American Farmland Trust
SAVING THE LAND THAT SUSTAINS US

THE CONSERVATION FUND

Climate change mitigation from an agricultural conservation easement

A CASE STUDY OF AN ILLINOIS FARM

Photo by USDA NRCS.

Contents

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Introduction

Agricultural conservation easements protect agricultural land from conversion to development. Assuming this avoided farmland development leads to smart growth development elsewhere, the easement mitigates greenhouse gas emissions. That is, an easement mitigates the loss of soil carbon from development excavation as well as the difference in household emissions between two scenarios: a less energy- and transportation-efficient low density residential development on the farm scenario and a more efficient smart-growth (infilling existing developed areas with more energy efficient housing and transportation) scenario. In addition, improving the soil health of the protected farmland has the potential to provide future GHG benefits. Surveys indicate that landowners and farm operators who put permanent easements on their agricultural lands are more likely to use conservation practices on the protected land, including practices that sequester carbon and reduce GHG emissions (Esseks et al. 2013).

The California markets for carbon offsets (both compliance and voluntary) have set a precedent for calculating and crediting the GHG benefits of conservation easements. These include the avoided conversion of forestland and the avoided conversion of grasslands to crop production. They require users to demonstrate a significant threat of development and place the land under a conservation easement to prevent development. California is also using the state's cap-and-trade revenue to secure farmland conservation easements on cropped farmland and has developed a methodology to calculate the climate benefits associated with that protection. Avoided forestland or grassland conversions keep ecosystems in place that sequester carbon, while avoided farmland conversions prevent the net emissions from less energy-efficient rural households versus more energy-efficient urban households. These net avoided emissions are orders of magnitude greater than the GHG source or sink potential of farmland management, as demonstrated below.

Development Risk on Bishop Farm

The proposed easement is for Bishop Farm in Tazewell County in central Illinois. The farm is within a Tazewell County Agricultural Preservation District, a buffer of ag land between the cities of East Peoria and Morton **(FIGURE 1).** The purpose of these districts, according to the Tazewell County, Illinois Code of Ordinances is

> *to benefit and protect agricultural uses throughout the county. The intent of the Agriculture Preservation District is to protect those areas which are best suited to the pursuit of agriculture in order to ensure that agriculture will continue to be maintained as a long term land use and a viable economic activity within the county. Non-farm uses, such as residential home sites on smaller tracts of land, are discouraged from locating in the A-1 District in order to minimize potential incompatibilities or restrict the growth of existing agricultural operations. (Code §157.085)*

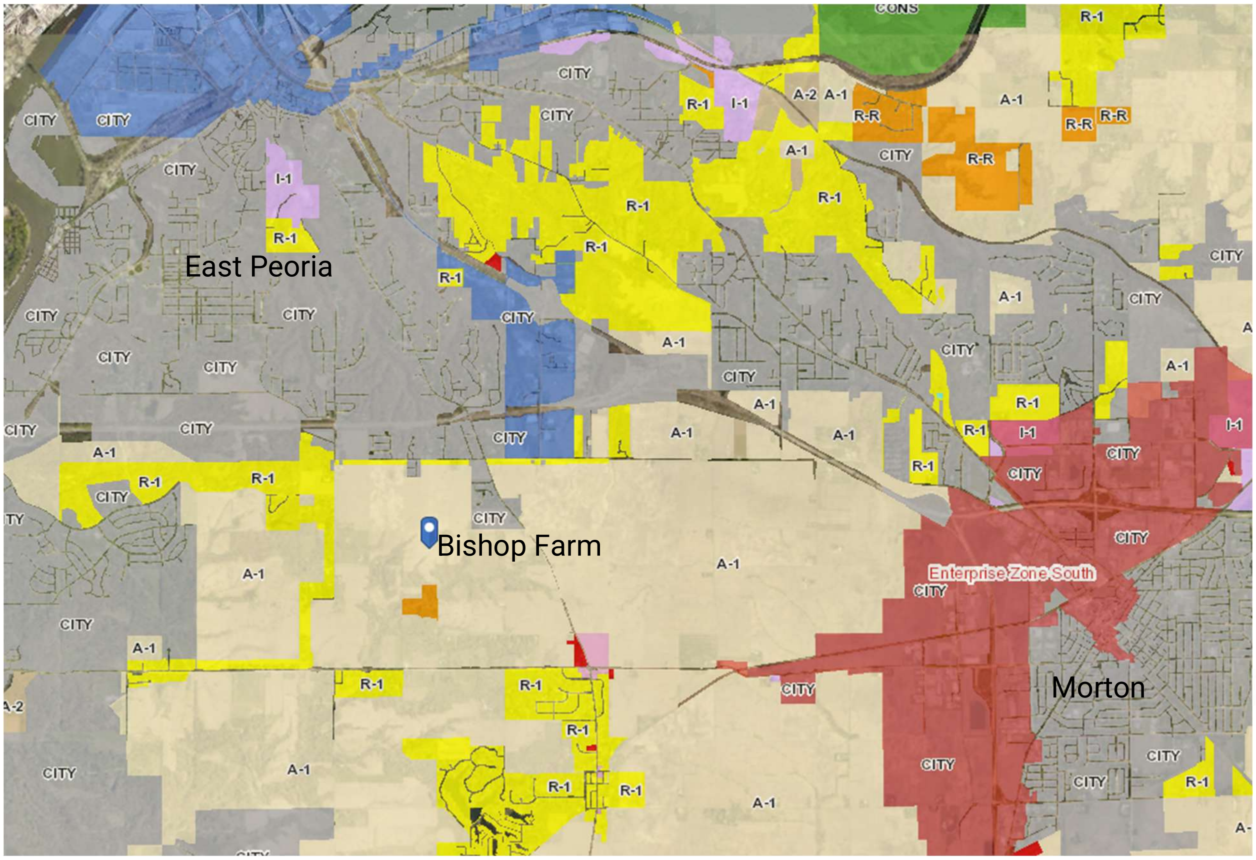

Figure 1. Tazewell County, Illinois zoning districts. The tan areas marked "A-1" are Agricultural Preservation Districts. Bishop Farm, indicated with a blue pointer, lies within an Agricultural Preservation District and between East Peoria to the northwest and Morton to the southeast.

The farm is outside of the East Peoria city limits but within the 1.5-mile buffer of the unincorporated region. Despite being in an Agricultural Preservation District, the City of East Peoria has the area within [Future Growth Area #2 Muller Road](), which includes Bishop Farm, identified by the City of Peoria as viable potential for future low density residential development (**FIGURE 2**). Given the farm's desirable location for East Peoria sprawl, the agricultural conservation easement is highly likely to be protecting the farmland from future low density residential development. Given the conflicting potential uses of Bishop Farm and its surroundings, an agricultural conservation easement within the Agricultural Preservation District contributes to establishing a permanent community separator or greenbelt between East Peoria and neighboring cities. This supports infill of existing developed areas, of which there are many opportunities within the existing East Peoria city limit. More easements within the Agricultural Protection District would strengthen the community separator and demand for infill. For these reasons, AFT concluded that the Bishop Farm agricultural conservation easement meets the prerequisites for calculating the GHG benefit from avoided conversion (high risk of development, low risk of leakage).

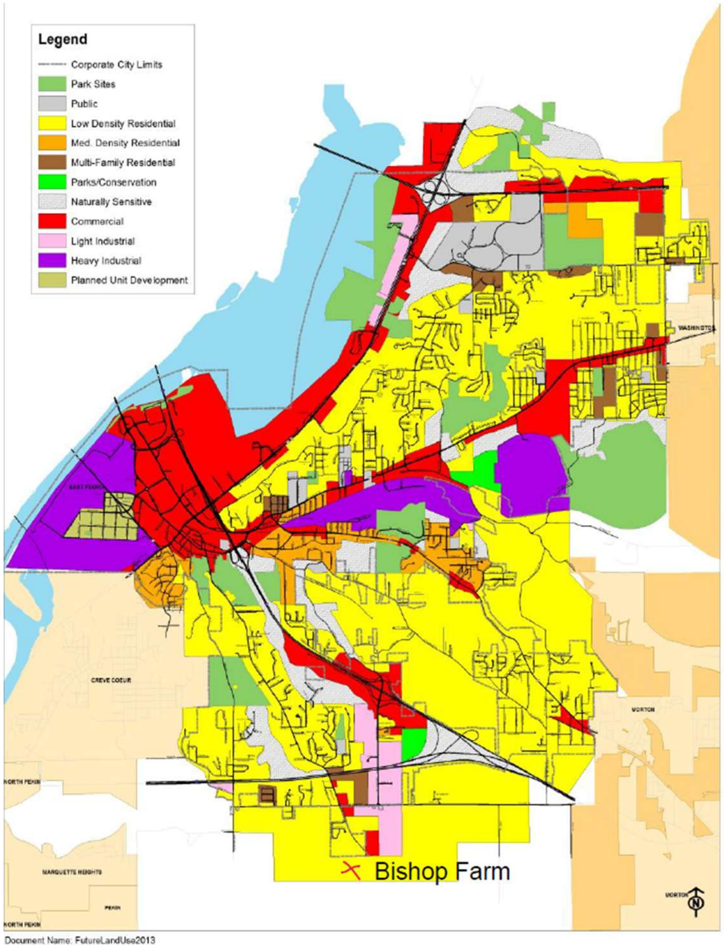

Figure 2. East Peoria Future Land Use Map. Yellow areas indicate future plans for low density residential development. Bishop Farm is indicated with a red X near the bottom.

