New York Agriculture and Climate Change: Key Opportunities for Mitigation, Resilience, and Adaptation

Final Report on Carbon Farming project for the New York State Department of Agriculture and Markets

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Executive Summary

Context

Following the New York State (NYS) Department of Agriculture and Markets (AGM) mandate (2008 NYS Bill S8148/ A10685), NYS fiscal year 2017-18 budget (S2004-D), and the Carbon Farming Act (A3281), this project, administered through NYS AGM develops a scientifically based assessment of opportunities and barriers to support climate adaptation and mitigation practices on working NYS agricultural lands.

Carbon Farming was defined as "the implementation of a land management strategy for the purposes of reducing, sequestering, and mitigating greenhouse gas emissions on land used in support of a farm operation and quantifying those greenhouse gas benefits". We evaluated three key greenhouse gases (carbon dioxide, CO_2; methane, CH_4; and nitrous oxide, N_2O) associated with working lands and identified co-benefits including water quality, profitability, adaptation to climate change, community relations, and energy, among others.

In an effort to assist NYS in meeting its ambitious greenhouse gas (GHG) mitigation mandates, we developed a SMART matrix to rank the most promising GHG mitigating strategies (Table 3). This matrix includes the following elements:

(1) Services: co-benefits from activities that also mitigate GHG;
(2) Measurable: a state level quantification of the mitigation opportunity and the degree to which it is verifiable;
(3) Achievable: a farm financial savings or financial support necessary to implement the mitigation practice;
(4) Realistic: ease or difficulty in implementation (e.g. number of stakeholders/acres needed to be engaged);
(5) Time Frame: the time scale over which the mitigation would occur and the degree to which the mitigation is permanent or reversible.

Key Takeaways for Incorporating GHG mitigation from Working Lands into NYS policy

1) ACCOUNTING
    a. The combined flux and permanence of all three agricultural GHGs (CO_2, CH_4 and N_2O) must be considered together when assessing working lands. The net GHG emissions over a specified time period may help NYS frame what it considers a permanent mitigation (i.e. not easily reversible) and verifiable from a given activity. Permanence and Verifiability are key elements for carbon farming accounting.
    b. For example: any effort to account for GHG mitigation by soil health practices will require feasible, credible, and cost-effective GHG verification over time to ensure credit to soil organic carbon stocks while also deducting the associated N_2O emissions. Notably, agricultural systems are governed by dynamic and complex processes that are easily reversible due to natural or human activities such as weather, climate, and landowner management decisions. Thus, for certain practices, permanence and verification are barriers to accounting for carbon farming.
2) OFFSETS
    a. If NYS has agricultural working lands participate in market-based or cap-and-trade offset programs with other sectors, it must determine the certainty of each practice for achieving 'real, permanent, additional, verifiable' mitigation that does not cause 'leakage' across sector or state boundaries.
    b. For example: to implement, measure, and verify carbon farming practices are sufficiently robust to count as agricultural GHG mitigation (either addressing within-sector emissions or qualifying as an offset for emissions from another sector), NYS must decide whether to spend resources on labor-intensive verification protocols (for rigorous cross-sector accounting) or to support farmers to implement best management practices (whole system ecosystem services similar to current water quality initiatives).

3) VERIFIED MITIGATION vs. IMPROVED FARM RESILIENCY
   a. As agriculture includes diverse products, practices, and changes in land use and tenure, NYS will need to balance its desire to maximize crediting from all farm practices against the costs of implementation, burdens of accounting, verifying, and ensuring the mitigation benefit is not reversed at a later date by subsequent activities.
   b. For example: NYS might choose certain agricultural practices to participate in market-based offsets because they are easily verifiable and permanent while also supporting less easily accountable mitigation activities as co-benefits to other important initiatives such as soil health or water quality.
4) COSTS
   a. The social cost of carbon is an estimate of the dollar value of the total long-term damages caused by emission of a metric ton of CO_2. NYS must determine its social cost of carbon to consider how future generations will be burdened by a changing climate.
   b. Funds will need to be collected and directed to implement GHG mitigation activities.
   c. We have identified practices which will save money for a farm (e.g. improved nitrogen management or improved feed management), earn money in coming decades (e.g. woodland management) or require upfront costs (e.g. manure storage cover + flare) but could participate in robust offset programs funded by other sectors.
   d. As discussed above, the degree to which verification and accounting is required adds costs that must be considered.
5) OUTREACH NETWORK
   a. NYS has a spatially distributed and robust technical assistance network (SWCD and CCE) with various farm assistance programs through state, non-profit and other organizational capacity. This existing network should be leveraged to further include GHG mitigation and outreach programming.
   b. For example: active water quality and soil health initiatives both target soil carbon and nitrogen management for water resource protection as well as farm profitability. Improved soil carbon and reduced nitrous oxide emission from improved nitrogen management practices are two co-benefits that could be incorporated into existing farm visits and management plans for water quality and soil health.
6) TECHNICAL ASSISTANCE
   a. Stronger technical assistance is needed to overcome barriers in all aspects of Carbon Farming.
   b. For example: measuring and analyzing GHG emission and mitigation potential from field management practices over time, creating demonstration plots, developing educational materials and tools, training educators, increasing peer-to-peer teaching, increasing agriculture and forest sector communication, administering grants, developing policies, crafting incentives, etc.

Priority Actions for Implementing GHG mitigating practices on NYS Agricultural Lands

In the main report, Table 3 presents opportunities in order of the size of total statewide GHG mitigation potential (largest technical potential first, smallest technical potential last). From that suite of practices, the following five practices were selected for priority implementation because they are the most cost effective and permanent opportunities using currently available technologies and realistic verification methods. These opportunities have co-benefits that are synergistic with other NYS initiatives such as water quality, farm profitability, and energy saving. To note, the 5th option, '*Activation of underutilized lands*', offers a large mitigation opportunity but deserves close scrutiny from a State planning perspective because it involves land-use changes that would affect current and future generations of stakeholders.

Manure storage cover and flare

Context: Manure storage units have been installed across NYS to improve water quality by reducing daily spread of manure. However, manure storage creates large amounts of methane (CH_4), a potent GHG.

Benefit 1: By covering these storage units, NYS further ensures water quality by preventing extreme precipitation from causing overflow and violations of State Pollutant Discharge Elimination System (SPDES) permit and/or water quality.

Benefit 2: By capturing and flaring the methane created by these storage units, NYS addresses a point source of GHG emission at a relatively low cost per unit of GHG mitigated (i.e. a low cost to society, but not necessarily to an individual farm). This system provides an easy to verify and permanent emission reduction with current technology and is practical because it requires participation of only a small group of about 500 farms.

Opportunity: This opportunity engages ~500 farms, has the potential to easily verify and permanently mitigate ~1.29 Tg CO_2e/yr at a cost of <$13 Mg CO_2e (based on GWP of $CH_4 = 25$).

Barriers: Has upfront costs; may require retrofitting as existing manure storage units may not be currently suitable to receive a cover; current water quality policies to implement new manure storage units should be revised to include a cover or include a design to retrofit a cover easily at a later date; milk prices might affect whether farmers are able to take advantage of the cost-share system currently in place (see incentives).

Incentives: Destroying methane addresses a potent Short-Lived Climate Pollutant (SLCP); "cover+flare" systems are inexpensive from a Social Cost of Carbon perspective; there is existing NYS AGM Climate Resilient Farming (CRF) cost share programming for "cover+flare" system expansion; there are farmers who have covers and flares who can share their first-hand experience; some farms install covers simply to reduce odors and improve neighbor relations.

Nitrogen management

Context: Nitrogen (N) is important for plant growth, but N that is not taken up by plants can result in nitrous oxide (N_2O) emissions, a potent GHG.

Benefit 1: Improving N use efficiency while maintaining or increasing yields will reduce emissions of ammonia that causes air pollution and reduce nitrate leaching that causes water pollution.

Benefit 2: Improving the efficiency of nitrogen (N) fertilizer use can save money while maintaining or increasing crop yields. This is accomplished by applying N fertilizers according the site-specific needs of a field using the 4R principles (right source, right time, right rate, and right place).

Benefit 3: Because N_2O is an extremely potent and long-lived GHG, small improvements in N management result in GHG reduction at low cost.

Opportunity: This opportunity engages all farms and could be verified indirectly to mitigate ~0.2Tg CO_2e/yr. We estimate ¾ of this mitigation opportunity could be achieved by cost-savings on farm or <$10 Mg CO_2e.

Barriers: Some farmers likely apply extra N as 'insurance' to avoid any yield penalty if growing conditions are extremely favorable. However, the 4R principle guidelines have gained traction and have modest upfront costs. The precision N-management systems have more upfront costs for tools, training technical assistance and extending these skills to farms and fields but provide improved profitability and reduced N pollution to watersheds and N_2O emission to the atmosphere.

Incentives: Improving N use efficiency can save money or be inexpensive to implement making it a rational decision for many farms. Farmers have support through NYS Soil and Water Conservation Districts (SWCD) and Cornell Cooperative Extension (CCE) to improve N use efficiency. Incentives may be needed to make more sophisticated precision management tools available along with proper training to education and outreach organizations like SWCD and CCE staff who do farm site visits. Alternatively, N-industry officials could subsidize tools and then function as carbon-credit aggregators but may have a conflict of interest (sell more fertilizer versus gain more credit for climate mitigation).

Livestock feed management

Context: Increasing feed efficiency can often improve farm viability by improving production efficiency; this reduces the CO_2, CH_4, and N_2O emissions from feed production, livestock (enteric), and manure.

Benefit 1: Improved feed efficiency can lower costs and improve farm profitability.

Benefit 2: Improved feed efficiency can reduce water, air and GHG emissions from feed production, enteric, and manure management system emissions.

Opportunity: This opportunity engages all dairy farms. We estimate this practice could be verified indirectly to mitigate ~ 0.7 Tg of CO_2e/yr. This practice could be implemented at a cost-savings to the farmer or would require modest support for improved feed management planning and implementation.

Barriers: There are up-front and ongoing costs for improved diet planning, feed and forage management, implementation, and sustaining implementation.

Incentives: Improves farm profitability. Reduces acres needed for feed production (beneficial leakage). Training, support, and peer-to-peer sharing may make this practice a long-lived cultural norm.

Woodland management

Context: According to NYS AGM, more than 21% of agricultural land is wooded (~1.4 million acres), providing an important carbon sink in NYS.

Benefit 1: Woodlands diversify the farm portfolio while providing wildlife habitat, improved water quality, and other ecosystem services.

Benefit 2: Protecting, maintaining, and better managing woodlands on farms conserves and enhances an important NYS carbon sink.

Opportunity: This opportunity engages 1.4 million acres currently owned by farmers. While we don't have an estimate of the total GHG mitigation potential for this opportunity, it represents a large sink that could be managed better for long term profitability, forest health and improved carbon sequestration at a low cost per unit of GHG mitigation.

Barriers: Improved GHG mitigation in woodlands requires decadal management but has 100-year or longer carbon sequestration benefits. Requires upfront investment for a qualified forester to develop a management plan, requires cost or labor to implement the plan and perform periodic maintenance. Policy makers and Cooperative Extension often function in silos of 'agriculture' and 'forestry' when there may be great benefit of sharing knowledge and strategy between these two important land types, landowners, and land managers.

Incentives: Educating and supporting improved woodland management to defray implementation costs improve farm profitability in the long term by increasing value of harvestable wood products. These activities also increase total carbon sequestration if properly implemented.

Activation of underutilized lands

Context: There are ~1.7 million acres of underutilized or former agricultural lands in NYS that could be activated (Wightman et al. 2015a) for purposes such as bioenergy production, solar arrays, and forestry (for increased wood products and concomitant GHG mitigation by carbon sequestration and/or fossil fuel displacement).

Benefit 1: Currently these lands provide a myriad of ecosystem services.

Benefit 2: If converted to forest, these lands could provide a very large new carbon sink for NYS. However, these lands could also support other valuable GHG mitigating activities such as agroforestry, renewable energy, perennial cropping systems, or increased livestock production.

Opportunity: This opportunity engages 1.7 million acres of idle or underutilized grass and shrub lands. *If* converted to healthy growing forests, this land area could mitigate ~4.9 Tg CO_2e/yr at a cost of ~$10-$50/Mg CO_2e.

Barriers: Afforestation requires substantial upfront investment and proper management to overcome pests and establish a forest stand although over time it could increase landowner income. These lands are of variable productivity, some are sloping, some are small parcels, and landowners have many goals for their land besides commercial agriculture, forestry, or energy production. Therefore, not all of these lands will be available and would also require a great deal of effort to mobilize the wide variety and large number of landowners to invest in commercial enterprises.

Incentives: The mitigation value for this land represents a large opportunity (see Afforestation of idle agricultural land in Table 3). Land use planning should be considered in any incentive program. With upfront investment, proper management, and supply chain development, activities could increase landowner income, but substantial incentives would likely be required.

