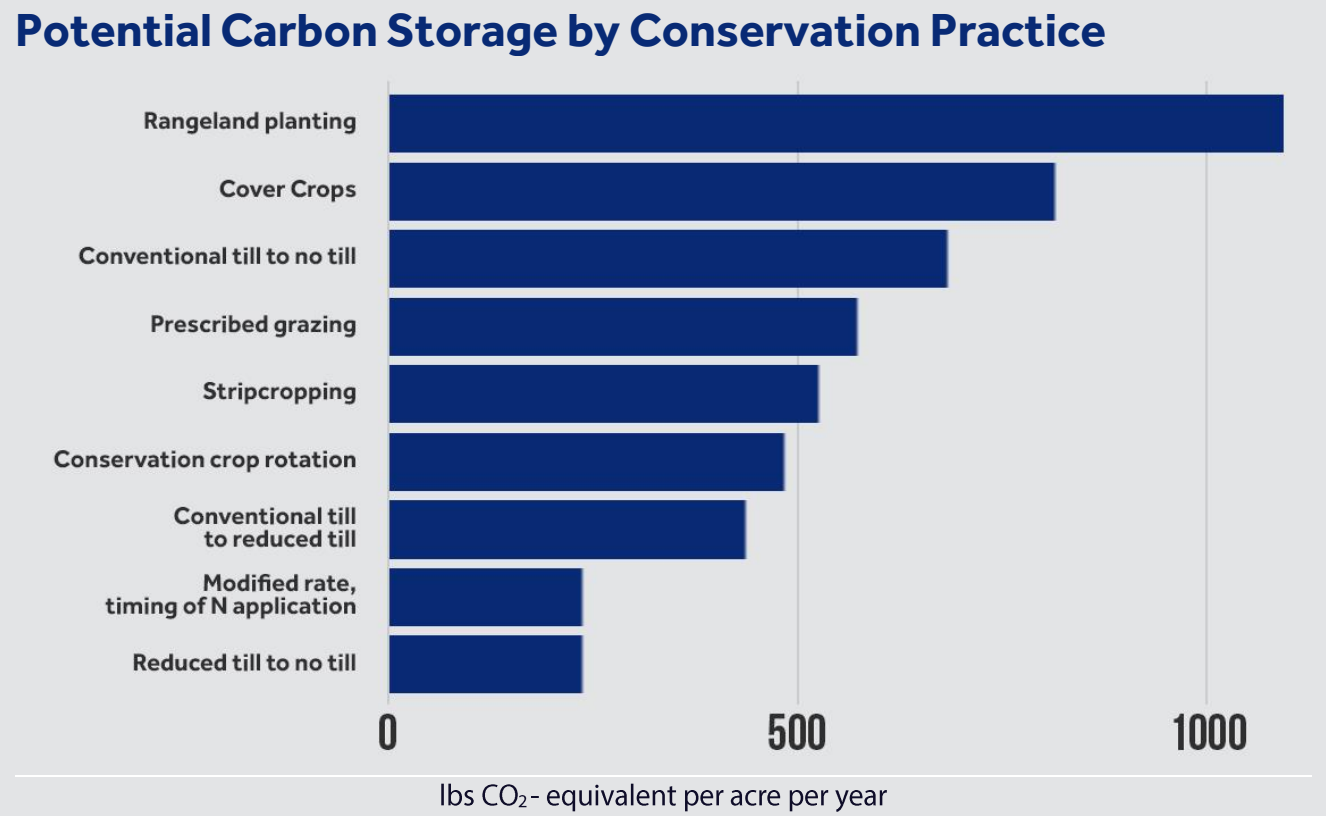

Fig 6 – Potential carbon storage or emissions reductions by conservation practice
Source: COMET-Planner[20]

For statewide adoption of a given conservation practice, the potential total annual carbon savings (expressed as carbon dioxide equivalents per year, or CO_2e/yr) is calculated by multiplying the practice-specific rate shown in Figure 6 and the estimated maximum number of acres for which that practice is deemed technically possible. This calculation assumes 100 percent adoption by farmers, which is unrealistic for some of the practices, but nevertheless is helpful in understanding quantitatively the potential carbon savings in Missouri agriculture. Appendix 1 describes how we estimated the maximum

number of acres statewide where a given practice is possible. Table 2 shows our estimates of carbon savings potential by individual conservation practices shown in Table 1, if these were applied on the maximum number of acres with 100 percent adoption. These savings reflect the quantity of carbon stored in the soil as a result of the practice and/or reduced agriculture-related greenhouse gas emissions to the atmosphere.