About Bishop Farm and Surrounding Agriculture

The farm has about 65 acres of cropland, 34 acres of woods, and 4 acres of residential site including a small specialty operation, and roadway. The non-operating landowner has leased the cropland to a local farmer for several years. The cropland is farmed conventionally with a corn-soybean rotation typical of this part of Illinois.

According to the 2017 Census of Agriculture, Tazewell County had 304,475 acres of land in farms with 857 farms. According to the 2017 Census of Agriculture, Tazewell County had about 850 farms on 300,000 acres of land. Between 2012 and 2017 the number of farms in the county dropped 9% and acres in farmland dropped 10%. In 2017, the average size of a Tazewell County farm was 355 acres. About one-fifth of farms in the county are similar in size to the Bishop Farm (in the 50-179 acre range). By use, 93% of the land in farms in the county is cropland, and crops make up 83% of county agricultural sales. Eleven percent of cropland acres in the county use cover crops, which is higher than the state cover crop adoption rate of 3% of cropland not including hayland. Sixty seven percent of acres employ no-till or reduced till management practices.

Methods I: Avoided conversion

Background

Before deciding on a methodology, AFT set out to determine if a scientifically valid and defensible case could be made to estimate the avoided GHG emissions associated with an agricultural land conservation easement (See literature review in Appendix).

AFT concluded that: 1) there was precedent for using avoided conversion calculations to establish GHG benefits; 2) a relevant methodology for the avoided conversion of farmland was available (the California Air Resources Board's Agricultural Conservation Easement Quantification Method, or QM, 2020); 3) the QM could be applied to the Illinois farm with some modifications.

The QM (2020) is used by California's Sustainable Agricultural Land Conservation (SALC) program to estimate the avoided GHG emissions and air pollutant emission co-benefits associated with agricultural land conservation easements. The QM uses spatial and other data to estimate avoided emissions from reduced vehicle miles traveled (VMT), reduced electricity and heat use, and avoided loss of soil organic carbon from avoided development on the farmland and instead in an urban smart growth scenario. At the parcel level, this is the only peer-reviewed methodology currently available for avoided conversion of farmland. The QM's principles and California-specific datasets ensure that the methodology applies at the project level, provides uniform methods to be applied statewide, uses existing and proven tools and methods, uses project-level data and results in GHG emission reduction estimates that are conservative and supported by empirical literature (CARB 2020).

In addition to the emissions accounted for in the QM, AFT explored the literature to determine whether the following potential emission sources were significant enough to include in the methodology:

- emissions from industrial processes such as cement and steel production associated with materials used for building homes and roads (Zhong et al. 2021) Each pound of concrete releases 0.93 pounds of CO_2 (Ramsden 2020).
- the use of refrigerants in homes (US EIA 2022) and vehicles (US EPA 2018)
- solid waste management in landfills (ICF International 2015)
- sewage treatment (Zawartka et al. 2020)

AFT also considered whether emission factors and/or data availability allowed for such additional calculations. Cement production in the US emits about 40 million metric tonnes (MMT) CO_2e per year, which is about 0.7% of net US emissions and 10% of US industrial emissions in 2020 (EPA). Iron, steel, and coke production emits about 37 MMT CO_2e per year, though not all steel used in the US is from US production. AFT was unable to find literature sources that provide the difference in cement and steel use in rural vs. urban home building. Research does show that sprawled communities require more road area per motor vehicle compared to smart growth communities (Litman 2015).

For the farm in question, TCF also wanted to document additional GHG benefits based on the potential for the permanently protected farmland to sequester carbon. For these calculations, AFT used COMET-Farm to calculate both a business-as-usual scenario based on current management and an alternative scenario incorporating soil health cropping practices and agroforestry practices, per TCF's instructions.

Calculations

The calculation tool called "IL Avoided Conversion worksheet.xlsx" is available here. AFT provided a video walk through of the tool that is available here. AFT followed the California Air Resources Board's Agricultural Lands Conservation Quantification Methodology (2020), or "QM", as closely as possible given differences in data availability between California and Illinois. These differences are detailed below. References to AFT's "IL Avoided Conversion worksheet.xlsx" are highlighted in gray. AFT's work on this project began in August 2022 using the 2020 QM. However a draft revision to the QM was published in October 2022 and was recently finalized (link to QM 2022). The main difference between the 2020 and 2022 QMs is the new version uses a commute time risk assessment by county to determine risk of conversion zoning densities. CARB published an update to its emission factors dataset on November 30, 2022, which has been incorporated into the spreadsheet. AFT's adaptation of the QM was reviewed by a scientist at CARB.

Development rights extinguished by the conservation easement **–** See **"1-Inputs" tab, rows 10-36.** To determine the GHG benefits from the easement, AFT first determined the number of development rights (used equivalently with "dwelling units" and "households" depending on the dataset) extinguished by the easement. The easement does not have a specific zoning proposal that gives the number of dwelling units for the parcel, but the QM provides a series of steps for estimating the potential housing density for the parcel. To do this, AFT modified the QM method for "Density Calculation for Risk of Conversion to Residential Areas" (QM page 10). AFT did not follow the method for "…Conversion to Rural Residential Areas" because 1) the parcel boundary is currently adjacent to an area zoned as city (and near others), 2) the February 1, 2016 Revised Comprehensive Plan for East Peoria states that the farm location is in a development area that will be zoned as (non-rural) low-density residential. Although the East Peoria Comprehensive Plan does not explicitly define 'low-density residential' zoning, the Code of Ordinances for Tazewell County states that Low-Density Residential Districts are designed for single-family and two-family residential housing opportunities, and to provide for the efficient use and orderly development of vacant land designated for residential uses.' AFT confirmed with the city planning office that this 2016 document had the most up-to-date plans for Future Growth Area #2 Muller Road and planned land uses. Importantly, if using the AFT spreadsheet for another parcel that is at risk of conversion to rural residential zoning do not follow the development rights steps in the spreadsheet, follow instructions on pages 10-11 in the QM.

Given that the project area at risk of residential conversion is smaller than any community within two miles of the site, following the QM, the housing density of the project site was set to the average housing density of the newest residential zone within two miles of the project section. The best way AFT was able to determine residential zone age was to use census tracts as a proxy. The American Community Survey provides number of houses per tract (not available per block) built by decade with "housing units built 2014 or later" as the newest category. The census tracts within two miles of the parcel are detailed in the **tab "Census Tract Yr Structure Built"**. Census tract 215 was the only tract within two miles with houses built in 2014 or later, and it also happens to be the tract the parcel is in.

Then, AFT used zoning data provided by Tazewell County to identify areas currently zoned as low-density residential within the above census tract and within two miles of the parcel (FIGURE 3). In these low-density residential zones, AFT identified residential structures using the Oak

Ridge National Laboratory/Federal Emergency Management Agency Geospatial Response Office structures inventory, a dataset that maps all structures in the US and its territories whose size is greater than 450 square feet. Although the dataset does distinguish residential structures from other categories including government, commercial, education, industrial, and other, in our focus area the categorical data were not complete, and all structures in the defined area were labelled only as 'other'. Therefore, to attempt to remove farm buildings, warehouses, outbuildings, and garages, AFT selected only structures greater than 1,000 and less than 10,000 square feet, acknowledging that this filter may remove some dwelling units as well. This filter removed 29 structures, leaving 665 structures AFT assumed to be dwelling units in an area of 925 acres. The resulting housing unit density was approximately 0.72 housing units per acre. The site does not have grades exceeding 15% (determined using the National Elevation Dataset in ArcGIS), so AFT did not have to reduce the density to account for steep grades.

Figure 3. Bishop Farm parcels, 2-mile buffer, newest census tract, structures, and Tazewell County Zoning Districts. Structures visible were used to determine likely low density residential dwelling unit density.

GHG benefits from avoided conversion

The QM determines avoided GHG emissions and air pollutant emission co-benefits associated with the first 30 years of the proposed agricultural conservation easement. To determine these emission reductions, the QM uses eight equations. This document walks through each equation below, noting where AFT made modifications for the Illinois calculations to accommodate for differences in available datasets between California and Illinois (**Table 1**).

Table 1. Data used in avoided emissions calculations by source and geographic coverage available. In order to use this method for other parcels, city- and state-specific data will be needed.