A note on the need for Policy Analysis for determining appropriate Policy Levers for Agricultural GHG mitigation

This report was motivated by the idea that a policy lever such as a tax incentive would help farmers adopt certain GHG mitigating practices. Adopting a beneficial practice is very different than accounting for the quantity or quality of the mitigation practice to be compared to other mitigation strategies or to verifiably attain state mandated GHG mitigation targets. This analysis provides a preliminary technical potential of GHG mitigation for a range of practices to inform policy analysis. Additionally, we have identified co-benefits associated with each practice and evaluated these practices with key terms important to policy analysis: Real, Permanent, Verifiable and Leakage. We do not qualify if a practice is Additional, for reasons discussed in Appendix B. While all of these criteria are important, our selected Priority Actions above were selected as being both permanent and verifiable. How policy levers are designed to maximize practice implementation within the larger state objectives is outside the scope of this report. Many criteria must be considered beyond the technical potential and the co-benefits of the practices. For example, policy analysis should help to minimize gaming, assess leakage among sectors or states, compare more rigorous additionality requirements to achieve real cross-sector reductions, or evaluate payments that support bundling of diverse benefits of improved working land practices. However, in listening to various stakeholders we have heard some relevant points listed below.

- A tax incentive is only useful if a farm is profitable enough to use this benefit implying this is only helpful to more profitable farms.
- The existing cost-share program (e.g. NYS AGM Climate Resilient Farming (CRF) program had a reduction of applications for manure covers + flare in years of low milk prices) and also seems to be dependent on farm profitability.
- Advocating that farms spend dollars now on improved woodland management requires upfront investment for establishment and maintenance and only becomes profitable decades later if there is demand for wood products. While agricultural woodlands can be harvested intentionally for planned events such as funding a child's college education or a landowner's retirement, they may also be harvested sub-optimally and aggressively to provide immediate cash during difficult economic times.
- Advocating that land be put into trusts to ensure GHG mitigation may inhibit the ability of farms to respond to social and economic shifts. Likewise, converting idle agricultural land into forests for more permanent carbon sequestration inhibits the state's ability to use that land to expand agricultural production.
- Payments for ecosystem services or incentives for a system change (e.g. converting annual crops to perennial crops or adding cover crops) require a commitment to sustain those payments and systems or else some or all of the GHG mitigation may be lost.
- The economy of scale for small farms to participate in a given opportunity (e.g. buy new equipment to implement a new practice that covers a small area) may be cost-prohibitive.
- Certain incentives to other sectors, such as programs to increase solar arrays could compete for high quality agricultural land in close proximity to roads or transmission lines.

The above points are not exhaustive of issues associated with different policy levers – rather they illustrate that NYS needs a framework for how it wants to engage its working lands for multiple benefits to society including food, feed, fiber, and fuel production, improved water and air quality, rural economic vitality, recreation, aesthetics, diversity, etc. While there are many ways to support farms, we have provided the rationale to incentivize certain more permanent and verifiable GHG mitigation practices while identifying other practices that are less permanent and verifiable as 'directionally beneficial' for GHG mitigation – a co-benefit that can be bundled with other NYS objectives like initiatives to support regenerative agriculture.

Summary

As NYS endeavors to meet its ambitious climate mitigation goals and as agriculture adapts to a changing climate, we recommend NYS prioritize the more permanent and easily verifiable GHG mitigating practices first as they reduce GHG emissions with a reasonable degree of accountability. There are many opportunities for farmers and other landowners to pro-actively mitigate GHG emissions, but it is critical that the flux of all three GHGs (CH_4, N_2O and CO_2) be considered together and that priority be given to more permanent mitigation required to address climate change. For example, there is a push to sequester carbon in soil or in growing trees but the former can be hard to verify and easily reversible while the latter can be easier to verify and more permanent. There are two major categories of cost, 1) practice implementation and 2) practice verification (including accounting, insurance, etc.). NYS will need to decide if it wants to implement more practices with less stringent verification, or if it wants the agricultural sector to actively participate in cross-sector offsets requiring more rigorous protocols to ensure real, verifiable and enforceable mitigation. Additional consideration should be given to avoiding detrimental leakage as well as promoting beneficial leakage such as reducing "upstream" emissions from fertilizer manufacturing that occurs outside NYS. There are also many competing demands for NYS land, with trade-offs for increasing agricultural production versus bioenergy feedstock production versus carbon sequestration. Above we have highlighted the top five best management practices (BMPs) for immediate policy development that could be implemented in the next 2-5 years. Below in Table 3 we include a wide range of other opportunities worthy of further research or more critical consideration before policy development.

Background

Twenty-five U.S. states and territories including New York State (NYS) participate in the US Climate Alliance to deliver on commitments to the Paris Climate Agreement (as of 2020). New York is the 4th most populated US State covering 54,000 square miles equivalent in size to countries such as Bangladesh, Greece, Uruguay, or North Korea. Of that area, 25% is agriculture and 63% is forested. New York is positioned to be a leader in combating climate change with ambitious GHG mitigation targets, including the passage of the Climate Leadership and Community Protection Act (CLCPA) which requires 85% reduction of greenhouse gas emissions from all sectors by 2050 (40% by 2030). This report identifies ways that working lands in NYS may help meet the 2030 goals at low cost and with other benefits to help our farms, forests and communities thrive in a changing climate.

Investing in conservation, restoration, and improved land management practices can increase carbon storage and avoid GHG emissions. A recent study for the USA quantified 21 Natural Climate Solutions (NCS) "pathways" such as improved forest management and improved agricultural practices that offer cost-effective climate mitigation opportunities (Fargione et al. 2018). In this report, we identify mitigation pathways that we believe are most promising for policy development by NYS to help meet its ambitious GHG mitigation goals, either directly through GHG-specific policies, or indirectly as co-benefits associated with achieving other benefits such as improved water quality, soil health, or increased renewable energy.

Every decision among the options presented is directly and indirectly a function of land-use and land-use change. That is, the policies developed will have land use and social consequences. For example, if food waste by end-users is reduced, less land is required for food production, freeing up land resources for other initiatives. Improved transportation systems combined with higher density development will use some land but may also reduce transportation emissions and reduce development of current agricultural lands. Increasing demand for renewable energy may favor large-scale solar installations on prime agricultural land in place of biomass derived forms of energy (food, feed, fiber, biofuel). We recommend that NYS take a bird's eye view of how it wants to use its finite land resource base over the next 100 years. We recommend an overarching assessment of the quality and quantity of the land resource base so that policies can be set in place to navigate community development (e.g. housing, roads), ensure ecosystem services (e.g. provision of clean water and air), evaluate production from non-developed lands (e.g. activate idle lands), manage market and other forces that cause land use change (e.g. agricultural land to forested land, housing, or renewable energy projects), and consider agricultural intensification (e.g. double cropping, alley cropping, and agroforestry). Climate planning around development, agriculture, forestry, and underutilized lands should have a land-use-planning component (not addressed in this report), an inventory of emissions and emissions reductions from the land (for a preliminary report see McDonnell et al. 2020 in press), and an assessment of feasibility for particular activities currently achievable as well as those likely to be achievable in the near future (addressed in this report). During the last century NYS has moved from being primarily agricultural to primarily forested (on a land area basis). However, these agricultural lands that have returned to forest are often not actively managed and increased efforts to provide information and assistance to landowners would be beneficial within Cooperative Extension and Soil and Water Conservation District agendas. As agricultural and forested lands are deeply linked socially, politically and geographically, we recommend an increase in Extension and outreach effort for the management of forests in the same way we advocate the management of active agricultural land for the benefit of all.

Following the NYS Department of Agriculture and Markets (NYS AGM) mandate (2008 NYS Bill S8148/A10685), NYS fiscal year 2017-18 budget (S2004-D), and the Carbon Farming Act (A3281), this project, administered through NYS AGM develops a scientifically based assessment of opportunities and barriers to support climate adaptation and mitigation practices on working NYS agricultural lands. Carbon Farming was defined as "the implementation of a land management strategy for the purposes of reducing, sequestering, and mitigating greenhouse gas emissions on land used in support of a farm operation and quantifying those greenhouse gas benefits". This report identifies the most promising on-farm practices that can deliver Real, Permanent, and Verifiable GHG mitigation to assist NYS in meeting its ambitious GHG mitigation goals. Where appropriate, we also point out issues of Leakage of emissions to other states or sectors that result from market or policy forces. These terms modified from the most recent US EPA Climate Leaders program (now discontinued) and other terms are defined in Table 1 below.

Common GHG definitions in the Working Lands Context

Below we give examples of common terms as they relate to dynamic and diverse working lands.

TABLE 1. Terms for Evaluating Mitigation Strategies

Term	Definition	Policy Implication (with a focus on agriculture)
Permanent	The GHG reductions must be permanent or have guarantees.	As mitigating climate change is a long-term project, a more permanent mitigation practice is likely more easily verifiable (less cost) and a payment for a more permanent practice will likely ensure a quantitative reduction in GHG emissions. Because working lands are constantly cycling nitrogen and carbon, reversible or less permanent practices require return visits to a site (increasing verification costs) to ensure a practice continues to meet GHG mitigation goals.
Verifiable	GHG reduction performance can be readily and accurately quantified, monitored and verified.	Verification safeguards the accounting of GHG mitigation within and between sectors and for society. Some practices require more resources to verify and therefore a practice that is inexpensive to implement might be expensive to verify.

Real	The quantified GHG reductions must represent actual emission reductions.	Real avoids 'gaming the system'. For example, a real reduction does not intentionally increase baseline emissions to gain more credit for mitigating, and also accounts for all three GHG to properly assess net benefit from a practice.
Additional	The GHG reductions must be surplus to regulation and beyond what would have happened anyway in the absence of the practice or in a business-as-usual scenario.	NYS must define the boundaries for its own version of additionality. It is important for identifying who pays for a change in practice, who is paid, and who gets the accounting credit. A practice with a high return on investment, or a practice with multiple benefits may be in the landowners best interest even if it is not currently a common practice. Defining additionality including predicting what would have happened without a policy is challenging (see Appendix B for discussion).
Leakage	Leakage means that a change in emissions in one location/sector induces change in emissions in another location/sector.	For example, reducing livestock production in NYS might reduce in-state emissions, but induce increased livestock production elsewhere, resulting in no net GHG benefit. Further information is provided in the section titled 'Measurable' and in Appendix B.
Social Cost of Carbon (SC-CO_2e)	The social cost of carbon is an estimate of the dollar value of the total long-term damages caused by emission of a metric ton of CO_2 (e.g., NAS 2017, Hsiang et al. 2017).	Under the CLCPA, NYS is required to define its own SC-CO_2e value. How NYS funds a GHG mitigation practice is a separate challenge. When possible, we provide estimates of the direct cost to implement proposed mitigation activities on farms, not including costs for verification, program management, etc. Our priority ranking chose practices with low cost implementation, high permanence, and high verifiability.

We evaluated three key greenhouse gases (carbon dioxide, CO_2; methane, CH_4; and nitrous oxide, N_2O, Table 2). We identified co-benefits including water quality, profitability, adaptation to climate change, community relations, and energy, among others. Whenever possible, we estimated the size of the mitigation opportunity state-wide, the number of stakeholders/acres etc. needed to accomplish the mitigation opportunity, and the farm financial savings or additional costs to achieve the mitigation practice (Table 3). We also identified potential barriers and incentives to implement the practice (Table 3).

To rank and prioritize the opportunities in Table 3, we used the "SMART" decision-making matrix for ranking Best Management Practices (BMPs) for GHG-mitigation, where we defined SMART as:

S = Services: In addition to GHG mitigation, there are often other co-benefits or "ecosystem services" provided by implementing a given BMP, as follows: Soil health, Community relations, Adaptation to climate change, Profitability, Air quality, Water quality, Biodiversity, and Energy.

M = Measurable: The estimated statewide GHG mitigation potential from a practice qualified by the degree to which it is *Verifiable.*

A = Achievable: The estimated direct cost of implementing a BMP.

R = Realistic: The amount of societal engagement (such as the number of acres, availability of appropriate tools, or number of stakeholders) that must be enlisted to implement *Real* emission reduction.

T = Time Frame: The time scale over which the mitigation would occur, qualified by the extent the mitigation is reversible or *Permanent.*

RANK = We use the SMART categories to develop a ranking. We apply a star for each letter S, M, A, R, T if the practice meets a threshold for that attribute. We recommend that 4 and 5-star practices are high priority for policy development whereas practices with 2 or fewer stars we recommend be developed further for second generation policy development.

Important aspects of GHG accounting include (1) beneficial or detrimental Leakage, (2) upstream or downstream emissions, (3) emissions across land-use/sector/state boundaries, (4) permanence or reversibility, and (5) the degree of verifiability (verifiable, reliable, or directionally beneficial). Notably, some directionally beneficial BMPs may support statewide GHG mitigation goals, but they may be difficult to verify or have issues with permanence, etc. In fact, NYS has robust soil health and water quality initiatives and many of these directionally beneficial GHG mitigation strategies could be integrated into these and other initiatives (e.g. renewable energy, air quality, etc.), while noting GHG mitigation as a co-benefit. That is, we have framed this analysis both holistically and empirically to achieve the most real and permanent GHG benefit at low cost to most effectively reduce GHG emissions and reduce the damage from climate change. Farms deliver many important services to society and we highlight practices that provide healthy and profitable food, feed, fiber, and fuel production along with environmental benefits including improved soil, air, and water quality.