Theoretical technical potentials for carbon storage in Missouri

NRCS Conservation Practice Standard (CPS)	Soil carbon storage per acre [i, ii] (lbs CO2e/acre/yr)	Maximum acres potentially available for a conservation practice [i, iii] (Millions of acres)	Theoretical technical potential for carbon storage or removal from atmosphere [i, ii] (Million short tons CO2e/yr)
Rangeland planting	1,100	8.08	3.89
Cover crops	815	8.864	3.28
Prescribed grazing	570	8.08	2.02
Stripcropping	530	5.109	1.35
Conventional till to no till	680	3.14	1.07
Conventional till to reduced till	440	3.14	0.69
Modified rate, timing of N application	240	3.691	0.45
Reduced till to no till	240	2.707	0.33
Conservation crop rotation	485	1.184	0.29

[i] Estimated technical potential
[ii] Estimates are for CO2 equivalents (CO2e), which accounts for the global warming impacts of changes in emissions of not only CO2, but also methane and nitrous oxide emissions.
[iii] See appendix for assumptions and data sources used to estimate this maximum area amenable to each practice. For these calculations, 100 percent adoption is assumed across the estimated maximum areas.

Table 2 Maximum potential carbon storage for individual conservation practices

Among the conservation practices in Table 2 rangeland planting has the most potential savings in the state. Cover cropping also has large potential. The potential for prescribed grazing and stripcropping are also significant, as is the potential for switching from conventional- to no-till farming.

The Greenhouse Gas Equivalency Calculator[22] provides some perspective on these carbon savings estimates:

- Using cover crops, like ryegrass or clover, on post-harvest fields could offset the estimated annual emissions of all cars belonging to residents of the cities of St. Louis and Kansas City, Missouri, combined.
- Switching from conventional- to no-till farming would annually save six times the carbon dioxide emissions from energy used by all households in Jefferson City, the state capital.
- Changing the application timing and amounts of nitrogen fertilizer could avoid nearly half-a-million tons of greenhouse gas emissions, or the equivalent savings provided each year by 115 wind turbine electricity generators.
- Practicing prescribed grazing would balance out the annual emissions generated by more than 400,000 cars.

County Level

The estimates of carbon savings potentials in Table 2 are rough estimates of the maximum potential for carbon savings for individual conservation practices, assuming 100 percent adoption rates. The estimates cannot be combined to estimate the effects of using multiple practices on the same acre. But Keith Paustian at Colorado State University and colleagues, using a different methodology from that described above, have estimated the carbon savings potential in the state county-by-county if farmers were to adopt multiple conservation practices.[23] Their estimates are for scenarios involving a "moderate" or an "aggressive" implementation of conservation farming, with realistic adoption rates. Separate estimates were made of the carbon storage potential in croplands, grazing lands and set-aside lands. For the latter, current croplands with marginal productivity were assumed to be returned to native permanent vegetation or planted with perennial non-food crops.

Five of the counties with the highest total potentials for carbon storage across all practices (Figure 7) are in southeastern Missouri, a region with a large agricultural presence. New Madrid shows the largest potential.