Data type	Source	Coverage available
Parcel spatial data	Tazewell County	county
City zoning geospatial data	Tazewell County	county
Land slope	National Elevation Dataset https://datagateway.nrcs.usda.gov/	national
Location and size of building structures	USA Structures https://gis-fema.hub.arcgis.com/pages/usa-structures	national
Census tract for parcel	American Community Survey https://www.census.gov/programs-surveys/acs	national
Population density	Census Demographic Data Map Viewer https://arcg.is/0eWzy8	national
Soil taxonomy	SoilWeb https://casoilresource.lawr.ucdavis.edu/gmap/	national
Vehicle fleet miles per gallon	Federal Highway Administration https://www.fhwa.dot.gov/policyinformation/statistics.cfm	national
VMT: county average, state rural, state total	Illinois Travel Statistics 2021 https://idot.illinois.gov/transportation-system/Network-Overview/highway-system/illinois-travel-statistics	state
Passenger vehicles as a % of all vehicles	Illinois Travel Statistics 2021 (see above)	state
County urban vs rural housing units	Decennial Census https://tinyurl.com/2mc3mdwd	national
Electric grid emission factors	EPA Power Profiler https://www.epa.gov/egrid/power-profiler	national
New single-family household rural vs. urban electrical consumption by region	Energy Information Administration (EIA) Residential Energy Consumption Survey (RECS) https://www.eia.gov/consumption/residential/data/2015/index.php?view=consumption#by%20fuel	national
Home heat per urban household by region	EIA RECS (see above)	national
Non-CO2 vehicle emission rates by vehicle type	Bureau of Transportation Statistics https://www.bts.gov/content/estimated-national-average-vehicle-emissions-rates-vehicle-vehicle-type-using-gasoline-and	national

The equations are listed in the order that they are used; equation numbers refer to their number in the QM.

1. *Equations 3 and 4: Baseline and Project VMT (vehicle miles traveled) for Development on Ag Land (QM page 21).* According to the 2020 Census AFT used the "Rural Sites" equations for the baseline (development on project site) VMT and project VMT; meaning, AFT needed to estimate average rural and urban, respectively, household annual VMT for the site region. California maintains VMT data for over 5,000 Traffic Analysis Zones, which CARB designated as rural or urban using census tracts (QM 2020 page 33). Illinois only provides VMT at the county level and only provides rural vs. urban VMT at

the state level. Therefore, AFT developed the following equation for estimating the average rural household VMT for Tazewell County:

$$VMT_{rural} = \frac{average\ VMT_{county}}{year} \times \frac{rural\ VMT_{state}}{total\ VMT_{state}} \times \frac{passenger\ vehicles_{state}}{total\ vehicles_{state}} \times \frac{1}{rural\ HH_{county}}$$

2. The above equation is applied in **tab "2-Equations"**:
   a. cells A23-24: average daily (converted to annual) VMT data by county from Illinois Department of Transportation for years 2012-2019 (excluding years 2020 and 2021 as pandemic outliers; no apparent trend in VMT over years data are available). 2012-2021 data are shown in **tab "MPG_Refs"** cells A25 – B35.
   b. cells A25-26: the proportion of IL annual VMT in rural and urban areas from Illinois Department of Transportation (not available by county)
   c. cells A27-28: multiply the annual county VMT by the rural vs. urban proportions above, gives a weighted estimate of rural vs. urban VMT in Tazewell Co.
   d. cells A29-31: multiply the above by the proportion of VMT in the state that are passenger vehicles from Illinois Department of Transportation (not available by county). Reference data shown in **tab "MPG_Refs"** cell E48.
   e. cells A32-35: use the number of urban and rural housing units in the county from the 2010 Decennial Census (most recent data available) to partition the weighted estimates of VMT to urban and rural households.
   f. cell A37: $\mathbf{VMT_{baseline}}$ (development on easement)
   g. Equation 4 is accomplished above. Cell A36 is $\mathbf{VMT_{project}}$ (smart-growth)

3. *Equation 2: GHG Benefit from VMT Reduction due to Agricultural Lands Easement (QM page 20).* California maintains county and year specific emission factors (EF). To do that in Tazewell County, Illinois AFT could use the number of vehicles registered by vehicle class by county, but that information does not include the distribution of vehicle ages, which is key for determining miles per gallon (MPG). So AFT used data from the Federal Highway Administration Highway Statistics Series Table VM-1, which provides an average MPG by vehicle class per year for the national fleet. AFT used the change in MPG for light duty vehicles short wheel base (LDVS) and light duty vehicles long wheel base (LDVL) for years 2007 to 2020 to predict year-specific MPG for years 2022 to 2051. These are shown in **tab "MPG & AVEFs by yr"** columns C and D, trendlines given in cells C53-54 and D53-54. AFT used the well-to-wheel GHG emission factor (g CO_2e / gal) for gasoline (diesel passenger vehicles make up only a small proportion of total passenger vehicles) from the California Air Resources Board Quantification Methodology Emission Factor Database, which is shown in tab "**MPG_Refs**" cell D59 to get the average emission factor ($AVEF_{Yr,Nation}$) in g CO_2e per mile in tab **"MPG & AVEFs by yr"** column F using:

$$AVEF_{Yr,Nation} = \frac{1}{0.5 \times (MPG_{LDVS} + MPG_{LDVL})} \times \frac{11{,}518.14\ g\ CO_2}{gal\ gasoline}$$

   a. Then multiply $\mathbf{VMT_{baseline}}$ **-** $\mathbf{VMT_{project}}$ by each $AVEF_{Yr,Nation}$ (tab **"MPG & AVEFs by yr"** column I)
   b. Back in **tab "2-Equations"**, follow QM Equation 2 (page 20).
   c. Sum all years in above (cell A19) and multiply by 10^{-6} to convert g to metric tonnes (cell A18). The result is $\mathbf{GHG_{VMT}}$ (cell A20) to use in Equation 1 (below).
   d. To get the total VMT avoided for the project, use the difference between $\mathbf{VMT_{baseline}}$ **-** $\mathbf{VMT_{project}}$ and multiply by 30 years (cell A17).

4. *Equation 5: Emission Reductions from Electricity Reduction* (QM page 22). Here AFT followed the QM. AFT used the following data sources:

a. Emission Factor (EF) for electrical use came from entering the project site zip code into the [EPA Power Profiler](), which gives a grid EF in lb CO_2 per MWh (cell A52) that AFT converted to metric tonnes (t) CO_2e per MWh (cell A54). **This EF will vary by sites in the Midwest.**
b. AFT used EIA RECS 2015 data for average annual single family household electrical consumption for rural and urban sites in the Midwest in millions of BTUs per household (values shown in **tab "Btu"** cells I10 and I13) which AFT converted to MWh per dwelling unit per year (cells A55-56).
c. Using the number of dwelling rights extinguished, AFT used the above values in Equation 5 to get $\mathbf{GHG_{ELEC}}$ (cell A57) to use in Equation 1 (below).

5. Equation 6: Emission Reductions from Natural Gas Use (QM page 23). Here AFT followed the QM. AFT used the following data sources:
    a. The baseline (development on farm site) uses the propane EF and the project (smart-growth) uses natural gas EF, both from California Air Resources Board Quantification Methodology EF Database (**tab "2-Equations"** cells A64 and A65, respectively).
    b. Predicted annual new single family urban household natural gas use came from the EIA RECS 2015 Table CE 2.3, therm per dwelling unit per year for Midwest urban areas is in cell A66 (full table shown in **tab "Btu"**).
    c. Using the number of dwelling rights extinguished, AFT used the above values in Equation 6 to get $\mathbf{GHG_{NG}}$ (cell A67) to use in Equation 1 (below).

6. *Equation 7: Avoided Soil Organic Carbon Emissions (QM page 24).* Here AFT followed the QM using the following data sources:
    a. AFT determined the project site soil type (using the method described in QM pages 13-17) to be Alfisols (see **tab "1-Inputs"** cell A43).
    b. Using **tab "SOC Ref"** rows 5-10 AFT pulled the appropriate CS_{ref} into **tab "2-Equations"** cell A72.
    c. With the number of dwelling rights extinguished, AFT used the above values in Equation 7 to get $\mathbf{GHG_{SOC}}$ (cell A77) to use in Equation 1 (below).

7. *Equation 1: Total GHG Benefit from Agricultural Land Easement.* This is the sum of $\mathbf{GHG_{VMT}}$, (Equation 2), $\mathbf{GHG_{ELEC}}$ (Equation 5), $\mathbf{GHG_{NG}}$ (Equation 6), and $\mathbf{GHG_{SOC}}$ (Equation 7), which are all calculated over the span of 30 years for the number of development rights extinguished with this conservation easement. See **tab "2-Equations"** cell A13.