To keep the main body of the report short and focused, we provide additional information in a series of appendices. These appendices include (1) a list of baseline assumptions of what we did not evaluate [Appendix A, Table A1], (2) what is assumed not to change [Appendix A, Table A2], (3) a section on definitions and abbreviations [Appendix B], (4) how the Natural Climate Solutions (NCS) pathway definitions compare to the Natural Resource Conservation Service (NRCS) and SWCC Agriculture BMP Systems Catalog definitions [Appendix B, Table B3], and (5) a list of tools, information sheets, resources, funding mechanisms, incentives and other states' programs and methodologies to spark a range of options for NYS policy makers to deploy an expanded suite of GHG mitigation policies [Appendix C, Table C1].

Methods

Services

Services listed are based on probable co-benefits from a well-implemented practice. They are generically defined, in order to include a broad categorization across a myriad of diverse practices. For example, Community Relations for covering and flaring emissions from a manure storage unit means the cover greatly reduces odors that drift onto neighboring properties, while Community Relations for reduced food waste means reduced trash, pests, truck trips, etc.

Broadly defined, this suite of co-benefits that may apply to a given BMP are coded as follows:

- Soil health (e.g. increased soil organic matter, productivity, water retention or infiltration)
- Community Relations (e.g. decreased odor, increased recreational land)
- Adaptation to climate change (e.g. resilient to extreme weather, improved animal housing temperatures)
- Air quality (e.g. decreased exposure to volatile organic compounds or particulate matter)
- Profitability (e.g. cost-savings, increased productivity, etc.)
- Water quality (e.g. improved nutrient efficiency, improved watershed protection)
- Biodiversity (e.g. increased habitat, ecological diversity, or species diversity)
- Energy (e.g. energy efficiency, renewable energy opportunity, reduced purchase of energy intensive products like synthetic nitrogen fertilizer)

Measurable

Measurable refers to a preliminary quantification of GHG mitigation potential at the State level (McDonnell et al. 2020, in press). "Measurable" is meant to assist planners in understanding the scale of a potential mitigation strategy. That being said, there are many competing uses for land, a wide variety of implementation practices, and changing conditions for what is a viable industry for that land (for example, sold to developers, converted to equine farms, leased to solar companies, converted to forest). As a result, the values listed are meant as a technical potential for a limited range of actual land-uses and BMPs.

We define three different categories to qualify "measurable" from high to low verifiability as follows:

- *Verifiable* practices have direct tools and methodologies for real, measurable, and cost-effective quantitative assessment.
- *Reliable* practices may have indirect tools or methodologies for quantification, may require collection and assessment of many sequential steps in a supply chain, or may be real but quantitatively small. For these reasons, formal verification is more difficult or costly.
- *Directionally Beneficial* practices may provide GHG benefit but are too small or variable to merit the costs of formal verification, verification is too onerous and therefore too costly, or the mitigation from a practice is easily reversible and potentially not a permanent practice.

To assist planners in understanding how well this technical potential can be tracked quantitatively for State level inventory and accounting purposes, we selected three terms for ranking reliability for quantitative assessment. Highest ranked practices labeled *Verifiable* have tools and methodologies that either track or can be tracked in a practical and cost-effective manner. As one example, a manure storage unit cover and flare system equipped with a meter and temperature sensor measures the gas flow and the flare effectiveness. As a second example, a forest management project with healthy growing trees can be verified once per decade (visually or quantified by measuring tree diameter and height and using standard allometric equations and factors to estimate stand volume and carbon content). The second highest ranking for quantitative assessment is *Reliable*. *Reliable* practices reliably reduce GHG emissions but may be calculated indirectly, require a large number of steps in a supply chain requiring much work to quantitatively verify, or may be a small but certain practice that can be evaluated simply with a site visit (trees planted as a riparian buffer can be visually verified to be still growing in that particular place). *Directionally Beneficial* is a term applied to practices for which the benefit is too small to merit the costs of formal verification, verification is too onerous and therefore too costly, or the mitigation from the practice is easily reversible and potentially not a permanent practice therefore it receives the lowest ranking. See also Time Frame and Appendix B for further discussion of Permanence. This is not intended as a final judgement, but rather identifies a need for more consideration to meet rigorous accounting objectives. For example, no-till or reduced tillage has many benefits for soil health, has a small technical potential for increased soil carbon if performed in careful combination with residue management, fertilizer management, and crop rotations, but it is not permanent and is very difficult to verify.

In general, "measurable" is the key component of our ranking system. A highly verifiable practice is a likely candidate for state supported initiatives. A large and highly verifiable practice offers a meaningful state-scale GHG mitigation opportunity. In contrast, a directionally beneficial practice is most likely best treated as a GHG-mitigating co-benefit of a non-GHG state initiative. For example, no-till might best be considered a water quality initiative or soil health initiative with a possible small or temporary co-benefit of GHG mitigation.

As NYS develops protocols for verification, some basic guidelines should be included. We present conceptual guidelines here to help inform selection of practices that may contribute to NYS's GHG mitigation goals. Verification upholds the integrity and quality of the data reported. Standardizing verification procedures promote relevance, completeness, consistency, accuracy, and transparency of emissions reductions reported by project developers. Transparent processes ensure practices are real, additional, permanent, verifiable and enforceable, compatible with other types of mitigation initiatives, support on-going monitoring, and minimize the risk of invalid or double accounting.

We suggest that it is useful to support all practices that are directionally beneficial even if they are difficult, expensive, or reversible. However, NYS needs to identify how it will prioritize actions and funding as the State navigates implementation of GHG mitigation within the agricultural sector and among all sectors. There are multiple types of cost including (1) developing state programs for implementation, (2) supporting education and outreach, (3) implementing the actual practices, (4) verifying mitigation, and (5) overall accounting. The task ahead is large; verification is a tool that is combined with a practice to determine its effectiveness with respect to the state-wide goal of actual emissions reductions. All activities can be verified to some degree, but some activities are easier to verify, reducing overall accounting costs.

Another important issue for GHG accounting and analysis of mitigation opportunities is "leakage". Leakage refers to a change in emissions implemented in one location that creates a change in emissions in another location. If this other location is outside the boundary of the region analyzing its inventory, such as NYS, it can greatly affect the interpretation of the efficacy of a GHG mitigation practice. For example, in response to one state's policy, a forest products company may place 1,000 acres of forest under a permanent conservation easement preventing any harvest in order to sequester carbon. However, to meet the market demand for lumber, the company may then increase production by harvesting 1,000 acres in another state. As shown in this example, leakage occurs due to market forces and policies across state boundaries. The effect is that GHG emissions are 'leaked' from one local farm, sector, or state and transferred to another site, industry, or governing body. Analyzing across all locations, leakage can either increase total net GHG emissions (detrimental leakage) or decrease total net GHG emissions (beneficial leakage). Detrimental leakage can be illustrated occur across sectors, for example if reforesting NYS agricultural lands to sequester carbon results in an increase of imported food grown on land in Pennsylvania, causing an increase of agricultural GHG emissions there. An example of beneficial leakage would be policies that cause NYS farms to use less synthetic N fertilizer (manufactured in Ohio), thus reducing the fossil fuels and associated GHG emissions used in Ohio to make that synthetic N fertilizer. For this reason, we focus primarily on mitigation categories that reduce the potential for detrimental leakage, and also point out when such leakage might occur.

Achievable

Achievable is a measure of cost/savings/investment for implementing a practice. Costs for implementation were generally derived from Marginal Abatement Cost (MAC) curves constructed from the available information in the literature (many from Fargione et al. 2018). A marginal abatement cost curve represents the monetary cost of achieving one additional ton of sequestered GHG or avoided GHG emissions and indicates the total quantity of net GHG reductions that can be achieved at different price points such as \$10, \$50, and \$100 per MT CO_2e. Scientists project that damages from climate change may cost society more than \$100 per metric ton of CO_2 emitted: this is known as the "social cost of carbon" (for example, NAS 2017, Hsiang et al. 2017). However, there is a very wide range of estimates for the social cost of carbon, and more recent literature that accounts for more factors finds higher values (for example Moore et al. 2015). Furthermore, a price of \$100 per ton of CO_2e is required to keep the 100-year average temperature from warming more than 2.5°C, and an even higher cost would be required to meet the Paris agreement goal of less than 2.0°C. Therefore, spending up to \$100 per ton can be considered cost-effective for climate benefits. This proportion of the maximum potential mitigation total is the best measure for understanding society's ability to employ natural climate solutions as a response to climate change. For some practices, the nationally averaged cost estimates (Fargione et al. 2018) were down-scaled to the State level and are accessible here: https://nature4climate.org/u-s-carbon-mapper/.

Because NYS will have to consider its own definition of 'affordability' for GHG mitigation practices we have simply indicated whether we think this measurable technical potential is achievable within this cost range (from saving money to spending \$100 per metric ton CO_2e). It is important to note that other co-benefits such as improved air quality, soil quality, and water quality also have financial benefits, even if they are difficult to quantify; the total benefits of a practice should be considered, not just the GHG benefits. As the social cost of carbon increases over time, NYS will need to decide if it wants to increase spending to make more-difficult-to-verify practices, verifiable, or if it wants to expand support to farms to increase their directionally beneficial but less verifiable practices. Drafting and implementing policies, educating, changing a practice, and verification all cost money. As a practice moves away from 'verifiable' to 'directionally beneficial' the costs of verification go up, reducing money available to implement new practices.

Note: Greenhouse Gas Accounting Issues
In July 2019 NYS Climate Leadership and Community Protection Act (CLCPA) was signed by Governor Cuomo. The CLCPA specifies that future analyses for NYS will use the 20-year Global Warming Potential (GWP) from the IPCC AR5 report (2014). This means a large increase for the calculated impact from methane (from 34 to 86) and a small decrease for nitrous oxide (298 to 268).

TABLE 2: Global Warming Potential (GWP) of GHG relevant to agriculture

GHG	**GWP** (20-year time scale)	**GWP** (100-year time scale)	**Source**
Carbon Dioxide (CO_2)	1	1	IPCC. AR5. 2014
Methane (CH_4)	86	34	IPCC. AR5. 2014
Nitrous Oxide (N_2O)	268	298	IPCC. AR5. 2014

The analyses reported here and elsewhere generally use a 100-year GWP value of 25 (AR4 value) for methane. Therefore, our estimates for methane related mitigation opportunities, presented are undervalued by a factor of ~three for calculations going forward under the CLCPA. This changes the accounting for methane-related projects; it increases the amount of emissions and mitigation potential (by ~3-fold) and decreases the cost of mitigation (by ~3-fold).

Realistic

Realistic refers to the scope of societal engagement required for the technical potential to make Real GHG mitigation. Factors that impact realistic implementation include the number of acres that would need to be involved to achieve a quantity of mitigation, the availability of appropriate tools to implement or verify a practice, or the number of stakeholders that would need to be enlisted to actually implement *Real* emission reductions.

Time Frame

The Time Frame is the time scale over which the mitigation would occur, qualified by the extent the mitigation is reversible or *Permanent*. This can include a limit to the time of benefit (lifespan of required equipment) or years before the benefit of a practice is fully realized across the participating lands, stakeholders, or management practices for NYS benefit. For example, a practice may increase soil carbon if maintained and not reversed but reach a new equilibrium after several decades with no further increase after that time. The time scale is also affected by the GWP of different gases associated with a practice. Also, a specific practice may be *Permanent* or *Reversible* over a particular time scale. When analyzing living biological systems like agriculture, the idea of permanence is problematic. Here, we consider aspects including fossil fuels not emitted because a tractor is more efficient, excess nitrogen that was not used thus reducing N_2O emissions while maintaining yields, acres committed to long term reserve with specific guarantees, or long-lived wood products harvested from a well-managed forest to be among the permanent opportunities providing long-term benefit. Rapidly reversible or short-lived sequestration would not be considered permanent and therefore not be considered a strong candidate for a long-term mitigation potential. This permanence consideration is applied to all industries (not just agriculture) and is an important concept for prioritizing and delivering the long-term GHG accounting necessary for mitigating climate change. For more discussion about Permanence, please see Appendix B. Again, less-permanent GHG mitigation practices might be best implemented as a co-benefit from an initiative focused on other primary benefits such as soil-health or water quality.

Comments on Units and GWP Conversions

Units: For statewide quantitative assessment (seen in the column named Measurable in Table 3 below), we have chosen to use the units of teragrams. One teragram (Tg) is 1 trillion grams equal to 1 million Mg (megagram) or equal to 1 million metric tons. In contrast, we have chosen to use the unit of Mg (megagram, or metric ton = 1.1 US tons) for the cost of implementation (seen in the column defined as Achievable in Table 3 below) as this is more appropriate for understanding the payment for implementation of a practice at a farm level and matches the units of the Social Cost of Carbon.