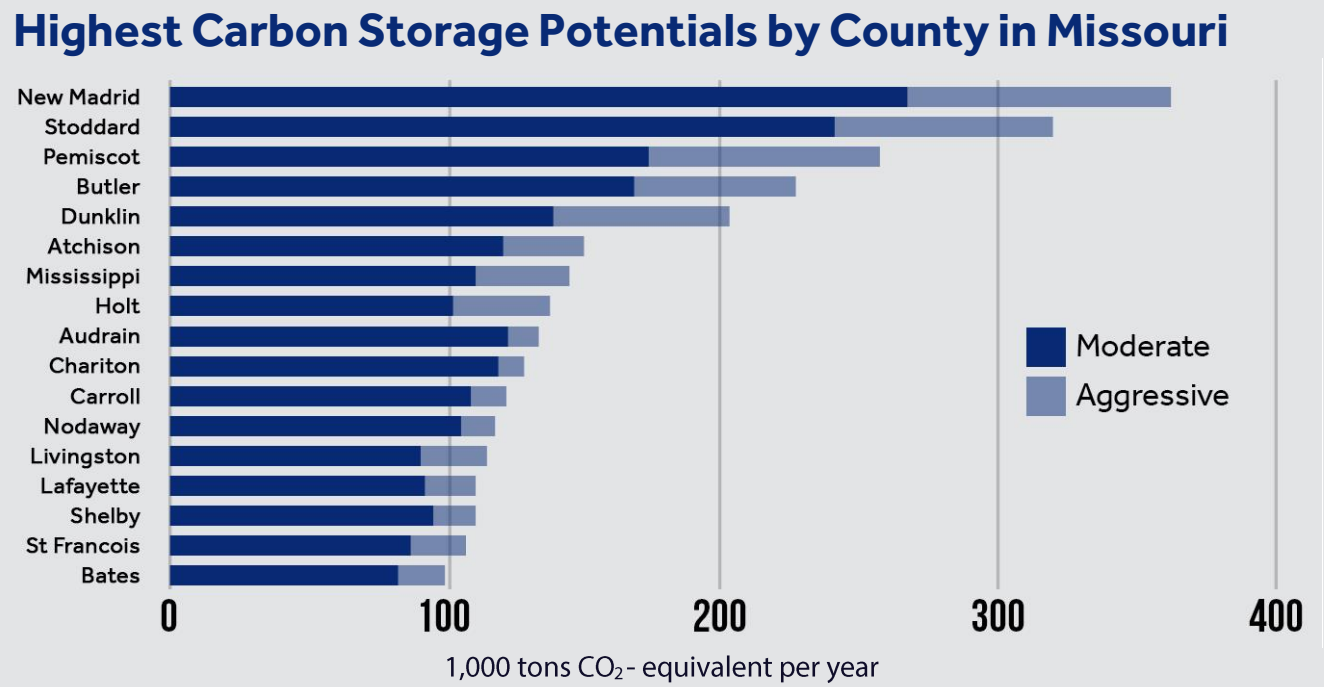

Fig 7
Source: Paustian, et al (2017)[23]

Statewide, Paustian et al.[23] estimate that the potential carbon storage from conservation practices on croplands, grazing lands and set-aside lands would total 5.2 million short tons per year of carbon dioxide equivalents for the moderate scenario and 6.5 million short tons per year for the aggressive scenario. That's more than twice the annual greenhouse gas emissions of the city of Columbia, Missouri, home to the state's flagship, land-grant university.[24]

Conclusion

Today's farmers feed not only America, but also the rest of the world, exporting soybeans, corn, pork and other food and feed commodities to countries throughout the globe. Most of the men and women in Missouri who produce this food come from family farms that often have been passed down through generations. Farmers now face new challenges, including an increase in the frequency and severity of extreme weather fueled by a changing climate. These extremes of heat, drought and downpours hurt livestock, damage crops and erode the soil.

However, ranchers and farmers can take steps to better weather the extremes by improving the health of their soil. Conservation practices that can increase crop productivity, improve livestock health and limit erosion can also sequester carbon in the soil. This analysis of potential carbon savings in Missouri of a variety of individual conservation farming methods found important carbon savings potentials in croplands and grazing lands.

Creating healthier soil can also potentially lead to a new revenue stream for farmers. By participating in small but growing carbon markets, farmers can get paid for creating carbon-rich soil that offsets the emissions of organizations and individuals who wish or are required to reduce their carbon footprint.

Missouri farmers pride themselves on being stewards of the land. They now can be keepers of the soil, and leaders in climate-smart agriculture.