8. *Equation 8: Emissions Co-Benefits (QM page 25).* Here AFT followed the QM, using our modified VMT estimation method and the following data:
    a. to calculate an average EF by year and county ($\mathbf{AVEF_{Yr,County}}$) for non-GHG VMT, neither county- nor state-specific emissions data were available. So AFT used national data from the Bureau of Transportation Statistics (BTS) that give estimated US average vehicle EF per vehicle by vehicle type using gasoline and diesel retrospective (2000-2020) and prospective (2021-2030). This dataset is pasted into **tab "nonCO2 EFs ".** The QM calls for ROG (reactive organic gases), which are listed in the BTS data as hydrocarbons (HC), also roughly equivalent to volatile organic compounds (VOCs). Equation 8 calls for PM_{10} EFs for vehicles, which were not available. Reference data were also pasted into **tab "MPG & AFEFs by yr"** columns K-T, rows 7-20. For EFs that change over time in the BTS data, years 2031-2051 were extrapolated from the years provided, or, if nearly 0, the 2031-2051 EFs were set at the 2030 value. The sum of the EFs for light duty vehicles-short and light duty vehicles-long was averaged per year and converted from g to lb (by dividing by 453.592) to get an $\mathbf{AVEF_{YrNation}}$ (**tab "MPG & AVEFs by yr"** column U), which is multiplied by $\mathbf{VMT_{baseline} - VMT_{project}}$ in column V. These are then summed in Equation 8 (**tab "2-Equations"** cell A82).
    b. For EF_{ELEC} in **tab "MPG & AVEFs by yr",** columns W-AA:

c. NO_x and $PM_{2.5}$ came from the EPA Power Profiler and are specific to the grid associated with the project site.
d. ROG was not available for the grid, so AFT used the California Air Resources Board Quantification Methodology EF Database, *which is California-specific*.
e. In Equation 8 (**tab "2-Equations"** cell A82), similar to Equation 5, these EFs are summed and multiplied by the difference in electricity consumption between rural and urban site in Midwest (cells A55-A56), times the number of households, times 30 years (see Equation 8 in QM page 30).
f. For the natural gas use term in Equation 8, AFT assumed that EF_{BL} and EF_{PR} do not change by region and used the EFs from California Air Resources Board Quantification Methodology EF Database. In Equation 8 (**tab "2-Equations"** cell A82), similar to Equation 6, AFT take the difference between these EFs, multiply it times NG_{Urban}, times number of households, and times 30 years.
g. Then the total Co-benefit in Equation 8, cell A82, is the sum of parts a, b, and c above.
h. Values are given in g, which were converted to lb, following the QM. AFT also converted the total co-benefit to t (cell A85).

Results I: Avoided conversion

Placing the Bishop Farm in an easement could result in an estimated reduction of 19,541 t CO_2e emissions. Of this, 38% would be from the reduction in vehicle miles traveled, 20% would be due to reduced soil carbon loss from excavations to build homes, 40% would be from reduced future electrical use and less than 1% would be from the reduced use of propane (**Figure 4** and

TABLE 2). In addition, 8.8 t of non-GHG pollution (e.g., $PM_{2.5}$ and NO_x) would be avoided.

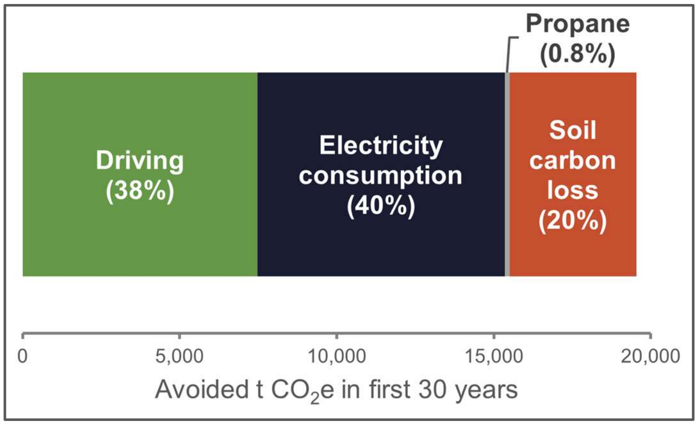

*Figure 4. Carbon emissions avoided by source for the Bishop Farm easement. This chart was made in **tab "Charts"**.*

*Table 2. Summary of Bishop Farm estimates. From tab "**3-Results**."*

Variable	Estimate	Units
30-year estimates for 74 households on 103-acre Bishop Farm		
Total avoided GHG emissions	19,541	t CO_2e in first 30 years
Avoided VMT	14,686,610	miles in first 30 years
Avoided VMT	7,472	t CO_2e in first 30 years
Avoided electricity consumption	11,735	MWh in first 30 years
Avoided electricity consumption	7,882	t CO_2e in first 30 years
Avoided soil carbon loss	4,040	t CO_2e for entire easement life
Avoided propane use	147	t CO_2e in first 30 years
Avoided air pollution	8.8	t NO_x, ROG, $PM_{2.5}$ and Diesel PM emissions from VMT, electricity generation, and propane combustion
Per acre per year estimate for Bishop Farm		
Avoided GHG emissions	6.3	t CO_2e per acre per year
Per household per year estimates for Bishop Farm		
Avoided GHG emissions	8.8	t CO_2e per household per year
Avoided VMT	6,602	miles per household per year

For the purposes of comparing mitigation opportunities, avoided conversion of Bishop Farm works out to about 6.3 t CO_2e per acre per year. Note that avoided emissions do not represent biogeochemical processes tied to specific acres or times of year in the same way that, e.g., grasslands sequester carbon per acre per year. The conservation cropping and agroforestry scenario (see below) estimates sequestration of 1.6 t CO_2e per acre per year. This comes to an estimated total of 7.9 t CO_2e per acre per year. For reference, avoided forest conversion (deforestation) avoids about 40 t CO_2e per acre per year and avoided grassland conversion to cropland avoids about 62 t CO_2e per acre per year (Fargione et al. 2018: Table S1). Both of these benefits are likely true for over 100 years. In addition to supporting smart growth, agricultural conservation easements on high quality farmland prevents displacement of that farmland to other lands – that is, the agricultural easement may prevent grasslands from being converted to new farmlands (Emili and Greene 2014).

AFT compared the avoided emissions estimates for the Bishop Parcel to the estimates for the 19 SALC projects in 2020-2021 (**Figure 5**). The Bishop estimates for t CO_2e per acre per year, t CO_2e per household per year, and vehicle miles traveled (VMT) per household per year fall within the interquartile range (the middle half) of the SALC projects. The Bishop estimate for t CO_2e over the first 30 years was less than the interquartile range but not an outlier. This could be because the project is smaller and/or at risk of less dense development than the California projects.

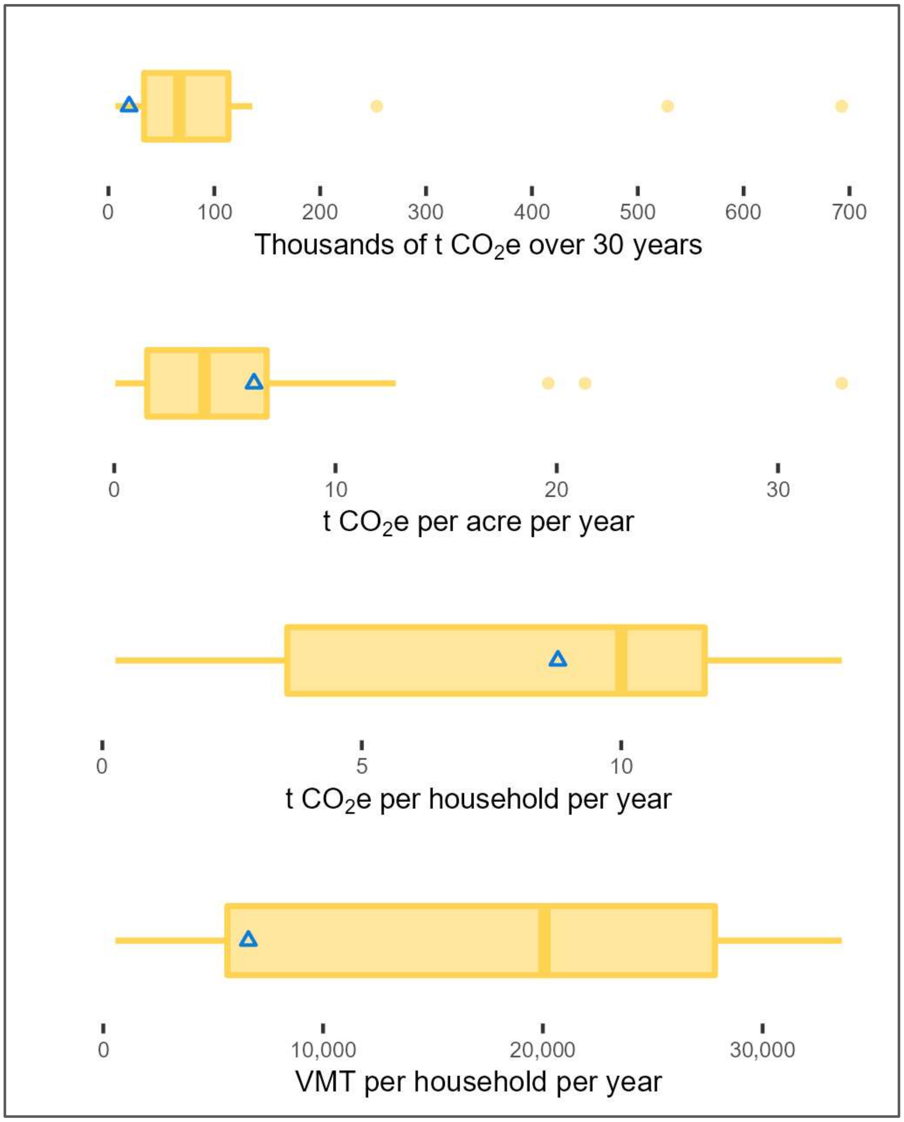

Figure 5. Comparison of SALC project estimates to the Bishop Farm estimate by AFT. Orange box and whisker plots show the distribution of easement benefits for [SALC 2020-2021 projects](). The blue triangle shows the Bishop Farm estimate. A box plot shows how a group of data are distributed, with the middle line indicating the median, the left end of the box is the 25th percentile of the data, and the right end is the 75th percentile. The left horizontal line (whisker) starts at the minimum and the right whisker ends at the maximum (excluding potential outliers, orange circles). Each graph indicates the difference in the labelled parameter between development at the agricultural easement site and the same number of households in an urban smart growth scenario.