Global Warming Potential (GWP): This analysis uses the 100-year GWP for N_2O and CH_4. In comparison to the CLCPA mandate to use the 20-year GWP effectively means our reported values are nearly three-fold lower for methane and slightly higher for nitrous oxide (see Table 2).

Mitigation Opportunities

TABLE 3. GHG Mitigation Opportunities by Size & SMARTness

PATHWAY	S Services	M Measurable	A Achievable	R Realistic	T Time Frame
Definitions	***Services*** are co-benefits that may apply to a given practice: • Soil Health • Community Relations • Adaptation to Climate Change • Profitability • Air Quality • Water Quality • Biodiversity • Energy	A ***Measurable*** quantity (Tg, teragram CO_2e) that is technically feasible in NYS, ranked into three categories of verifiability from high (1) to low certainty (3): • ***Verifiable*** *(rank 1)* • ***Reliable*** *(rank 2)* • ***Directionally Beneficial*** *(rank 3)*	***Achievable*** refers to the relative cost estimate for implementing a practice (0-$100/ Mg CO_2e, where Mg is megagram or metric ton). Note. These are estimated costs to implement, not including cost to measure, verify, or account in formal registries.	***Realistic*** refers to amount of engagement necessary to activate a mitigation practice, such as acres of applicable lands, number of stakeholders to be engaged, or availability of technical tools.	***Time Frame*** refers to lifespan of infrastructure, temporal limits of mitigation strategy (saturation of practice), and short-and-long term effectiveness. (indirectly a measure of ***Permanence***)

NYS MITIGATION OPPORTUNITIES, Larger Scale (1-5 Tg^ CO_2e/yr) ^Tg (teragram) = 1 million Mg (megagram) or 1 million metric tons

3.1 Afforestation of idle or underutilized agricultural land Increased carbon sequestration in above and below ground biomass and soils gained by converting non-forest (<25% tree cover) to forest (>25% tree cover) in areas where forests are the native cover type.					
Rank **** **Priority**	**Services** * • Soil Health • Community Relations • Adaptation to Climate Change • Profitability • Biodiversity • Energy	**Measurable** * -4.9 Tg^ CO_2/yr Rank 1: Verifiable	**Achievable** * $10-50/Mg CO_2e or higher	Realistic ~1.7 million acres (not confident this is realistic due to significant competing uses, but represents a large mitigation opportunity)	**Time Frame** * Decadal With 100-year impacts
Services. Services include a broad range of co-benefits: Soil Health, Community Relations (e.g. improved recreational and aesthetic areas), Adaptation, Profitability, Biodiversity, Energy production potential from forest management residues. However, loss of grass and shrub habitat also reduces habitat for species that depend on such land cover.					

Measurable. Verifiable. We estimated mitigation potential (McDonnell et al. 2020 in press) by combining area estimates from Wightman et al. (2015) and average growth of maple-beech-birch forest stands from Smith et al. (2006). Carbon sequestration in a growing forest can be verified by visual inspection & measurements of trees.
Achievable. Upfront and middle term costs based on national average values from Fargione et al. (2018). Long term financial gain possible if managed properly and wood markets are available in the future.
Realistic. Real but maybe not Realistic. While afforestation provides a significant and real opportunity for short-and-long term mitigation benefits, this scale of opportunity assumes all current shrub and scrubland (878,170 ac) as well as all miscellaneous herbaceous land (870,997 ac) is converted to forest (Wightman et al, 2015, revised). This is the technical potential but achieving it ***depends on landowner adoption*** to actively establish forest on underutilized agricultural land and then ***maintain it for long periods*** such as 100 years; ***As there are a myriad of competing interests*** for land use, this number represents an upper limit as much of this land could be used for other products such as renewable energy (below) and other uses.
Time Frame. Permanent. While a timely and important mitigation quantity and quality, afforestation of underutilized agricultural lands also makes a return to agricultural production difficult. GHG benefit is predicated on commitment to long-term forest growth/management. If this land is properly managed as forest for 100 years, it should be considered a Permanent mitigation opportunity.

Barrier: It is highly unlikely that this technical potential will be achieved. One barrier is the large number of individual landowners with different goals for how this land should be managed. Another barrier is that perhaps it is not in the best interest of NYS to afforest all of this land area as it could have other important uses such as growing biomass for food, feed, bioenergy, etc. The technical potential listed above will likely only be achieved if there are significant incentives to make afforesting (and maintaining for long periods such as 50-100 years despite other potential land uses such as selling to a developer) hard to resist. Research of land suitability for competing uses should be evaluated to identify areas especially suitable for afforestation versus land-uses such as increased pasture or hay production, solar energy siting, etc. If converted to forest for example, this land requires a large upfront investment and proper management to establish a forest stand, although these activities will likely increase landowner income over time. This mitigation strategy depends on the ability to establish native species, including obtaining plants and/or seed, planting, managing weeds, diseases, pests and herbivores, ***particularly deer***. If forest growth rates on idle lands in NYS are limited by establishment costs, herbivory or other factors, it may be difficult or costly to achieve the mitigation potential estimated herein.

Incentive: With upfront investment, proper management, and product development, activities will increase landowner income. This practice is real, permanent, verifiable and is an excellent candidate for trading, tax-relief, reimbursement, or other kinds of policy incentives. We recommend stronger technical assistance, further research into addressing pests for successful forest stand development, and financial support for implementing this and other types of practices on this underutilized land. With a smart plan in place that identifies and supports priority areas of afforestation, this opportunity could be implemented within the decade, sustaining benefits over the next 100 years if managed well. Combined with existing woodlands on farms, we believe that farmers, with support for the long-haul, could be excellent stewards, managing forests as they manage other crops.

Caveat: Clearing forest land to make ‘new’ agricultural land is an energy intensive process. We recommend NYS consider the other uses for this ‘idle agricultural land’ such as increased agricultural production before choosing to advocate an afforestation policy.

3.2 Manure Storage Cover and Flare Retrofitting liquid manure storage with cover & flare so that methane produced is captured and combusted.					
Rank ***** **Priority**	**Services** * • Community Relations • Adaptation to Climate Change • Air Quality • Water Quality	**Measurable** * -1.29 Tg CO_2/yr Rank 1: Verifiable	**Achievable** * $13/Mg CO_2e (based on GWP of $CH_4 = 25$)	**Realistic** * ~ 500 farms and current technology (high confidence)	**Time Frame** * Annual but with 100-year impact (system lifespan of 10-20 yrs)

Services. Services include: Community Relations (odor reduction), Adaptation (prevents overflow in extreme weather events), Air Quality (Volatile Organic Compounds, VOCs), Water Quality (improved timing of land application) with the potential for energy self-sufficiency (not included) if methane is used for energy displacement (heat, electricity, transport fuel) in an Anaerobic Digester System (ADS).
Measurable. Verifiable. A cover system that comes with a flare and meter is a verifiable way to assess quantity of methane burned. However, the amount of methane released if there are leaks in the system, or due to management operations may not be easily tracked. The value is based on a GWP for CH_4 of 25 and is modified from Wightman & Woodbury (2016) to include other large livestock farms beyond dairy (McDonnell et al. 2020 in press).
Achievable. Achievable. **Cost** $13/Mg CO_2e with GWP of 25 for CH_4 (and conservatively assumes a 10-year life span for the system, Wightman & Woodbury 2016). Using the CLCPA mandated 20-year GWP of 86, this practice will cost ~1/3 of the $13/Mg CO_2e.
Realistic. Real. This opportunity provides short-and-long term mitigation benefits with current technology. The majority of this Measurable opportunity could be achieved by targeting the 493 CAFOs (in 2017), involving a limited group of stakeholders.
Time Frame. Permanent. While this opportunity has upfront costs (we previously estimated $100,000-300,000 per farm based on a 10-year lifespan and 100-year GWP, Wightman & Woodbury 2016), the very real, measurable, verifiable, and permanent mitigation of CH_4 could be realized inexpensively per Mg CO_2e with multiple co-benefits to farmers. Listed as annual (for a system lifespan operating 10-20 years), the long-term benefits of destroying methane (a short-lived climate pollutant, SLCP) is meaningful for addressing the high Global Warming Potential (GWP) of methane (compare 20-yr GWP = 86 with 100-yr GWP = 34 values, IPCC, 2013). This objective has a large 10 to 20-year immediate benefit that is also significant on a 100-year timeline.

Barriers: Has high upfront costs per farm; may require retrofitting as existing manure storage units may not be currently suitable to receive a cover; current water quality policies to implement/install new manure storage units should be revised to include a cover or include a design to retrofit a cover easily at a later date; milk prices will likely affect whether farmers are able to take advantage of the cost-share system currently in place (see incentives).

Incentives: This mitigation system is real, permanent, verifiable, and is an excellent candidate for offset trading, grant, tax-relief, reimbursement or other kinds of policy incentives. Destroying methane addresses a potent Short-Lived Climate Pollutant (SLCP); "cover+flare" systems are inexpensive from a Social Cost of Carbon perspective; there is existing NYS AGM Climate Resilient Farming (CRF) cost share programming for "cover+flare" system expansion; there are farmers who have covers and flares to share their first-hand experience; some farms put on covers simply to address odor to improve neighbor relations. With the relatively low upfront cost of manure storage cover and flare systems (relative to many GHG mitigating activities as well as anaerobic digestion systems (ADS) for generating electricity), and the manageable number farms involved, we feel this opportunity could be fully applied in <5 years with an ambitious and comprehensive program. If energy prices increase dramatically, cover & flare systems could be converted to ADS.

Caveats: It should be noted that for the US Climate Alliance, this opportunity falls under the SLCP initiative rather than the Natural and Working Lands (NWL) initiative. It should also be noted that the 2019 *Climate Leadership and Community Protection Act (CLCPA*) was signed into law by Governor Cuomo, specifying that the 20-year GWP be used. As the 20-yr GWP for methane is 86, this indicates the emission would be ~3x greater resulting in a mitigation cost per Mg CO_2e would be approximately 3x lower than listed above.

3.3 Reduce Food Waste

Food waste occurs throughout the food system (farms through supply chains including pre- & post-consumer).

Rank *	**Services** *	Measurable	Achievable	Realistic	Time Frame
	• Community Relations • Adaptation to Climate Change • Profitability • Air Quality • Water Quality • Energy	-1.19 Tg CO_2/yr Rank 3: Directionally Beneficial	Cost savings throughout the supply chain	Everyone (supply and demand)	Annual

Services. Services include: Community Relations, Adaptation, Profitability, Air quality, Water Quality, and Energy. This community benefit includes reduced trash, rats, odor, truck trips, landfill space, etc. All the co-benefits occur due to increasing efficiency and thereby decreasing the emissions from the food system.
Measurable. Directionally Beneficial but not easily Verifiable. Reducing food waste is a sensible initiative for a myriad of co-benefits but is difficult to measure/verify. However, benefits will be real, meaningful and cost-beneficial up and down the supply chain and assumes a 50% decrease in current food waste. We developed this preliminary "placeholder" estimate based on a USEPA estimate of 31% food waste (Buzby et al. 2014) and a USEPA mitigation goal of half of that value by year 2030, applied to all agricultural emissions (McDonnell et al. 2020 in press). This estimate does not include reduced emissions from landfills, hauling, etc., but rather includes the reduction in emissions from agriculture to produce the food. The purpose of this preliminary estimate is to draw attention to this important issue, more rigorous analysis is needed to better quantify the opportunities at various steps in the food system.
Achievable. Every increase in efficiency in this supply/demand chain saves money for producers, processors, retailers, consumers, and municipal waste managers.
Realistic. Real but difficult to make Realistic. This practice requires nearly every member of society to participate which makes it a difficult but real opportunity, probably realized most efficiently at the supply-side of the chain with market forces assisting on the demand side of the chain (with probable complications for low income individuals).
Time Frame. Annually Permanent, but reversible behavior. This practice is likely slow to realize its potential but would provide holistic social benefit in the near and long term. Requires significant education/outreach and system wide evaluation. While we list this benefit as annual (i.e. culture can easily reverse its improved behavior), we feel there are various trends (like New York City composting campaigns such as "Zero waste by 2030") leading to longer term and measurable methods for keeping food waste out of landfills reducing methane production, and returning nutrients to the land. Combined with upstream initiatives that improve

efficient production and distribution, this could also make more land available for other purposes or could reduce food imports to the State with "beneficial leakage" reducing global GHG emissions.

Barriers: This initiative requires more research, will require significant outreach, and is likely difficult to measure and verify. While we think this is a fantastic holistic opportunity, it requires a systems strategy and more research on both quantification at different points in the food system as well as approaches for effective implementation. As this opportunity requires a cultural shift, cultural reversal or other issues make this difficult to consider as a long term, measurable solution until the cultural shift is steady.