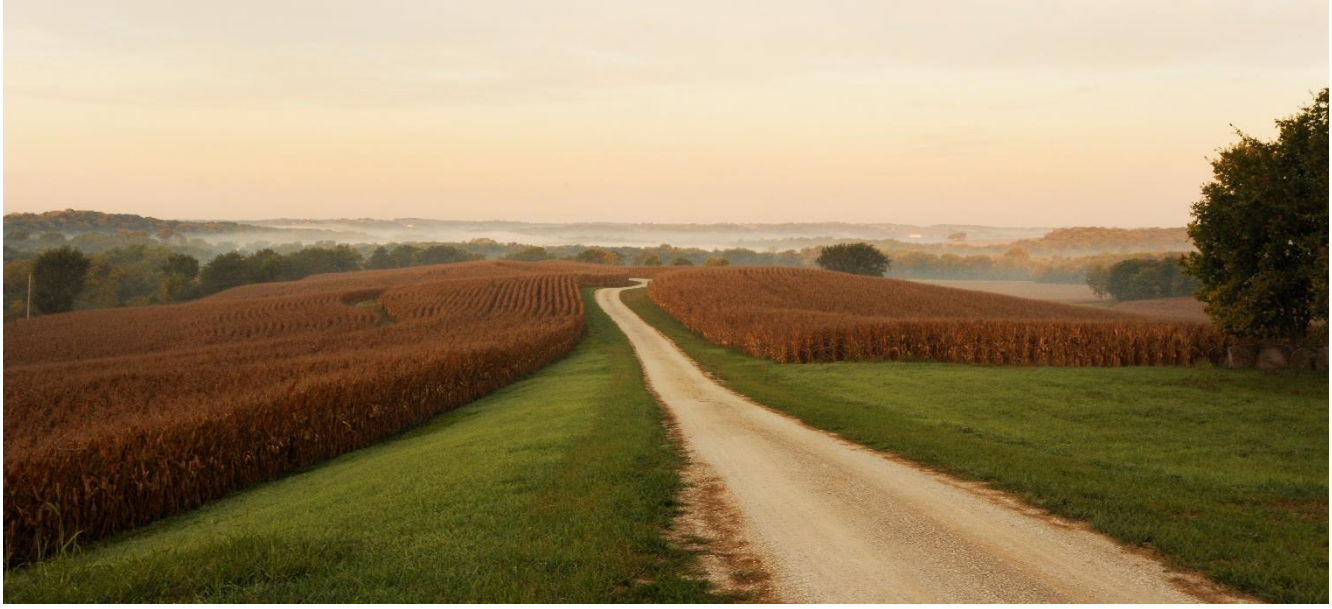

Photo: Bill Hankins

Appendix

Assumptions and data used to estimate potential land areas in Missouri to which NRCS conservation practices could be applied:

Conventional, no-till, and reduced-till cultivation

The total acreage of field crops, as reported in the 2012 USDA Census, was 9.865 million acres, of which 3.140 million were reported as conventionally tilled, 4.018 million were reported as cultivated using no-till, and 2.707 million were reported as cultivated using reduced (or conservation) tillage.[25] The Census reports total harvested cropland in Missouri in 2012 as 12.918 million acres.[26] The 3.053 million acre difference between total harvested cropland and the field-crop acreage is accounted for by lands producing hay or other perennial crops.[27] For purposes of our analysis, only field-cropped acreage is assumed to be amenable to reduced-tillage or no-till cultivation.

Cover crops

The total acreage in cover crops, as reported in the 2012 USDA Census, was 0.390 million acres.[25] Since that time, cover cropping in Missouri has grown substantially, and a rough estimate is that one million acres are currently cover cropped.[28] The total potential acreage amenable to cover crops is assumed to be total field crop acreage (9.865 million acres in 2012). Thus, we estimate there are 8.865 million acres potentially available for cover cropping.