Limitations

The estimates provided here are specific to Bishop Farm and Tazewell County and should be used for planning purposes only. AFT was unable to quantify the uncertainty in the estimates because the estimates are not averages from repeatedly measured data. This study did assess risk of leakage (see **DEVELOPMENT RISK ON BISHOP FARM**), i.e., the possibility that the conservation easement supports low-density residential development somewhere else rather than smart-growth. Scaling up the estimates for Bishop Farm to larger areas should be done with caution and with appropriate caveats.

Improving estimate accuracy

The number of development rights extinguished from the conservation easement could be improved with more detailed information about the age of homes in the vicinity of the parcel. The accuracy of VMT_{Year} per household could be improved with county-specific rural vs. urban VMT and proportion of passenger vehicles in the fleet. $AVEF_{YrNation}$ accuracy could be improved to $AVEF_{YrState}$ or $AVEF_{YrCounty}$ with state- or county-specific data about the age distribution and emissions of passenger vehicles in the fleet per year. The avoided soil organic carbon loss estimate could be improved with site-specific soil organic carbon measurements to at least 30 cm.

Regional Midwest Application

This avoided conversion approach can also be applied to easements in the other RCPP states. Although very few states have the kind of detailed information that California makes publicly available and that is used in the QM, AFT was able to use a mix of national data, city zoning spatial data, and state travel statistics, which should be easily available for other cities and states (**TABLE 1**).

Methods II: Potential Additional GHG Benefits from Agricultural and Agroforestry Conservation Practices

The QM does not consider GHG emissions from farmland. However, permanently protected farmland can also provide GHG benefits by sequestering additional carbon. AFT used CarbOn Management and Emission Tool (COMET-Farm) to calculate for the Bishop Farm a baseline (business-as-usual) emissions scenario based on typical management and three alternative emissions scenarios that incorporate cropland and agroforestry conservation practices. COMET-Farm is an integrated web-based platform for whole farm and ranch carbon and greenhouse gas accounting. The tool uses detailed spatially explicit data on climate and soil for each defined parcel and estimates carbon and greenhouse gas emissions and reductions using the DayCent simulation model and other empirical and regional regression models for biomass stocks estimates. Users enter detailed management information for both the historic and future scenarios for their operations.

Ideally, users enter detailed information on all annual crop, pasture, livestock, agroforestry, and forest management practices, as applicable. In the cropping system module, the required information includes annual cropping sequence and approximate planting and harvest dates; type of grazing system (for pasture or range areas); tillage type and timing; fertilizer rate, timing, type, and application method; manure and compost applications; irrigation method, application rate and timing, and residue management - starting from the year 2000 for the baseline management and projecting into the future for the scenarios described below. However, because the Bishop Farm (**FIGURE 6**) is rented, a detailed set of management records back to 2000 was not available. The landowner described the farm management practices as conventional for the area. So, AFT used IL staff knowledge to inform the baseline scenario below. AFT applied the following assumptions in COMET-Farm for historic management: prior to 1980 this upland farm was non-irrigated, from 1980 to 2000 this upland farm was non-irrigated with annual crops in rotation and intensive tillage. AFT used COMET-Farm to estimate changes in carbon sequestration and greenhouse gas emissions among a baseline scenario and three hypothetical scenarios:

1. *Baseline Management Scenario (65 acres)* - a business-as-usual system, typical of corn-soybean production practices for the area. Staff on the AFT Midwest team based in central Illinois provided input on the typical management practices for the region. COMET-Farm parameters:
   - Rotation: Corn - Soybean
   - Tillage: Two tillage passes prior to corn and soybean planting
   - Planting dates: corn, 4/20; soybean, 5/10
   - Harvest dates: corn, 10/14; soybean, 10/11
   - Average yield: corn 180, bushels per acre; soybean, 60 bushels per acre
   - Non-irrigated
   - Fertilizer application: 219.51 lbs Anhydrous Ammonia (180 lbs N) per acre one week before planting corn
   - Calcitic lime at 2 tons per acre every 10 years.
   - No burning of residues

2. *Conservation Cropping Scenario (65 acres)* - a system with cover cropping, no-till, compost application, and fertilizer reduction. COMET-Farm parameters:
   - Planting and harvest dates, average yields, no irrigation, and lime application are the same as the Baseline Scenario
   - Rotation: Corn - annual rye/legume/radish cover crop - Soybean - annual rye/legume/radish cover crop
   - Tillage: No-till
   - Fertilizer application: Reduced by 37.5% to 137.2 lbs Anhydrous Ammonia (112.5 lbs N) per acre one week before corn planting
   - Applied 3 tons compost (60 lbs N) per acre

3. *Alley Cropping Conservation Scenario* – the above conservation cropping system with black walnut alley crops within cropping area. COMET-Farm parameters:
   - Reduce cropping system from 65 to 58 acres – management same as above
   - Add 7 acres of agroforestry: Alley cropping with black walnut

4. *Multi-practice Conservation Scenario* – the above alley cropping system with additional perennial woody plantings in riparian buffers, woodlots, and wind breaks. COMET-Farm parameters:
   - Reduce cropping system from 65 to 42 acres - management same as above *Conservation Cropping Scenario*
   - Add 23 acres of agroforestry practices
     - Alley cropping with 2-year-old black walnut on 7 acres (same as scenario 3)
     - Farm wood lot of 2-year-old oak and walnut on 7 acres
     - Riparian buffers of mixed 2-year-old oak mixture on 7 acres
     - Three-row wind breaks of 2-year-old hackberry, red cedar, and pine on 2 acres

Figure 6. Bishop Farm parcel as it appears in county survey.

To create estimates for the emissions reductions in the agroforestry scenarios, the 65-acre Bishop Farm cropland was split into 3 parcels in COMET-Farm:

a. a 42-acre parcel in the center of the farm's fields, which remained as a cropping system for all scenarios
b. a 7-acre parcel was created in the northeast corner to represent alley cropping woody plantings – in order to prevent double counting the GHG impacts of the annual and woody cropping systems, the alley cropping area that would be within a cropping area is modeled as a separate parcel in COMET-Farm.
c. a 16-acre parcel that was defined adjacent to the existing woody plantings on the farm to represent the riparian buffers, woodlots, and wind breaks in the Multi-practice Conservation Scenario.

In the cropland module for scenarios 3 and 4, the management of agroforestry areas (b and c above) were defined with perennial grasses to mimic the GHG inventory of an unmanaged understory below the woody plantings, while the agroforestry module estimated the GHG impacts of the woody plantings. This allowed COMET-Farm to estimate implementing the agroforestry practices (e.g., a woodlot and additional riparian buffers, respectively) in the same area as the cropping system without double counting the impact of conservation practices. AFT consulted the COMET-Farm team to confirm this was the best approach. COMET-Farm estimates the potential GHG benefits of the cropland and agroforestry modules separately, which can then be combined to estimate the total impact of scenarios using both modules (scenarios 3 and 4).

Results II: Potential Additional GHG Benefits from Agricultural and Agroforestry Conservation Practices

Based on the COMET-Farm estimates for the cropland practices, the average annual net t CO_2e emissions for the Baseline Scenario, conventional corn-soybean system over a 10-year period is approximately 62.4 t CO_2e $year^{-1}$ on 65 acres (

Table 3 and **FIGURE 7**). The average annual t CO_2e emissions of the Conservation Cropping Scenario (add cover crop mix, no-till, and compost; reduce synthetic nitrogen fertilizer) over a 10-year period are approximately -24.7 t CO_2e $year^{-1}$ on 65 acres, in other words, 24.7 t CO_2e is sequestered in this system each year (

Table 3 and **FIGURE 7**). This is due to increased soil carbon storage and decreased CO_2 emissions, which altogether emits 86.7 t CO_2e $year^{-1}$ less than the Baseline Scenario. When the scenarios include agroforestry practices there are slight differences in the average annual CO_2e emissions of the cropped acres due to the differences in cropped acreage and the perennial grasses planted on the agroforestry acres (ranging from -24.4 to -25.4 t CO_2e $year^{-1}$ on 42 to 65 acres) (

Table 3).

Table 3. COMET-Farm report summary results of the cropland module comparing GHG emissions of the four scenarios. Only the bottom row includes carbon sequestered in biomass from woody plantings.