Incentives: This initiative is good for everyone. Improved food system efficiency provides permanent mitigation for any annual accomplishments. It also reduces the land area needed to grow our food, allowing this land to be used for other constructive purposes. It is possible this issue could be solved by market-induced efficiency and consumer awareness.

NYS MITIGATION OPPORTUNITIES, Smaller Scale (<1 Tg^ CO_2e/yr) or Size To Be Determined (TBD)
^Tg (teragram) = 1 million Mg (megagram) or 1 million metric tons

3.4 Renewable Energy

Renewable energy includes wind and solar energy production on farmland.

RANK *** **Priority**	**Services** *	**Measurable** *	Achievable	Realistic	**Time Frame** *
	• Community Relations • Adaptation to Climate Change • Air Quality • Profitability • Energy	Large (TBD) Rank 1: Verifiable	TBD	TBD Realistic proposition, requires proximity to the grid (infrastructure), with land-use impact (leakage), reflecting policy and market forces.	Annual (for the life of the system)

Services. Services include: Community Relations (development), Adaptation, Air Quality, Profitability, and local sources of renewable Energy for farm or grid.
Measurable. Verifiable. Metered system.
Achievable. Invest, then Earn. This opportunity has significant potential to cause detrimental leakage and given how this initiative intersects with NYS mandate of 100% clean power by 2040, there will be significant land-use/land-change implications. Whether wind, solar, biomass, or reforestation (see above), this opportunity is ideally limited to the area of underutilized lands and not prime farmland, but siting is likely to be strongly determined by access to electrical transmission lines, roads, etc. Even on underutilized lands there is competition with other opportunities of increased agricultural production, reforestation, recreation, hunting, equine, etc. However, cost to connect with the grid must be included.
Realistic. Real. While there is real mitigation, landowners will need meaningful decision support to identify what is right for them in the near-and-long term life of the system. While a completely realistic opportunity to

support, market forces (e.g. driven by policies to achieve the 100% carbon-free power by 2040) might strongly influence land-use decisions for NYS.
Time Frame. Permanent. Upfront costs, but measurable and real benefit for the life of the system.

Barriers: Grid connection proximity will strongly influence where renewable energy projects are installed, which could remove valuable agricultural land from production.

Incentives: Renewable energy is a Real, Measurable, Verifiable, and Permanent opportunity with multiple co-benefits. That said, how it is implemented within the agricultural sector as well as for landowners in general must be seriously considered. There is an urgent need for assessment of opportunities and land-use considerations as the electric sector is targeted to be 100% clean power by 2040. Therefore, landowners must receive unbiased information and support for navigating private industry initiatives, such as leasing large tracts of land for large scale solar installations. Leakage considerations, landowner compensation, and education on contracting needs to be developed immediately.

Caveat: This opportunity needs to be balanced with land use changes (development, forestry, habitat, etc.) as it competes with other uses for the finite land area in the state (see afforestation mitigation opportunity 3.1 above). This opportunity could also cause detrimental leakage by displacing current agricultural production and its concomitant emissions outside NYS. This is an example of how initiatives to reduce emissions from the energy sector impacts the agricultural sector. Also, in GHG accounting, energy production falls under the energy sector not the agriculture sector, so cross-communication between sectors is required for GHG policy and accounting purposes.

3.5 Woodland Management

Farms have a variety of woodlands (agroforestry systems, forest systems). According to the NYS Office of the Comptroller (2019) 21% of agricultural land (6,866,171 acres) is woodland (1.4 million acres). Changes in management practices to increase net forest carbon sequestration could alter species composition, stand structure, and stand density.

Rank **** **Priority**	**Services** *	**Measurable** *	**Achievable** *	Realistic	**Time Frame** *
	• Adaptation to Climate Change • Profitability • Water Quality • Biodiversity • Energy	Large (TBD) Rank 1-2: Verifiable &/or Reliable	TBD Invest then Earn	1.4 million acres owned by farmers trained to manage working lands	Decadal with 100-year impact.

Services. Services include: Adaptation to Climate Change, Water quality, Profitability, Biodiversity and Energy. Notably, if woodlands are converted to non-forest uses it would cause substantial GHG emissions. Current wooded areas provide significant cultural and environmental services so maintaining them is a significant defensive strategy for maintaining current sequestration and supporting state GHG mitigation goals.
Measurable. Verifiable and/or Reliable. If woodland is actively managed for long-lived timber products, maintaining and optimizing woodland management can be Verifiable. Depending on the practice, woodland managed for silvopasture or agroforestry may be a reliable source of improved GHG mitigation and other benefits.
Achievable. Improved woodland management will likely increase greenhouse gas mitigation and profitability. However, poor harvest practices due to difficult economic times or particular life events (retirement, college

tuition, medical bills), if not planned and implemented properly, can reduce the GHG mitigation benefit. While woodlands could be managed to maximize carbon sequestration, the cost of doing so may be difficult for some farmers to afford without financial support. However, improved woodland management is a very achievable opportunity. Likewise, investing in new products through agroforestry will likely have upfront costs with subsequent income from the sale of new products.
Realistic. Real. While this practice is real, and there are significant amounts of land available, the profitability will be a function of timber or agroforest product markets. Also, parcel size will often be small in a 'forest management' perspective, making it a lower priority for a farmer to consider or a forester to manage for profitability. That being said, farmers are great land and product managers and improving woodland management could provide multiple benefits to landowners and society.
Time Frame. Permanent if active forest management, likely permanent if agroforestry. If viewed like other cropping systems and managed accordingly, this opportunity could fit well within a long-term plan for farm viability as long as investment capital and wood product markets are available.

Barriers: Improved management requires management every decade but has carbon sequestration benefits for more than 100 years. Requires upfront investment for a qualified forester to develop and implement a management plan. A national survey of farms that own woodlands indicated only 30% of these landowners have a forest management plan (Huff 2019). Notably this value is similar to forest-only private landowners. So while policy makers and Cooperative Extension tend to function in silos of 'agriculture' and 'forestry', there may be great benefit of sharing knowledge and strategies between these two important land types, landowners, and land managers to increase forest management plans across all privately owned forests.

Incentives: Improved management could be a verifiable, real, and permanent increase in mitigation potential. Educating and supporting improved management and defraying implementation costs could improve farm profitability in the long term by increasing the value of harvested wood products. These activities also increase total C sequestration if properly implemented.

Caveat: The most important opportunity is to keep healthy growing woodlands as woodlands so as not to lose the carbon sequestered in the trees and soils. Alternatively, woodland management for agroforestry products may also be considered. See afforestation section for related information content.

3.6 Cover Crops (including double crops)

Planting grasses, legumes, and forbs in the fallow season between main crops increases the overall annual vegetative cover with potential soil carbon sequestration and other benefits.

Rank *	**Services** *	Measurable	Achievable	Realistic	Time Frame
	• Soil Health • Adaptation to Climate Change • Profitability • Water Quality	-0.85Tg CO_2/yr Rank 3: Directionally Beneficial	\$10/Mg CO_2e (likely higher if not double cropping)	>1.9 million acres	Annual, circa 30-year limit of soil carbon increase, prone to reversibility/ impermanence

Services. Services include: Soil Health, Adaptation to extreme weather (water retention during drought and erosion prevention during extreme precipitation), Profitability, especially if the crop is harvested, and improved Water Quality due to nutrient and sediment retention.
Measurable. Directionally Beneficial, not easily verifiable. While one can measure increases in soil carbon, it is a labor-intensive and costly process and therefore difficult to verify at most sites. There is also potential for

increased N_2O emission if legumes and N fertilizer are not carefully managed (benefit more likely when paired with nutrient management). There is the potential for decreased yield of the main crop without careful management. This estimate is from a disaggregation of a national estimate to NYS (Fargione et al. 2018 and state-level web site derived from it, McDonnell et al. 2020 in press).
Achievable. Cover cropping may be indirectly beneficial by improving soil health while double cropping may garner an increase of saleable product for a farm while contributing to beneficial leakage. Invest and likely earn if cover crops become double cropping systems or if soil health benefits are cost effective. While achievable across NYS cropland, states like MD (~$60/ac), IL and IA ($5 discount for crop insurance/ac) have been subsidizing adoption of this practice. We recommend this as a soil health initiative with a co-benefit of possible GHG reduction, rather than as a primary GHG mitigation initiative. Careful management is required to avoid reducing yield of the main crop and to manage N cycling especially with leguminous cover crops. 96% of this mitigation potential could be achieved for <$10/Mg$CO_2$e.
Realistic. While realistic to implement if appropriately funded, it may not be real, and a new soil carbon steady-state will be achieved after some decades with no further SOC sequestration. This practice also interacts with current and future tillage, nutrient, and residue management. Requires training and incentives (e.g. MD). If suitable species are identified for double cropping, profitability would increase.
Time Frame. Easily Reversible and therefore not Permanent. While this practice in principle can help sequester carbon in the soil as part of a suite of soil carbon sequestration practices, events such as extreme rainfall, sale of the farm to another entity, etc. can quickly reverse decades of carbon sequestration in a few years. We do not consider this to be a Permanent practice, but it is important for soil health, adaptation, and water quality benefits.

Barriers: There is substantial uncertainty in this potential mitigation for three reasons: 1) potential for increased N_2O emission especially with leguminous cover crops exceeding the benefits from the c-sequestration; 2) potential for a cover crop to decrease yield of the subsequent crop if not managed correctly and discounting the GHG mitigation per unit product; 3) the uncertainty and impermanence of increasing soil carbon by means of cover cropping. All of these points make verification difficult. Additionally, some of this potential has already been achieved in NYS and should therefore be counted as a reduction of current emissions rather than a new mitigation potential.

Incentives: Because of the many co-benefits, this objective is better viewed as a water quality and farm viability initiative with GHG mitigation as a minor co-benefit.

3.7 Feed Management

Manipulating and controlling the quantity and quality of available nutrients, feedstuffs, or additives fed to livestock and poultry to reduce enteric emissions of CH_4 and reduce the Volatile Solid (VS) and nitrogen (N) available in manure so to reduce CH_4 and N_2O production in manure management systems.

RANK *** Priority	**Services** *	Measurable	**Achievable** *	Realistic	**Time Frame** *
	• Soil Health • Air Quality • Profitability • Water Quality • Energy	-0.7 Tg CO_2/yr Rank 2: Reliable	Cost savings	Applicable to most farms (but a focus on ruminant systems)	Daily with 100-year impact

Services. Services include: managing the N for Soil Health, increased Profitability as animals are making more product through more efficient metabolism of feed, Air Quality benefits from reduced volatilized C and N,

improved Water Quality by reduced N in manure, and Energy savings by reducing feed and associated energy used in production.
Measurable. Reliable. As this is indirect measurement, we consider this to be a reliable practice at reducing the availability of volatile solids (VS) and N that end up in the manure, thus reducing the potential to create CH_4 and N_2O in manure management systems. See Veltman et al. (2018) and McDonnell et al. (2020 in press).
Achievable. This mitigation practice is low to no cost and may even make farms more financially viable. Improved feed efficiency improves production and/or profitability and there is evidence of this occurring already in NYS.
Realistic. Real. Farmers are already doing this to some extent, but there is still room for improvement. To fully achieve the mitigation estimate listed, it requires a comprehensive training of all farmers to use feed management tools. Peer-to-Peer communication might be the most effective way to advance this cost-saving and pragmatic opportunity.
Time Frame. Annually Permanent, but reversible behavior. Management to reduce enteric and manure CH_4 production and decreased N_2O production in the manure has real impact on near and long term GHG mitigation.

Barriers: Employing this pragmatic practice has up-front costs for education, improved diet planning, feed and forage management, implementation, and sustaining implementation.

Incentives: This mitigation system is indirect but real and permanent. It is an excellent candidate for improving farm viability with many co-benefits. Reduces acres needed for feed production (beneficial leakage). With its cost savings, this may be a great candidate for peer-to-peer learning, resulting in a long-lived cultural norm.

Caveat: The 2019 *Climate Leadership and Community Protection Act (CLCPA*) was signed into law by Governor Cuomo, NYS, stipulating use of the 20-year GWP (AR5, where methane GWP= 86), making the methane mitigation contribution of this assessment significantly larger (calculation presented uses AR4 100-year GWP = 25 for methane).