Stripcropping

Specific data on the extent of stripcropping in Missouri are not available. However, the NRCS has estimated the prevalence of "structural practices" in the Missouri River Basin.[29] Structural practices include various measures for overland water or wind flow control (terraces, buffer strips, stripcropping, in-field vegetative borders, and others), for concentrated flow control (grassed waterways, grade stabilization structures, diversions, and others), and edge-of-field buffering and filtering (riparian forest or herbaceous buffers, filter strips, and others). Structural practices are designed primarily to control erosion. They also have the potential for additional benefits, including helping build soil carbon. For purposes of this analysis, we assume that stripcropping is practiced in Missouri to the same extent that structural practices as a whole are practiced, as estimated by the NRCS in a 2012 study that relied on survey data collected from 2003 to 2006.[29] That study estimated the conservation treatment level for structural practices in each of 29 sub-regions of the Missouri River Basin, designating the level to be Low, Moderate, Moderately-High or High.

Factors considered in assigning treatment levels were the number of overland flow, concentrated flow, and edge-of-field practices that were estimated to be present. Specifically, the report estimates that High treatment level characterizes acreage where edge-of-field mitigation and at least one structural practice (concentrated or overland flow practice) are in place. Moderately-High treatment characterizes acreage where either edge-of-field mitigation or both concentrated and overland flow practices are in place. Moderate treatment applies when there is no edge-of-field mitigation and only concentrated or overland flow controls. Low treatment applies to acres with no edge-of-field mitigation and no structural practices.

Based on these descriptions, we assume that acreage categorized as having Low or Moderate treatments would be amenable to stripcropping (or structural practices with equivalent carbon impacts) as well as (nominally) half of land classified as having Moderately-High treatment. The percentage of Cx`ropped acres by treatment level in the four sub-regions of the Missouri River Basin that lie partially or entirely within the state of Missouri are given in Table 3. To determine a statewide average current treatment level, we determined which Missouri counties were in each sub-region (with help of USGS tools[30]), assigned the corresponding sub-region percentage of cropland acres currently receiving Low, Moderate, or Moderately-High treatments to each county, and then calculated the weighted-average treatment level across all cropland in all counties in the four sub-regions (but assuming only half the acreage in counties with Moderately-High treatment levels). About one third of Missouri's cropland lies outside of the four sub-regions and so was not included in the weighted average. The resulting weighted-average value of land amenable to stripcropping, 52 percent of field crop acreage was taken to be the statewide average for purposes of estimating potential carbon benefits.

Table 3. Conservation treatment levels in sub-regions of the Missouri River Basin falling partially or entirely inside the state of Missouri.*				
Sub-region	**1024**	**1028**	**1029**	**1030**
Percent of cropped acres at four conservation treatment levels for structural practices.				
High	**6**	**6**	**1**	**8**
Moderately-High	**42**	**24**	**26**	**27**
Moderate	**33**	**26**	**29**	**32**
Low	**19**	**45**	**43**	**33**

*From Table B4 in NRCS (2012)[29]

Conservation crop rotations

Details of conservation crop rotations practiced in Missouri are not widely reported. However, NRCS (2012)[29] states that "In the Missouri River Basin, crop rotations that meet NRCS criteria (NRCS conservation practice standard 328) occur on about 88 percent of the cropped acres." While the state of Missouri accounts for only a small portion of the eastern Missouri River Basin, with soil and climate conditions much different from those of the western portion of the Basin, lacking other data we assume that Missouri farmers are already practicing conservation crop rotations that meet NRCS criteria at the same average rate (88 percent) as practiced by farmers across the Missouri River Basin. The remaining 12 percent of field crop acreage is assumed to have the potential for carbon benefits via implementation of conservation crop rotations.

Nitrogen management

The acreage of field crops in Missouri currently receiving conservation treatment levels for nutrient management is estimated based on NRCS (2012).[29] Factors considered in that study in characterizing treatment levels in 29 sub-regions of the Missouri River Basin were rate, timing, and method of nitrogen application. Specifically, the report states that High treatment level applies when all crops have: (1) total nitrogen application rates (including manure) less than 1.2 times the nitrogen in the crop yield for crops other than small grains and less than 1.5 times the nitrogen in the crop yield for small grains; (2) all applications occur within three weeks before planting or within 60 days after planting; and (3) all applications are incorporated or banding/foliar/spot treatment is used. Moderately-High treatment applies when all crops have total nitrogen application rates (including manure) less than 1.4 times the nitrogen in the crop yield for crops other than small grains and less than 1.6 times the nitrogen in the crop yield for small grains. Timing and method of application criteria may or may not be met. Moderate treatment applies when all crops meet either the above criteria for timing or method, but do not meet criteria for rate. Low treatment applies when some or all crops in rotation exceed criteria for rate and either timing or method.