Sources and Sinks	**Baseline** (65 acres) (t CO_2e per year)	**Conservation Cropping System** (65 acres) (t CO_2e per year)	**Alley Cropping System** (58 acres) (t CO_2e per year)	**Multi-practice Conservation** (42 acres) (t CO_2e per year)
Soil C Storage	24.9	-60.2	-56.4	-48.1
Soil CO_2 Emissions	-1.7	-4.3	-3.6	-2.0
N_2O Total	39.2	40.1	35.3	24.8
Direct Emissions	29.8	28.7	25.4	18.2
Indirect Emissions	9.3	11.4	9.9	6.6
Cropping System Total	62.4	-24.4	-24.7	-25.4
Total with agroforestry practices	62.4	-24.4	-31.6	-132.4

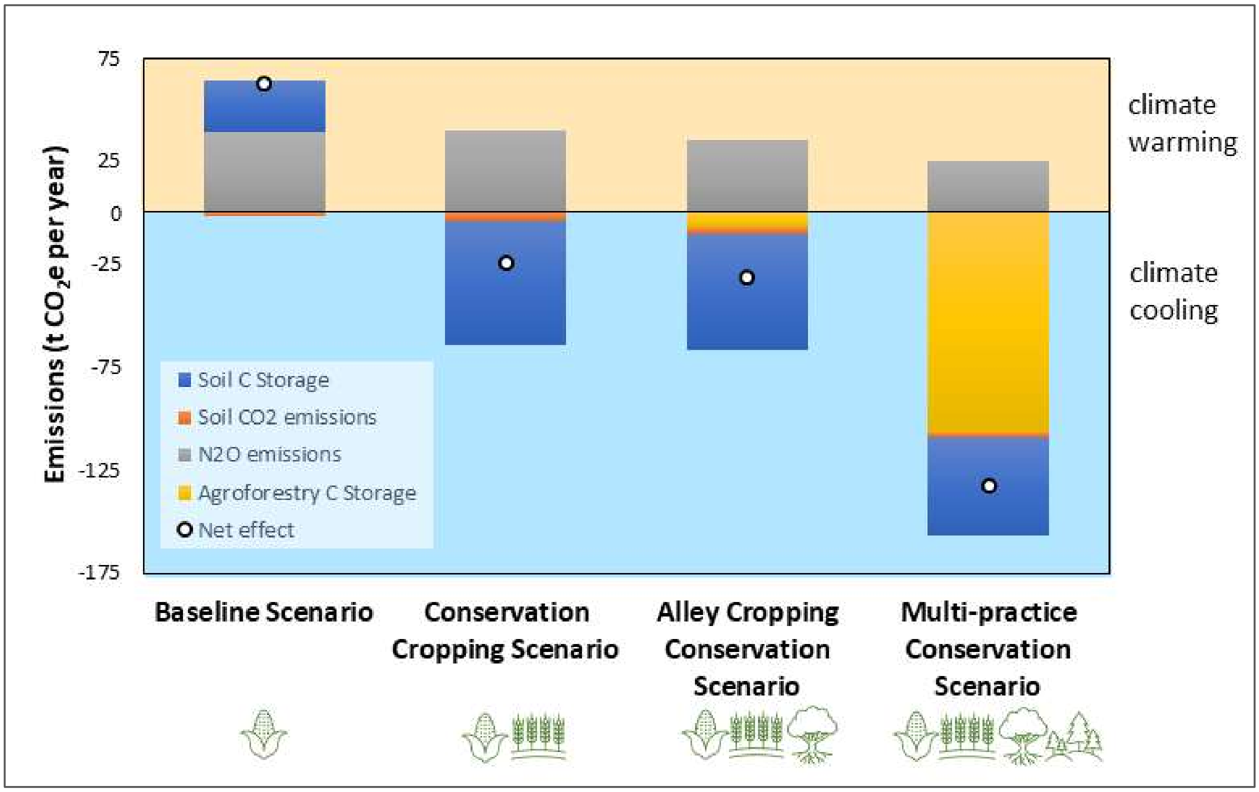

Figure 7. Average annual carbon emissions (or emission reductions) for Baseline, Alley Cropping Conservation, and Multi-practice Conservation Scenarios on 65 acres.

The agroforestry report from COMET-Farm calculates the carbon sequestration of new woody plantings as an annual average over a 50-year period, based on species and acreage. The average yearly sequestration for the Alley Cropping Conservation Scenario is 6.9 t CO_2e $year^{-1}$ on 7 acres. In the Multi-practice Conservation Scenario, the sum of the average yearly sequestration for all four agroforestry practices (alley cropping, woodlot, riparian buffer and 3-row windbreak) totals 107 t CO_2e $year^{-1}$ on 23 acres (IN THE previous section, AFT estimated that avoided conversion of the Bishop Farm to low-density residential avoided about 19,541 t CO2e emissions in the first 30 years. The COMET-Farm analysis demonstrates what the additional GHG benefit could be from the Bishop Farm easement if the protected farm implemented additional conservation practices (TABLE 5). *Note: When reporting the carbon sequestered by agroforestry over the next 30 years below, AFT uses the cumulative totals given in ERROR! NOT A VALID BOOKMARK SELF-REFERENCE., which account for the changing rate of carbon sequestration in wood and soil over the lifetime of a tree. This is more accurate than multiplying the annual averages of the 50-year COMET-Farm scenario given in TABLE 3 or ERROR! NOT* a valid bookmark self-reference. by 30 years. If the farm continues with conventional management, the 65 acres of cropland will emit 1,872 t CO2e over the next 30 YEARS (annual values from Table 3 times 30 years), which means avoided conversion is still a net gain for the climate mitigation. Following THE SAME calculation based on Table 3, if the farm implements the Conservation Cropping System, the 65 acres of cropland will sequester 732 t CO2e over THE next 30 years (Table 5). In the THIRD scenario, according to Error! Not a valid bookmark self-reference. by 2052 the walnut trees will sequester 100.4 t CO2e on 7 acres and, according to Table 3, 741 t CO2e on 58 acres of annual crops for a total OF about 841 t CO2e between 2022 and 2052 (Table 5). In the fourth scenario, Multi-practice Conservation, by 2052 the 42 acres OF cropland will sequester 762 t CO2e (calculated from Table 3), the agroforestry will sequester 2316 t CO2e (Error! Not a valid bookmark self-reference.), for a total of about 3078 t CO2e over the next 30 years, equivalent to about one-sixth of the avoided conversion total.

Table 4 and **FIGURE 8**).

The carbon sequestered on this parcel with the Alley Cropping Scenario is 313 t CO_2e total over a 10-year period on 65 acres. The carbon sequestered on this parcel with the Multi-practice Conservation Scenario is 1324 t CO_2e total over a 10-year period on 65 acres.

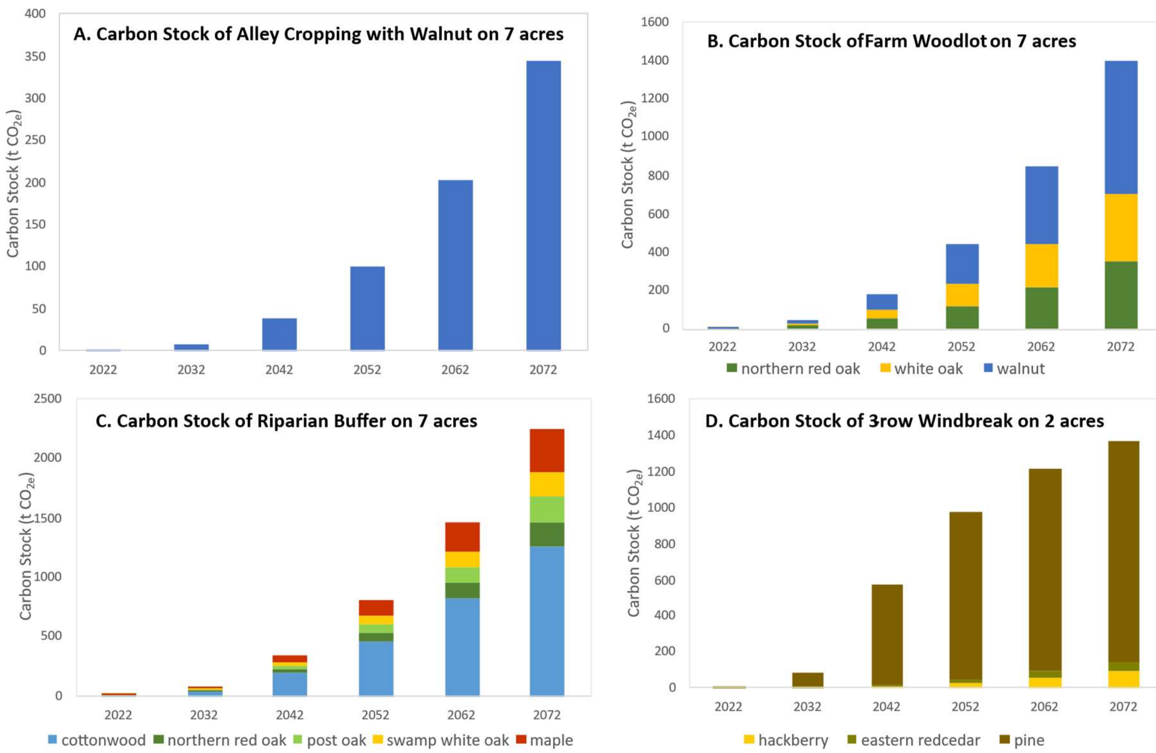

Figure 8. Carbon stock estimates from COMET-Farm for the four agroforestry practices used in the conservation scenarios; alley cropping, riparian buffer, 3-row windbreak, and woodlot, respectively on a total of 23 acres. Note: charts have different vertical axes.