3.8 Alley Cropping

Carbon sequestration gained by planting wide rows of trees with a companion crop grown in the alleyways between the rows (applicable to <10% of agricultural area)

RANK ***	**Services** *	**Measurable** *	Achievable	Realistic	**Time Frame** *
	• Soil Health • Adaptation to Climate Change • Profitability • Air Quality • Water Quality	-0.67 Tg CO_2/yr Rank 1-2: Verifiable &/or Reliable	\$50-100/Mg CO_2e	Up to 10% of current row crops or ~350,000 ac	Decadal

Services. Services include: Soil Health, Adaptation, Air Quality, Water Quality, and possible increased Profitability.
Measurable. Verifiable and/or Reliable. This practice was quantified assuming use of 10% of cropland area with increased carbon sequestration in the alley trees but may reduce total production of the field (presenting potential detrimental leakage, depending on what the crop/tree is and how it affects the total yield). This opportunity can be readily verified with visual inspection or measurements of trees. Verification should include

productivity of the row and tree crops. Fargione et al. (2018) estimated the C balance for this category at the national scale, and subsequently dis-aggregated this national estimate to the state level (https://nature4climate.org/u-s-carbon-mapper/). 80% of this mitigation potential could be achieved at <$50/Mg$CO_2$e (McDonnell et al. 2020 in press).
Achievable. There are upfront costs and a learning curve for this practice because it is very rare in NYS and the Northeast. If the trees are crops there is potential for increased income if markets are available.
Realistic. While the opportunity is Real provided no yield loss by the companion crop, it is not clear what fraction of cropland might be realistically engaged because there is very little experience with it in NYS.
Time Frame. If sustained, this is a Permanent opportunity for sequestering carbon in trees with long term benefit.

Barriers: This initiative requires more research into combinations of species, effective management, pilot projects, field trials, demonstration plots and market analysis before a farm is likely to adopt this practice.

Incentives: This is a potentially permanent and easily verifiable practice but may impact production of traditional row crops. This proposed change in practice calculated for 10% of all cropland area could be a verifiable practice but the cropping systems need further research and development in NYS. Therefore, this opportunity needs more research to identify systems that support farm profitability and assess leakage issues.

3.9 Replace Annuals with Perennials

Replacing annual crops with perennial crops has many potential benefits for soil health and can increase C storage in agricultural soils, but it may be difficult to find perennial crops with equal value as annual crops.

RANK **	**Services** *	**Measurable** *	Achievable	Realistic	Time Frame
	• Soil Health • Adaptation to Climate Change • Water Quality • Energy	-0.62 Tg CO_2/yr Rank 2-1: Reliable &/or Verifiable	TBD	Real but not realistic. Applied to 160,000 acres of ‘retired’ corn silage land due to increased feed/milk production efficiency	Circa 30-year maximum, easily reversible.

Services. Services include: Soil Health, Adaptation to extreme weather, improved Water Quality, and Energy if perennial bioenergy feedstock is produced.
Measurable. Reliable and/or Verifiable. Like alley cropping, depending on yields and objectives, perennial replacement may cause leakage, depending on whether the perennial crop has the same yield and/or value as the annual crop. This practice can be verified visually combined with models and/or measurements of soil carbon sequestration. It should however include yield and value of both perennial and annual crops. The mitigation value was calculated using published land area projected to become available due to ongoing increases in the yields of major crops and by increased dairy production efficiency (Wightman et al. 2015). These lands could be used for perennial crops while maintaining total current annual crop production. The annual increase in soil C storage that would occur if these lands were converted to perennial crops was estimated (Wightman et al. 2015, Woodbury et al. 2007, McDonnell et al. 2020 in press).
Achievable. Planting of carefully selected perennial crops will have upfront costs that are intended to be paid back over the long term, depending on yields and value of the perennial crop.

Realistic. Real but maybe not currently realistic. Depending on the perennial crop and the end use (e.g. grain crops for food/feed or short-rotation willow for bioenergy) varieties that are applicable and profitable in NYS require further evaluation, therefore this very meaningful and real mitigation strategy for NYS agriculture requires further research and development to assure farm viability. Substituting perennial forage acres (e.g., long-term, intensively managed grass hay) for annual forage crops acres (e.g., corn silage) on livestock farms is perhaps the most proven example of this practice in NYS.
Time Frame. Perennials with 10-year or 30-year cycle of re-planting provide a meaningful opportunity to build and sequester soil carbon if maintained as perennials. While significantly more permanent than reduced tillage practices, re-planting every 10 to 30 years will likely be required to maintain yields and to take advantage of new cultivars.

Barriers: This initiative requires more research into profitable perennial species, effective management, pilot projects, field trials, demonstration plots and market analysis before a farm is likely to convert current cropland to a perennial system. Alternatively, careful use of double crops and cover crops, especially if over-seeded could provide some of the benefits without the risks of perennial crops.

Incentives: This is a potentially permanent (though reversible) proposed change in practice on up to 10% of all cropland area and could be a verifiable practice but the cropping systems need further research and development in NYS. Fundamentally this is an important opportunity and we encourage funding for more research into perennial cropping system development.

3.10 Crop Nutrient Management (N fertilizer reduction)

Avoided N_2O emissions due to more efficient use of nitrogen fertilizers and avoided upstream emissions from energy-intensive synthetic fertilizer manufacture.

RANK *** Priority	**Services** *	Measurable	**Achievable** *	Realistic	**Time Frame** *
	• Soil Health • Profitability • Air Quality • Water Quality • Energy	-0.2 Tg^ CO_2/yr Rank 2: Reliable	77% of potential opportunity could cost less than \$10/Mg CO_2e	Virtually all farmers	Annual implementation with long term benefit

Services. Services include: Soil Health, Profitability in many cases, Air Quality, Water Quality, and Energy savings by reducing the energy-intensive production of synthetic N fertilizer (beneficial leakage).
Measurable. Reliable. As this is an indirect measurement (reduce N applied while maintaining crop yields), this is a reliable and meaningful mitigation strategy to reduce N_2O that can be indirectly verified (combining crop yield and N-use data) using farmer self-reported or fertilizer sales data. We considered four improved management practices combined: 1) reduced whole-field application rate, 2) switching from anhydrous ammonia to urea, 3) improved timing of fertilizer application, and 4) variable application rate within field. We estimated the mitigation value by disaggregating our published national estimate for NYS (Fargione et al. 2018 and web site, and McDonnell et al. 2020 in press).
Achievable. This reduction is a function of 4 different and integrated practices; some practices will save the producer money while some practices will cost the producer money to implement. 77% of this mitigation potential could be achieved at <\$10/MgCO_2e.
Realistic. This practice is real and realistic as it is relatively inexpensive and easy to implement but to fully achieve the mitigation estimate listed, it requires a comprehensive training of all farmers in the use of sophisticated nutrient management tools and in some cases new equipment and data collection.

Time Frame. Annually Permanent. Given the long lifespan of N_2O in the atmosphere and its relative potency, these annual activities have century long implications and merit implementing as soon as possible, especially considering the low cost or cost savings and the other environmental benefits.

Barriers: Farmers are often assumed to apply extra N as 'insurance' to avoid any yield penalty. The 4R principle guidelines have gained traction and have modest upfront costs. The precision N-management systems have more upfront costs for tools, training technical assistance and extending these skills to farms and fields. Indirectly verifiable and permanent as long as crop yield is maintained, which is feasible if tools are implemented correctly.

Incentives: This is a low cost or cost savings opportunity for a persistent annual dependence on N for crop systems with substantial co-benefits. While this includes all farmers (and landowners with yards and golf-courses, etc.), this objective dovetails nicely with existing water quality initiatives, and can be integrated into established Agricultural Environmental Management (AEM) education/outreach/peer-training, Soil and Water Conservation Districts (SWCD), and Cornell Cooperative Extension (CCE) field agents and protocols. More sophisticated tools may need incentives to be made available with proper training to education and outreach organizations like SWCD and CCE staff who do site visits. Alternatively, the N-industry officials could subsidize tools and then function as carbon-credit aggregators but may have a conflict of interest (sell more fertilizer or gain more credit for climate mitigation).

3.11 Riparian Buffers

An area of predominantly trees and/or shrubs located adjacent to and up-gradient from watercourses or water bodies. If planted with trees, it is also a long-term form of carbon sequestration (albeit on a small area).

RANK ***	**Services** *	Measurable	**Achievable** *	Realistic	**Time Frame** *
	• Soil Health • Adaptation to Climate Change • Water Quality • Biodiversity	Small Rank 2: Reliable	Expensive, but supported by existing water quality initiatives	Small discrete areas <13,000 ac total	Decadal for forested buffer

Services. Services include: Soil Health, Adaptation to extreme precipitation, Water Quality, and Biodiversity.
Measurable. Reliable. While riparian buffers will likely be a measurable opportunity (making it technically verifiable) the scale of the opportunity is relatively small suggesting that perhaps this is dealt with as a co-benefit associated with water quality initiatives. However, despite the high cost and the relatively small area, if placed in sensitive locations, buffers can help manage nutrients from a much larger uphill area of cropland. We have estimated the GHG mitigation potential on a per-area basis, but it is not clear how much additional area could be brought into buffers to provide new GHG mitigation.
Achievable. Currently there are initiatives to support planting riparian buffers (e.g. Trees for Tributaries, see Appendix C for other opportunities). So perhaps there is sufficient funding to address this modest but meaningful mitigation through existing means, making it very achievable with existing policy.
Realistic. Real but possibly not realistic. While riparian buffers offer real benefits, sometimes it may not be realistic as this land is often very productive and profitable making it difficult to switch. According to Pape et al. (2016), there may be as many as 13,000 acres of riparian buffer area in NYS.
Time Frame. If trees are planted and maintained properly during the early years, then they are very likely to last for many decades.

Barriers: Often riparian buffers are on very productive lands making it difficult to convince a landowner to convert.

Incentives: This is a potentially permanent and verifiable practice that impacts very specific and small areas already covered by a NYS water quality initiative. We suggest it continue in this way, offering GHG mitigation as a small but reliable co-benefit.

3.12 Biochar

Biochar is produced by pyrolysis and is essentially charcoal that can be incorporated into soils where it lasts much longer than adding other carbon sources such as crop residue.

Rank *	**Services** *	Measurable	Achievable	Realistic	Time Frame
	• Soil Health • Adaptation to Climate Change • Water Quality	TBD	TBD Needs more research	Real but needs more research and demonstrations to be considered realistic	As biochar is difficult to break down, it has the potential to store C in the soil. However the system of converting biomass to char (vs. other use) needs to be seriously considered

Services. Services include: increased soil carbon with likely Soil Health benefits, possibly improved Air Quality if pyrolysis produces energy in place of more polluting combustion technologies, and improved Water Quality by its ability to 'soak up" excess nutrients in soil.
Measurable. The potential for biochar to sequester carbon depends on the supply of suitable biomass feedstocks (competing uses), the energy to process, the cost, etc. At this time, while it is possible to estimate the amount of biochar applied and the average time it takes to break down, it has the potential for tying up soil nutrients, thus requiring a farmer to add energy-intensive new nutrients. While promising as a reliable and verifiable method of storing carbon, more research is needed to compare and develop systems that provide net energy gains while improving nutrient management and cropping system performance.
Achievable. While Achievable, this practice requires more research and pilot studies before receiving incentives as a statewide initiative for GHG mitigation.
Realistic. Real but needs demonstrations to be Realistic. While biochar is a long-term storage of carbon making it a real opportunity for sequestering carbon, it has not been demonstrated to be realistic and cost/energy effective for many farms.
Time Frame. While biochar promises long-term sequestration, it requires more research analyzing the whole system (from feedstock to field bioenergy and nutrient management) before receiving incentives to apply this potential GHG mitigation practice across the State.

Barriers: Biochar is a new concept for NYS that has not yet been demonstrated to be realistic and cost effective for many farms. Additionally, it is unclear that pyrolysis of biomass to biochar is the most effective use of that biomass (from an energy or GHG lifecycle standpoint). More research is needed on assessing the system-wide costs and benefits of pyrolysis of biomass to create a long-lasting carbon sink and to improve nutrient management and reduce water pollution.

Incentives: Biochar is a long-term storage of carbon making it a real opportunity for sequestering carbon more permanently in soil. However, system development, pilot projects, field trials, demonstration plots and market analysis must be completed before it is applied as a greenhouse gas mitigation strategy. Fundamentally this is an important idea and we encourage funding for more research into the costs/benefits of biochar systems.

3.13 Reduced Tillage/No Tillage

Minimizing soil disturbance and increasing the amount crop residue on the soil surface.

Rank *	**Services** *	Measurable	Achievable	Realistic	Time Frame
	• Soil Health • Adaptation to Climate Change • Profitability • Air Quality • Water Quality • Energy	Rank 3: Directionally Beneficial	TBD	TBD	30-year maximum, easily reversible.

Services. Services include: Soil Health, Adaptation, Profitability Air Quality, Water Quality, and modestly reduced Energy from reduced labor and equipment use.
Measurable. Directionally Beneficial. While improved soil carbon is beneficial for many reasons, reduced tillage needs to be practiced with addition of residues or cover crops to reliably increase soil carbon. Also, no-till can increase soil N_2O emissions at least in the short term. Due to the large GWP of N_2O, small increases of N_2O emissions can negate large amounts of mitigation from soil carbon-sequestration. In addition, given that it is difficult to measure flux in N_2O, and difficult to verify tillage practices, this practice is difficult to measure and verify.
Achievable. A change in this practice may not be an achievable way of mitigating GHG emissions without substantial discounting because subsequent tillage can quickly reverse the soil carbon sequestration.
Realistic. Possibly Real/Realistic. Soil carbon is important for soil health and supports climate adaptation, productivity, and resiliency measures that make this an important BMP from a farm-management perspective but should not be prioritized as a GHG mitigation strategy until after other more permanent and verifiable practices are supported.
Time Frame. Easily Reversible. Like gains from cover crops, soil carbon gains from reduced tillage are easily reversible and therefore not permanent. While this practice in principle can help sequester carbon in the soil as part of a suite of management practices, subsequent tillage can quickly reverse decades of C-sequestration in a few years. Therefore, it should <u>not</u> be considered a permanent GHG mitigation practice, though it can have soil health benefits.