Based on these descriptions, it appears that acreage currently receiving Low or Moderate treatment levels would be amenable to improved nitrogen management. The percentage of cropped acres by treatment level in the four Missouri River Basin sub-regions that lie partially or entirely within Missouri are given in Table 4. To determine a statewide average current nitrogen management treatment level, a similar procedure as described above under stripcropping was followed. The resulting calculated weighted-average percentage of field-cropped land amenable to improved nutrient management is 37 percent.

Table 4. Conservation treatment levels in sub-regions of the Missouri River Basin falling partially or entirely inside the state of Missouri.*				
Sub-region # >>	**1024**	**1028**	**1029**	**1030**
Percent of cropped acres at four conservation treatment levels for nitrogen management.				
High	**17**	**27**	**23**	**19**
Moderately-High	**44**	**40**	**44**	**38**
Moderate	**26**	**24**	**29**	**33**
Low	**13**	**8**	**5**	**10**

*From Table B4 in NRCS (2012)[29]

Prescribed grazing and rangeland planting

Total grazing acreage in the state, as reported in the 2012 USDA census, was 9.74 million acres, including 7.1 million of permanent pasture and rangeland, 1.74 million of pastured woodlands, and 0.57 million acres in the cropland category classified as pasture/grazing lands.[26] Craig Roberts, a University of Missouri forage specialist, estimates that 1.65 million acres of grazing lands (or 17 percent of the total) were managed as part of prescribed grazing systems in Missouri as of 2014.[32] Based on this figure, we assume that 83 percent (or 8.08 million acres) of grazing lands in Missouri are amenable to management practices that increase soil carbon content.

Equivalency Calculations

Emissions savings from Table 2 were entered into EPA's Greenhouse Gas Equivalencies Calculator (https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator) to put the numbers into more relatable terms. Below are some of the assumptions made outside of the EPA calculator to further translate these measures into Missouri-based units.

- The number of households in Jefferson City (16,961 households) was obtained from US Census Quick Facts https://www.census.gov/quickfacts/fact/table/jeffersoncitycitymissouri,US/HSG010216
- The number of cars owned by residents of St. Louis (1.27 cars per household x 140,116 households) and Kansas City, MO (1.58 cars per household x 196,418 households) http://www.governing.com/gov-data/car-ownership-numbers-of-vehicles-by-city-map.html, https://www.census.gov/quickfacts/fact/table/kansascitycitymissouri,stlouiscitymissouri/PST045217

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For additional reading and data

Missouri Sustainable Agriculture Research and Education
https://www.northcentralsare.org/State-Programs/Missouri
Missouri Soil and Water Conservation Districts
https://mosoilandwater.land/
Missouri Climate Center
http://climate.missouri.edu/
University of Missouri Extension Service Cover Crop Resource Guide
http://crops.missouri.edu/covercrops/
USDA Conservation Practices
https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/technical/cp/ncps/?cid=nrcs143_026849
Cover Crop Innovators Video Series
https://www.sare.org/Events/Cover-Crop-Conferences/National-Conference-on-Cover-Crops-and-Soil-Health/Cover-Crop-Innovators-Video-Series
Comet-Planner: Carbon and Greenhouse Gas Evaluation for NRCS Conservation Practice Planning
http://www.comet-planner.com/
Comet-Farm: Whole Farm and Ranch Carbon and Greenhouse Gas Accounting System
http://cometfarm.nrel.colostate.edu
SARE: Cultivating Climate Resilience on Farms and Ranches
http://www.sare.org/content/download/80674/1415715/Cultivating_Climate_Resilience_on_Farms_and_Ranches.pdf?inlinedownload=1
National Climate Assessment
https://nca2014.globalchange.gov/
USDA Midwest Climate Hub
https://www.climatehubs.oce.usda.gov/hubs/midwest
Solutions from the Land
https://www.sfldialogue.net/
Climate Central
https://www.climatecentral.org

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