In the previous section, AFT estimated that avoided conversion of the Bishop Farm to low-density residential avoided about 19,541 t CO_2e emissions in the first 30 years. The COMET-Farm analysis demonstrates what the additional GHG benefit could be from the Bishop Farm easement if the protected farm implemented additional conservation practices (**TABLE 5**). *Note: When reporting the carbon sequestered by agroforestry over the next 30 years below, AFT uses the cumulative totals given in ERROR! NOT A VALID BOOKMARK SELF-REFERENCE., which account for the changing rate of carbon sequestration in wood and soil over the lifetime of a tree. This is more accurate than multiplying the annual averages of the 50-year COMET-Farm scenario given in* ***TABLE 3*** *or ERROR! NOT A VALID BOOKMARK SELF-REFERENCE. by 30 years.* If the farm continues with conventional management, the 65 acres of cropland will emit 1,872 t CO_2e over the next 30 years (annual values from **TABLE 3** times 30 years), which means avoided conversion is still a net gain for the climate mitigation. Following the same calculation based on **TABLE 3**, if the farm implements the Conservation Cropping System, the 65 acres of cropland will sequester 732 t CO_2e over the next 30 years (**TABLE 5**). In the third scenario, according to ERROR! NOT A VALID BOOKMARK SELF-REFERENCE. by 2052 the walnut trees will sequester 100.4 t CO_2e on 7 acres and, according to **TABLE 3**, 741 t CO_2e on 58 acres of annual crops for a total of about 841 t CO_2e between 2022 and 2052 (**TABLE 5**). In the fourth scenario, Multi-practice Conservation, by 2052 the 42 acres of cropland will sequester 762 t CO_2e (calculated from **TABLE 3**), the agroforestry will sequester 2316 t CO_2e (ERROR! NOT A VALID BOOKMARK SELF-REFERENCE.), for a total of about 3078 t CO_2e over the next 30 years, equivalent to about one-sixth of the avoided conversion total.

Table 4. COMET-Farm cumulative and annual emissions estimates for each agroforestry practice. Negative values indicate net sequestration.

Source	2022 (Cum. t CO_2e)	2032 (Cum. t CO_2e)	2042 (Cum. t CO_2e)	2052 (Cum. t CO_2e)	2062 (Cum. t CO_2e)	2072 (Cum. t CO_2e)	Average Emissions (t CO_2e per year)
Alley Cropping (with walnut) (2 yr saplings at planting on 7 acres)							
walnut	0.5	8.2	37.8	100.4	202.2	344.0	-6.9
Farm woodlot (with walnut) (2 yr saplings at planting on 7 acres)							
northern red oak	1.1	14.6	50.8	118.3	219.1	351.6	-7
white oak	1.1	14.6	50.8	118.3	219.1	351.6	-7
walnut	1.1	16.5	76.4	202.3	407.3	692.8	-13.8
Total	3.3	45.8	177.7	438.8	845.4	1395.9	-27.9
Riparian buffer (with oak mixture) (2 yr saplings at planting on 7 acres)							
cottonwood	0.7	37.1	188.9	458.7	821.9	1248.5	-25
northern red oak	0.7	8.8	30.5	71	131.4	210.9	-4
post oak	0.7	8.8	30.5	71	131.4	210.9	-4
swamp white oak	0.7	8.8	30.5	71	131.4	210.9	-4
maple	0.7	15	58.4	134.2	238.5	364.7	-7.3
Total	3.3	78.5	338.8	805.8	1454.7	2245.9	-44.9
3-row windbreak (2 yr saplings at planting on 2 acres)							
hackberry	0.1	2.2	10	26.7	53.8	91.5	-1.8
eastern redcedar	0.3	3.1	10.4	21.9	36.6	53.5	-1.1
pine	0.3	82.8	547.5	922.6	1125.1	1219.7	-24.4
Total	0.7	88	567.9	971.1	1215.5	1364.6	-27.3

Table 5. Emissions from the baseline and three conservation scenarios over 30 years. Negative values indicate sequestration or reduced GHG emissions. Estimates from COMET-Farm.

Scenario	Cropland (t CO_2e 30 years)	Agroforestry (t CO_2e 30 years)	Total (t CO_2e 30 years)
Baseline	**1870**	**0**	**1870**
Conservation Cropping System	**-732**	**0**	**-732**
Alley Cropping System	**-742**	**-100**	**-842**
Multi-practice Conservation	**-760**	**-2316**	**-3076**

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Appendix: Avoided Conversion Literature Review

Scope of Work

For AFT's goal to develop a scientifically valid and defensible case study to estimate the avoided greenhouse gas emissions (GHG) associated with an agricultural land conservation easement, AFT reviewed the requirements for estimating GHG emissions at the farm scale, carbon offset protocols, and the relevant methodologies that set a precedent for avoided conversion of a land use.

Setting the stage for avoided conversion of farmland to development

The Food, Conservation and Energy Act of 2008 directed USDA to prepare technical guidelines and science-based methods to measure environmental service benefits from conservation and land management activities. Its first effort focused on carbon. First, USDA reviewed techniques that were in use for estimating GHG emissions and removals from agricultural and forestry activities (Denef et al. 2011; Denef et al. 2012). The agency then prepared a technical report that outlined preferred science-based approach and specific methods for estimating GHG emissions at the farm or forest scale (USDA OCE 2014). They established the following criteria for methods to maximize their usefulness:

- ✓ Stand on their own, independent of any other accounting system while being consistent with other accounting systems as much as possible.
- ✓ Be scalable for use at entity-scale sites across the U.S. with applicability at county and/or state levels as well.
- ✓ Facilitate use by USDA in assessing the performance of conservation programs.
- ✓ Provide a broad framework to assess management practices to evaluate the GHG aspect of production sustainability.
- ✓ Maintain maximum applicability for use in environmental markets.
- ✓ Be scientifically vetted through USDA, U.S. Government and academic expert review and public comment.
- ✓ Provide reliable, real, and verifiable estimates of onsite GHG emissions, carbon storage and carbon sequestration.
- ✓ Provide a basis for consistency in estimation and transparency in reporting.

USDA's guidance on estimating the net GHG flux resulting from changes between land use types focused on conversions into and out of cropland, wetland, grazing land or forest land. Although developed lands were recognized as a land use category, there were no methodologies for the avoided conversion of croplands and/or other agricultural land types to development available to review at that time.

Yolo County, California set California on a path to developing such a methodology when it commissioned an inventory of its GHG emissions. The inventory was used to develop a strategy for smart growth implementation, GHG reduction, and climate change adaptation (Yolo County 2011). The Yolo County inventory relied on existing data and emission factors obtained from the California Air Resources Board (CARB) for mobile sources and US EPA and the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Fertilizer use was estimated using University of California Cooperative Extension (UCCE) Current Cost and Return studies for various crops grown in Yolo County and California Department of Food and Agriculture (CDFA) Fertilizer Tonnage Reports. The average emissions per acre of urban land were over 70 times more than the estimates for irrigated cropland. The average emission rates in t CO2e per acre per year were 1.7 to 2 for rangeland, 4.9 to 5.4 for cropland and 376 for urban land. These results along with other studies using projections out to 2050 under different climate scenarios showed that the most important climate change mitigation policy that Yolo County could adopt would be to restrict urban development to infill locations within existing cities and keep existing farmland in agriculture (Jackson et al. 2012; Haden et al. 2013).

AFT followed up by analyzing subsequent research done on GHG emissions from agricultural and urban land uses throughout California and concluded that, on average, urban areas emit 58 times more GHG per acre than the state's farmland (Schaffer and Thompson 2015). In 2017, a similar analysis by AFT in New York found that farmland emits approximately 66 times fewer GHGs per acre than developed land in New York (Arjomand and Haight 2017).

Precedence for avoided conversion protocols

The development of the avoided conversion of forestland and the avoided conversion of grasslands to crop production methodologies set a precedence for avoided conversion of a land use. The methodologies require users to demonstrate a significant threat of conversion and place the land under a conservation easement to prevent conversion from happening. However, these protocols are not completely analogous to avoided farmland conversion. While avoided forestland or grassland land projects keep land uses in place that sequester carbon, avoided farmland conversion projects keep a land use in place that might emit GHGs depending on management and climate, but at a much lower rate than the alternative land use, urban development.