Barrier: The reversible nature of soil carbon makes it difficult to verify. The change in practice may increase carbon storage but also increase the much more potent N_2O emissions potentially negating the soil carbon benefit. Natural and human events can quickly reverse the gains in soil carbon that took decades to build. All of these points make verification difficult.

Incentive: Like cover crops, reduced tillage has multiple soil health co-benefits making it better suited primarily for water quality, soil health, and farm viability initiatives (with a small and reversible GHG mitigation co-benefit).

In summary, we feel that agriculture could mitigate its own greenhouse gas emissions, but only with a substantial effort including afforestation of 1.7 million acres of idle and underutilized former agricultural land. However, a few key points need to be stressed.

1) Agriculture is a living system based on the active cycling of carbon and nitrogen while providing many key products for our society. However, given that it is a complex system, in certain situations it may be very difficult to quantify greenhouse gas benefits on the time scales necessary for climate change mitigation.
2) Many social forces (market, aesthetics, history) affect how land is currently used and how it will be used in the future. As this land is mostly privately owned, it will be very difficult to ensure that efforts to mitigate emissions today will continue for decades in the future with changes in ownership and land-use.
3) The more verifiable and permanent GHG mitigation practices using currently available technologies were ranked as priority activities for developing near-term policy. This ranking was employed because it means more money can be spent implementing real and permanent practices than spent on verifying and ensuring less permanent practices. This does not mean other practices cannot also be developed in the future or that other practices do not have merit for a myriad of other reasons. Our highest ranked practices cover a range of small and large farmers as well as other landowners, have relatively low costs compared to the social cost of carbon, and have the necessary real, permanent and verifiable attributes suitable to accounting and fiduciary responsibility.
4) Below, we have outlined a range of activities that could assist in developing the next generation of priority actions.

Goals, Priorities and Ideas to Increase Adoption

<u>This section is meant as a brainstorm of ideas that NYS could consider for increasing adoption of greenhouse gas mitigation opportunities.</u>

1. Develop policies to assist landowner adoption of Greenhouse Gas (GHG) mitigating practices.
   - 1.1. Identify a portfolio of landowner mitigation practices that anyone can voluntarily do now.
   - 1.2. Identify opportunities to integrate greenhouse gas management into current state statutes and programs related to land, water, and nutrient management. Such opportunities can include integrating climate change policy initiatives with existing initiatives focused on water quality, soil health, forestry, smart growth, grid infrastructure development, and land fragmentation policies, among others.
   - 1.3. Identify a portfolio of landowner mitigation practices that NYS will actively pursue that accomplish Real, Additional, Verifiable, and Permanent GHG mitigation and then establish appropriate funding to meet the needs of each practice and participating stakeholders.
   - 1.4. Continue New York's participation in the U.S. Climate Alliance including allocating Agency staff time and travel funding to participate in national and regional meetings, including the following.
     - 1.4.1. "Natural and Working Lands" (NWL) component (https://www.usclimatealliance.org/nwlands/)
     - 1.4.2. "Short-Lived Climate Pollutants" (SLCP) component https://www.usclimatealliance.org/slcp
   - 1.5. Continue to network with other states to learn from and share initiatives, policies, tools, education/outreach programs, and other forms of communication across sectors, private and public agents, administrators, educators, and landowners.
   - 1.6. Expand NYS departmental capacity to facilitate use of existing tools, policies, and outreach as well as develop new efforts.
     - 1.6.1. Increase collaboration between legislative branches and administration to implement programming and at-large capacity building.

1.6.2. Expand staff/capacity of the NYS Department of Environmental Conservation (DEC) Office of Climate Change to bolster programming, formal and informal education, increase stakeholder engagement, assist stakeholders in applying for grants/opportunities, administer and oversee practice implementation, increase capacity for developing verification protocols and documenting mitigation results.

1.6.3. Expand NYS Department of Agriculture and Markets (AGM) office staff/capacity to facilitate similar activities described for DEC but include administration and effective implementation of practices either internally or by supporting more Soil and Water Conservation Districts (SWCD) field staff to assist landowners. Increase education and outreach to inform, advocate, and implement practices effectively.

1.6.4. Expand capacity for applied research and extension by funding programs at the Land Grant University (Cornell) as well as other relevant programs within the SUNY system to survey landowners/stakeholders, expand research initiatives, and support sound decision making and implementation with research-based guidelines. Such funds should be budgeted as additional funds not already dedicated to current programs/agencies.

1.6.5. Increase communication between agricultural initiatives and forest initiatives to increase landowner decision making capacity for both sectors as well as to engage a broader group of landowners beyond commercial producers, such as horse farmers, owners of idle agricultural lands, owners who rent to farmers etc.

1.6.6. Integrate climate mitigation planning into existing land and water management programs and guidelines such as standards (e.g., comprehensive nutrient management plans, NRCS conservation planning), planning, technical assistance, and cost share programs.

1.6.7. Consider developing a team of regional policy makers, members in the department of taxation, and other groups to work across disciplines to identify the most effective methods (funding streams, finance levers, etc.) and support for implementing specific practices that provide GHG mitigation benefits, focusing on the highly ranked opportunities analyzed above.

1.7. Develop a comprehensive plan to integrate soil health, water quality, land-use change, forest management, renewable energy, and GHG mitigation initiatives across land-use types and at different scales for implementation (landowner, municipal, regional, and state).

1.7.1. Create resource maps to support local and regional decision-making, for example (1) identify the highest quality idle lands that should be encouraged to return to farming, (2) assess slope and aspect to identify suitable solar siting or reforestation locations that do not compete with the best cropland, (3) map existing energy infrastructure with nearby land resources that could produce biomass feedstock production for Combined Heat & Power (CHP) plants, proximity to appropriate locations on the electrical grid, etc.

1.7.2. Review existing policies to identify possible trade-offs between environmental quality initiatives and solutions to address multiple goals. For example, increased liquid storage of manure on farms regulated by the Concentrated Animal Feeding Operation (CAFO) permits to protect water quality has increased the methane emissions, but a cover & flare system can greatly reduce methane emissions. Consider aggressively incentivizing cover and flare systems to all applicable manure storage units on CAFO permitted farms. While not feasible to make it a permit requirement given the strict water quality focus of the CAFO permits and the limitations on covering manure for barns using sand bedding, current incentive structures (e.g., as in Track 1 of the Climate Resilient Farming Program) could be significantly expanded to expedite cover and flare systems on all applicable CAFO regulated farms.

1.7.3. Consider smart growth approaches to increase in-fill development and urban density, reduce road expansion, increase transportation efficiency, and conserve valuable agricultural and forest working land resources.

2. Expand technical support for landowner adoption of climate mitigating practices.

2.1. Expand funding for Technical Support for Landowner Adoption of identified practices.
   2.1.1. Expand outreach component of Climate Resilient Farming (CRF) component of the state AEM framework (https://www.nys-soilandwater.org/programs/crf.html).
   2.1.2. Expand administration component of CRF to advertise to prospective landowners to increase participation, assist prospective landowners in applying for opportunities, and expand SWCD training on these identified opportunities.
2.2. Increase financial support for land-based climate mitigation activities.
   2.2.1. Expand current NYS DEC and NYS AGM/SWCC cost-share and technical assistance programs.
   2.2.2. Increase funding to assist landowners to apply for, implement, and report on practices implemented (fill out proposals/measure impacts).
2.3. Increase knowledge of GHG mitigation practices by Field Educators.
   2.3.1. Identify and train agents across NYS that implement other State goals (i.e., water quality initiatives, etc.), to be able to also assess GHG mitigation strategies with these existing practices.
   2.3.2. Support grant opportunities through organizations like the NY Farm Viability Institute for on-farm climate mitigation research, trials, and demonstration.
   2.3.3. Increase the dialogue between field agents and landowners on the importance of GHG mitigation.
   2.3.4. Consider training Field Educators to become 3rd party evaluators for NYS functioning as a kind of aggregator that assesses mitigation quality and quantity resulting from practice implementation.

3. Facilitate communication among landowners and land managers to share goals and BMP lessons learned.

3.1. Foster cooperation and information sharing among stakeholders.
   3.1.1. Facilitate SWCD, Cornell Cooperative Extension (CCE) and forestry managers to work together holistically and regionally.
   3.1.2. Provide venues, panels, and pilot studies for outreach and education.
   3.1.3. Create peer-to-peer initiatives to share challenges and benefits of land management practices.
   3.1.4. Promote discussions of unintended consequences, identify barriers to use of improved practices, raise awareness, establish case-studies of failures and successes, identify gaps in knowledge, promote a shared goal of climate mitigation as part of environmental stewardship among all stakeholders.
   3.1.5. Acknowledge existing good practices and synergies among practices.
3.2. Build on the progress of the statewide efforts such as the Comprehensive Nutrient Management Plans (CNMP), Carbon Farm Plans (CFP), etc. to provide a platform for sharing information, planning, events, resources, and priorities for land managers to help meet climate mitigation goals.
3.3. Formalize a committee of stakeholders (universities, agencies, non-governmental organizations (NGOs), farmer organizations, businesses) focused on increasing adoption of climate mitigation practices that are beneficial for agriculture and society at large. The committee will:
   3.3.1. Define climate mitigation and adaptation goals and identify approaches for improving health, resilience and carbon capacity of NYS soils, reduce methane emissions from animal agriculture, reduce nitrous oxide emissions from agriculture, conserve prime farmland and maintain existing woodlands, and increase energy conservation and efficiency as well as renewable energy where feasible.
   3.3.2. Identify challenges and opportunities for implementing climate mitigation opportunities in both rural and urban areas, (for example, reducing food waste throughout the entire food system).
   3.3.3. Oversee analysis of opportunities for integrating climate mitigation into current programs and statutes related to soil, water, air, energy, and nutrient management.

3.3.4. Provide leadership and coordination in promoting climate mitigation assessment and management.
3.3.5. Promote and facilitate outreach, applied research, demonstrations, and farmer-to-farmer communication.
3.3.6. Facilitate communication and raise awareness with policy makers and potential funders.
3.3.7. Integrate farm nutrient management planning and NGO/industry initiatives such as "NY-4R Nutrient Stewardship Program".

3.4. Support a survey and analysis of the following topics:
3.4.1. Detailed farm practices, for example: (1) how do you manage your manure, (2) how do you manage your wooded areas, (3) how do you manage nitrogen fertilizer, (4) what percent of your land is used for horses, (5) if you have idle land – why is it idle, etc. These could be incorporated into new and existing AEM Tier 1 and 2 worksheets.
3.4.2. Landowner participation in quantifiable and qualitative GHG mitigation opportunities to identify leaders, identify barriers to implementation, and encourage these leaders to share information with peers.
3.4.3. Anticipated future use of their land, for example (1) transfer to family members, (2) sell to a developer, (3) lease to solar industry, (4) lease to a young farmer, (5) obtain conservation easements, (6), expansion farming operation, etc.

4. Develop Markets (and market diversification)

4.1. Identify methods and mechanisms for increasing sales resulting from expanded farm activities for existing and new crops, for example double cropping, woodland/silvopasture, or conversion of annual to perennial crops.
4.2. Identify energy initiatives that assist farms to use or produce renewable energy that both protects high quality agricultural lands and provides adequate financial return.
4.3. Facilitate availability of resources related to climate mitigation opportunities for agribusiness ventures such as low-cost loans, technical assistance, equipment rental, risk management for implementing GHG mitigation practices, etc.
4.4. Facilitate farm diversification of products and mitigation strategies to buffer against and adapt to changing climatic conditions.
4.5. Consider how existing infrastructure could be improved (grid, rail, slaughterhouses, bioenergy processing, wood product processing) to increase farmer participation in new initiatives, efficiency of production, or add value to raw resources.

5. Establish NYS-specific basic and applied research

5.1. Conduct a quantitative survey of land resources across the state and identification of critical barriers.
5.1.1. Include a special focus on underutilized lands.
5.1.1.1. Characteristics and best practices across diverse parcels.
5.1.1.2. Economics of the use of underutilized lands.
5.1.2. Plans for land preservation and easement, open space, transportation, watershed management, energy.

5.2. Policy Impacts
5.2.1. Land use change resulting from energy and GHG policies.
5.2.2. Renewable energy contracting and policy analysis of impact of renewable energy initiatives on active and idle agricultural land.
5.2.3. Planning for local and regional energy production.
5.2.3.1. Siting from both resource and demand perspectives (proximity to electrical grid, highway, urban demand, value of land for agriculture, etc.).