Forest Avoided Conversion Protocol

The CARB Compliance Offset Protocol - U.S. Forest Projects establishes emission offsets through Avoided Conversion Projects, by establishing a Qualified Conservation Easement (CARB 2011), which was updated in 2015 (CARB 2015). The project must demonstrate that the forest land placed in the easement was under significant threat of conversion to a non-forest land use and meet other additionality and reporting requirements. The baseline for avoided conversion projects is a projection of onsite forest carbon stock losses that would have occurred over time due to the conversion of the project area to a non-forest use. Project duration is a minimum of 100 years

Grassland Avoided Conversion Protocols

Both the Climate Action Reserve (CAR) and the American Carbon Registry (ACR) have developed protocols that quantify emission reductions from the avoided conversion of grasslands. The CAR protocol uses default emission factors developed through a probabilistic composite modeling approach and uses USDA Major Land Resource Areas to identify emission factors. The ACR protocol uses two types of models to quantify emission reductions: process-based biogeochemical models and empirical models based on time series measurements and proxy sites. Based on its review of both protocols, California's Compliance Offsets Protocol Task Force Subgroup recommended that CARB consider the adoption of a protocol which credits avoiding the conversion of grasslands to croplands and evaluate the potential for the development of a protocol which credits avoiding the conversion of grasslands or croplands to the built environment (COPTF 2021).

- Grassland Protocol V2.1 (Climate Action Reserve) – GHG emission reductions are quantified by comparing actual project emissions to the calculated baseline emissions (emissions that would have occurred in the absence of the project). The baseline assumption is that the project area would be converted to cropland absent the project activities. Since detailing the exact nature of the converted land use (crop rotation, tillage practices, fertilization, ongoing management) is uncertain and subjective, CAR adopted a modeled composite approach to determining carbon emissions for the baseline scenario. The protocol establishes emissions estimates for 1,002 total strata within the U.S., using geography and associated climate, soil texture and previous land use for its stratification (Climate Action Reserve 2020). It uses a 100-year time period but allows a project owner to agree to a shorter commitment in exchange for a discounted number of credits. The Climate Action Reserve released the Canadian version of their Grassland Protocol in October 2019. It calls for project commitments between 20 and 100 years and the shorter the time commitment, the greater deduction on offset volume received. Grasslands: Avoided Conversion of Grasslands and Shrublands to Crop Production (American Carbon Registry 2019) – First drafted in 2014, the intent of the Methodology is to incentivize avoided soil carbon loss and agricultural GHG emissions by placing grasslands under conservation easements that preclude cultivation. The methodology quantifies the emissions avoided from preventing the conversion of grasslands and shrublands to commodity crop production in the U.S. In addition to the avoided cultivation and oxidation of soil organic carbon, several crop production practices, such as fertilizer application, may also be avoided. Livestock, primarily cattle, are anticipated to be common in the project scenario and associated emissions from enteric fermentation and manure management are included. There are two baseline scenarios: one where the conversion agent is identified and one where the conversion agent is unidentified. If the latter, the historical rates of conversion of existing grasslands and shrublands within a county are used along with the various land capability classes suitable for agriculture at the field level. The methodology includes a default market leakage estimate to account for leakage due to removal of grasslands from the supply of potential new cropland. Forestland and Grassland Avoided Conversion Protocol – A global methodology for avoided ecosystem conversion was also developed by the Verified Carbon Standard (VCS) (VCS 2014). It quantifies net GHG emission reductions and removals from project activities that prevent conversion of forest to non-forest and of native grassland and shrubland to a non-native state. The protocol differentiates between eight baseline types based on the proximate agent of conversion, the drivers of conversion, whether the specific agent of conversion can be identified, and the progression of conversion. For forest baseline types, conversion usually means logging or conversion to cropland. For grassland baseline types, conversion includes the land-use categories of agriculture, development (including housing) or other anthropogenic land use discernable from remotely sensed imagery. The project must provide evidence that the project area was intended to be converted in the absence of the easement.

Zeroing in on avoided farmland conversion

In 2014, AFT discussed the possibility of developing an Avoided Farmland Conversion protocol with several members of the Coalition on Agricultural Greenhouse Gases(C-AGG) (Shaffer 2014). They concluded that a protocol development would need to address specific issues that the avoided forest lands and avoided grasslands protocols did not:

- Accuracy and preciseness of emissions quantification.
- Additionality of the farmland protection transaction from both an emission and an economic standpoint.
- Leakage as far as the efficacy of permanent farmland protection to prevent sprawl and leapfrog development.
- Determining who holds the emission offset credits.

AFT developed two methodologies for determining the impacts of avoided conversion at the state level. In 2015, AFT calculated the weighted statewide average of emissions from seven of California's leading crops and compared it to a statewide weighted average of emissions from 13 cities (Shaffer and Thompson 2015). The analysis used the DeNitrification-DeComposition

Model (DNDC) to calculate the GHG emissions from the studied crops. AFT used the Cool Farm Tool to add emissions from on-farm fossil fuel use. To calculate the GHG from development, AFT used the inventories developed in the Climate Action Plans of 13 California cities to calculate per acre urban emissions, dividing the total emissions by the land area of the respective cities reported by the U.S. Census Bureau.

Two years later, AFT analyzed the impacts of avoided conversion in New York State (Arjomand and Haight 2017). For this analysis, AFT calculated the GHG emissions from three major agricultural GHG emission sources: manure, enteric fermentation, and fertilizer use. The analysis did not include long-term carbon sequestration in orchards, tree farms, pastureland or woodlands associated with farms nor the annual carbon sequestration by crops. To calculate the areas of agricultural lands within each county, AFT used the 2006 National Land Cover Data. The data for developed emissions was gathered from county-level emission inventories completed by each Regional Economic Development Council through the New York State Energy Research & Development Agency (NYSErDA) Cleaner, Greener Communities program. These inventories were based on the New York Community and Regional GHG Inventory Guidance for the baseline year of 2010. They included residential, commercial, and industrial development.

Around the same time, California's Sustainable Agricultural Lands Conservation Program (SALC is a grant program launched in 2014-15 to provide funds to acquire agricultural conservation easements) started taking steps toward reducing GHG emissions caused by farmland conversion to urban and suburban uses (Merrill and Wheeler 2015).

In August 2020, CARB released the Agricultural Lands Conservation Easement Quantification Methodology (QM) (CARB 2020). It estimates the avoided GHG emissions and air pollutant emission co-benefits associated with agricultural lands conservation easements. At the parcel level, it is the only currently available peer-reviewed methodology. It was developed after CARB staff reviewed the literature and available tools and consulted with experts. CARB released the draft QM and on-line tool for public comment in August 2020 and then finalized it to address public comments where appropriate. The QM includes equations to estimate benefits of each proposed project component and uses calculations to estimate avoided emissions from reduced vehicle miles traveled, reduced utility use, and avoided loss of soil carbon. The implementing principles ensure that the QM applies at the project level, provides uniform methods to be applied statewide, uses existing and proven tools and methods, uses project-level data and results in GHG emission reduction estimates that are conservative and supported by empirical literature.

SALC now uses the QM to estimate the outcomes of proposed projects, inform project selection and track the results of funded projects. The QM has been approved for use by but is not limited to SALC and the Climate Adaptation Readiness Program (CARP). The CARB staff periodically review each quantification methodology and update them if necessary. A draft update QM was released in September 2022 for public comment.

Farm GHG emissions

The QM does not factor in GHG emissions from producing crops. By using the COMET-Farm tool, AFT can add a convenient and scientifically rigorous way to evaluate the carbon sequestration and GHG emissions related to annual crop production, and livestock, and the on-farm energy use for the farm being considered for an easement (Perez and Cole 2020). COMET-

Farm integrates activity data (specific to the land use and management practices used) with emission rates that estimate GHG fluxes as a function of the activity data and the climate and soil conditions at a particular location (Paustian et al. 2017; Kaplan et al. 2021). The COMET-Farm estimates are built upon the biogeochemical process model DayCent, which is also used in the official U.S. National Greenhouse Gas Inventory. The DayCent model has been evaluated for its ability to accurately predict soil carbon change, crop yield and greenhouse gas emissions. COMET-Farm also offers an agroforestry module that allows landowners and land managers to view agroforestry systems in the same context as agricultural operations (Ziegler et al. 2016).

Projected development
A property appraisal report can be used to determine the amount of development that could occur if it stipulates the Highest and Best Use (HBU) of the land. Property appraisal data may provide a detailed analysis of its market value before and after the conservation easement, the zoning, the estimated value of the land, etc. The HBU is typically based on case-specific characteristics (size and shape of property, location, zoning (the maximum allowed rural development density), topographic characteristics, ease of access to essential utilities (i.e., roads, water, sewer, electricity), historical use and proximity to nearby urban centers. In California, a property may also have certificates of compliance (COC) that help determine the amount of development permissible. It indicates that an area is an existing legal lot or parcel that may be sold, leased, or financed separately from other pieces of property without further processing required under the Subdivision Map Act. This kind of information has been used to calculate avoided land use conversions and carbon loss from conservation purchases in California (Moanga et al. 2018). In Illinois, a conservation easement appraisal is not always required but can help determine the amount of any income tax deduction available and can be important in estate planning or in reviewing value for property tax purposes. Appraisals may also be needed to obtain a mortgage subordination, to support a request for a property tax adjustment or to receive payment in exchange for the easement. Appraisers typically look at the location and character of the property, existing zoning regulations, development potential and future land use trends, specific restrictions placed on the land, specific rights reserved by the landowner and the existence of contiguous or other property owned by the landowner or landowner's family and the potential of the easement to enhance the value of the other property. The IRS has very specific requirements for appraisals of conservation easements where the landowner is claiming a charitable contribution deduction for the value of the easement (Natural Land Institute 2022).

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