- 5.2.3.2. Other environmental benefits or issues (e.g. particulate matter emissions, etc. from renewable energy or farm activities).
- 5.2.3.3. Promote circular economies and use of co-products, (e.g. industries that use waste heat sited next to CHP).

5.3. Suitable cropping systems and system analysis.
- 5.3.1. Perennial crops suitable for efficient bioenergy systems.
- 5.3.2. Perennial crops for food and feed production.
- 5.3.3. Double crops for winter and fallow periods of working cropland.
  - 5.3.3.1. Cultivar selection, crop rotation, and cropping system planning.
  - 5.3.3.2. Integrating cover crops, double crops, and reduced tillage into cropping systems.
- 5.3.4. Food waste analysis and mitigation research throughout entire food systems.
- 5.3.5. Managing livestock feed, manure, and production efficiency.
- 5.3.6. Cultivars/species that may maintain yields under changing conditions (temperature, precipitation, pests).
- 5.3.7. Pyrolysis/Biochar
  - 5.3.7.1. Life cycle analysis of costs and benefits of different biochar systems including soil, air, and water quality, energy production and economic viability.
  - 5.3.7.2. Nutrient storage and release dynamics for working croplands.
  - 5.3.7.3. Supply of biomass and efficiency of conversion to useful energy.
- 5.3.8. Actively managing woodlands and forests.
- 5.3.9. Agroforestry/Silvopasture/AlleyCropping/Wooded Riparian Buffers
  - 5.3.9.1. Changes in production (reduced yield per acre or diversified yield per acre).
  - 5.3.9.2. Species selection for productivity, co-benefits, adaptability.
  - 5.3.9.3. Short term vs. long term planning and management.
  - 5.3.9.4. Product utilization/marketing, developing New York supply chains.

5.4. Economic feasibility of:
- 5.4.1. GHG mitigation opportunities.
- 5.4.2. Options for using idle and underutilized lands for livestock vs. reforestation vs. bioenergy vs. crops.
- 5.4.3. GHG accounting and verification protocols.

5.5. On-farm demonstrations and field trials.

5.6. Identify gaps and opportunities in technology (e.g., digital agriculture), farm equipment (e.g., for small scale application and vegetable crops, or specialized equipment for tillage and cover crop management, such as roller-crimpers).

Appendices

Appendix A: Assumptions

Boundary 1: Items Not Assessed

This table is meant to illustrate topical areas, system pathways, and/or potential opportunities we did not assess for this report. There were multiple reasons why we did not assess them, some were outside the scope of this analysis which focused on agricultural land, some did not seem to have a significant opportunity at this time, some had insufficient data or resources to analyze, or some practices identified globally are not applicable to NYS. Some of these topics are listed, along with the rationale for not including them, in Table A1.

TABLE A1. Potential Mitigation Pathways Not Assessed in this report

Name of Pathway	Explanation	Notes
Avoided Forest Conversion	Outside the scope of our analysis, but an important opportunity.	
Improved Forest Management	Outside the scope of our analysis, but an important opportunity.	SUNY ESF (via CAFRI) will be analyzing this opportunity from 2019 to 2021.
Grassland Restoration	Refers to restoring grassland from tilled agriculture. We have included this category in our "annual to perennial" category.	See also afforestation for restoration of native ecosystems from underutilized agricultural land.
Windbreaks	Small opportunity (uncommon practice), but see Alley Cropping and other agroforestry opportunities.	NYS windbreak instructions: https://www.dec.ny.gov/animals/9394.html
Urban Reforestation	Outside the scope of our analysis, but an important opportunity with multiple co-benefits.	NYS DEC urban forest benefits. https://www.dec.ny.gov/lands/4957.html See also economic analysis by Kroeger et al. (2018) <https://www.vibrantcitieslab.com/resources/where-the-people-are-current-trends-and-targeted-investment-opportunities-to-mitigate-pollution-and-heat-island-effects/>
Seagrass Restoration	Outside the scope of our analysis, but an important opportunity with multiple co-benefits.	Please see this NYS DEC Map for location of opportunities.
Tidal Wetland Restoration	Outside the scope of our analysis, but an important opportunity with multiple co-benefits.	Please see NYS DEC wetland restoration objectives https://www.dec.ny.gov/lands/31879.html

Improved Lime Management	Small opportunity while maintaining production because lime is required for most agricultural production on acidic soils.	Lime has an important role for N management and crop productivity.
Improved Grazing	Small opportunity for GHG mitigation but has other co-benefits.	
Legumes in Pasture	It is unclear if it offers real GHG mitigation but has other benefits for farms to consider.	Legumes in pasture are suitable for soil health initiatives but more research is needed before counting this practice as a GHG mitigation opportunity.
Improved Rice	n/a	NYS does not produce rice.
Fire Management	n/a	Over the last 25 years, on average NYS had 217 fires burning 2,103 acres per year (for context, NYS has 18.9 million acres of non-federal forested lands)
Improved Plantations	Outside the scope of our analysis.	While there has been a history of forest plantations in NYS for many purposes (https://www.dec.ny.gov/lands/4982.html), they have mostly been phased out. However, there are some new bioenergy feedstock plantations of short-rotation woody crops in NYS.
Pest Management	While pest impacts are important to the economy, climate adaptation and mitigation, we do not include it.	See Table A2 below.
Horse Land	While land associated with equine activities is quite large, we do not include it here because it is not clear what GHG mitigation opportunities are feasible.	Ropel, S. and B. Smith (2007). New York Equine Survey 2005. Albany, NY, New York Agricultural Statistics Service**:** 54.
Peatland/ Muckland Restoration	There are an estimated 30,000 acres of highly productive muck soils (Histosols) in NYS in vegetable production: we do not include this opportunity because it might remove these valuable lands from agricultural production.	Histosols are soils with very high organic matter than form in wetlands, including both peat and muck soils (also called "black dirt" in NYS). When drained they can be highly productive agricultural soils. However, because of this drainage, Histosols typically have much higher GHG emissions than other croplands. There may be opportunities such as controlled drainage to reduce emissions while maintaining production that are worth exploring in the future.

Energy Conservation & Efficiency	Outside the scope of our analysis, but an important opportunity. There are many ways that farms can save money, time, energy and GHG through energy efficiency improvements, but they are usually accounted for in other sectors (e.g. heating, electricity & transportation fuel sectors)	We do however indicate when energy conservation, efficiency, or production potential is a potential co-benefit for a GHG mitigating practice. This is an important topic in NYS due to rapid expansion of solar installations and some expansion of wind installations.

Boundary 2: Items assumed not to change to maintain system stability.

In our analysis we assume that certain behaviors, systems, and conditions are maintained. For example, we assume there are not changes to land-use between sectors or that climate conditions (precipitation, temperature, pests) do not radically change our current production systems. These are summarized in Table A2.

TABLE A2. Behaviors, Systems, and Conditions that are Assumed to be Maintained

Topic Area	Assumption	Importance to GHG mitigation and accounting
Current Agricultural Land	We assume that active agricultural land remains in agriculture in the future.	Maintaining current agricultural production avoids detrimental leakage that would occur if production decreases and food and feed imports from outside NYS increase.
Current Forest Land	We assume that forestland remains forest.	Forests are a very large source of ongoing C sequestration in NYS.
Responsiveness to Changes in Pest Management	Changes in temperature and precipitation may lead to increased pest problems and increased challenges for pest management, but we do not analyze this topic.	If a pest causes serious damage to a crop or tree species, there may be serious losses to carbon sequestration and current production with effects on GHG emissions.
Responsiveness to Changes in Extreme Weather	During coming decades, changes in climate will increasingly affect many management choices including crop and cultivar selection, irrigation, and pest management. We do not analyze this topic.	Like pests (see above), choosing appropriate varieties that are well suited to changing climate conditions has implications for how we currently (and in the future) account for GHG emissions and mitigation from agricultural activities.

Appendix B: Definitions

There are several words and phrases that are used in specific ways in relation to climate mitigation and adaption. The most recent definition for framing offset programs for the electric sector (US EPA Climate Leaders Program, 2018, now discontinued, https://www.epa.gov/climateleadership/climate-leadership-awards-frequent-questions) is as follows:

- **Real:** The quantified GHG reductions must represent actual emission reductions that have already occurred.
- **Additional:** The GHG reductions must be surplus to regulation and beyond what would have happened in the absence of the practice or in a business-as-usual scenario based on a performance standard methodology.
- **Permanent:** The GHG reductions must be permanent or have guarantees to ensure that any losses are replaced in the future.
- **Verifiable:** The GHG reductions must result from practices whose performance can be readily and accurately quantified, monitored and verified.

These words and phrases are important as they help ensure the overall accounting of GHG with respect to the collective goal of mitigating emissions within and across sectors (within and across states). As there are many stakeholders involved, a strong commitment to these criteria will help inform boundaries of implementation (farm level, state level, federal level) as well as legal accountability (across farm practices, sectors, c-trading regimes, policy, accounting systems).

Below, we illustrate these terms with respect to the manure storage cover+flare practice:

1. **Real**: The quantified GHG emission reduction must represent actual emission reductions.
    a. **For example,** methane captured and destroyed with a manure storage cover and flare is real, because a meter can measure the amount of methane destroyed by a flare.
    b. It will not measure the methane that it does not flare, but it will measure the volume of methane that is actually captured and destroyed at the flare.
    c. Complication, if a farm amends their manure by adding materials (such as whey from yogurt production), this is *intentional* methane production and must be evaluated to determine if a credit should be granted to a farm that intentionally increases its methane production. This may be considered 'gaming', or it may be providing other ecosystem services (such as producing more biogas that could be combusted in a generator to produce electricity).
2. **Permanent:** The GHG emission reductions must be permanent and must be backed by guarantees in the event that they are reversed (e.g., re-emitted into the atmosphere).
    a. **For example,** the carbon in CH_4 that is flared to CO_2 is permanent. Once CH_4 has been oxidized to CO_2, it is 34 (or 86 on a 20-year time scale) times less potent a GHG than CH_4.
    b. Please see section on "Permanence and Managing Risk" as applicable to the responsibilities of policy makers, below.
3. **Verifiable**: The GHG emission reductions must result from practices whose performance can be readily and accurately quantified, monitored, and verified.
    a. **For example**, manure covers with flare are equipped with digitally reporting meters for measuring the amount of methane produced and the temperature of the flare indicating its combustion effectiveness. The gas flow which passes a cold flare will not count as mitigation.
    b. Please see section on rigor of GHG verification (below) in the context of other state goals (currently existing or in development).

4. **Additional**: The practice-based GHG emission reductions must be beyond what would have happened anyway or in a business-as-usual scenario (not driven because of another regulatory requirement, an improvement in production efficiency, or other requirements).
    a. **For example,** farms have been installing manure storage units to protect water quality as per CAFO regulations. While there are other benefits to covering a manure storage (reducing odors, reducing manure hauling, reducing SPDES violations from extreme weather events etc.), there is currently no regulation to flare. Thus, adding a flare, meter etc. is an additional project.
    b. Please see below for a detailed discussion about Additionality as a policy decision.

Another very important topic is leakage.

1. **Leakage:** Leakage refers to an emissions reduction strategy implemented in one location that creates an increase or decrease of emissions in another location. If this other location is outside the boundary of the region being analyzed, such as NYS, it can greatly affect the interpretation of the efficacy of a GHG mitigation practice (on a global scale).
    a. **For example,** a lumber company in NYS may place 1,000 acres of forest under permanent conservation easement preventing any harvest in order to sequester carbon. However, to meet the market demand for lumber, another company may deforest 1,000 acres outside NYS. In this example, detrimental leakage occurs due to market forces, but can occur by many mechanisms including policies. The result is that GHG emissions from a local farm, sector, or State are in effect transferred to another location outside the boundary of the policy initiative.
    b. Analyzing across all locations, leakage can cause either increased total GHG gas emissions (detrimental leakage) or decreased total GHG emissions (beneficial leakage).

Permanence and Managing Risk

As described above, Permanence refers to GHG emission reductions that must be backed by guarantees in the event that they are reversed (e.g., re-emitted into the atmosphere). The Coalition on Agricultural Greenhouse Gases (C-AGG, 2010) developed a useful synopsis for managing risk of permanence. We have summarized and modified their work in table format below. Table B1 lays out the source of the risk and the ability of landowners and or policy makers to control this risk. For example, neither landowners nor policy makers have much control over natural disaster impact on GHG mitigation practices, but both have significant agency within socio-economic terms. Table B2, lays out mechanisms to help transparently address risks of reversal for GHG mitigation practices.

TABLE B1. Sources of risk to permanence of GHG mitigation practices

Source of Risk*	Description	Landowner Control	Policy Control
Natural	Loss by disease, drought, flooding, insects, wildfire, wind, other natural disasters	low	low
Socio-Political	Loss by changing regulatory policy, political instability, or social unrest, or leakage	low	**high**
Technical	Loss if technologies or practices used fail to maintain carbon stocks or mitigate GHG as expected	low	low to **high**
Financial	Financial failure of an organization may lead to dissolution of agreements and change of management activities (a farm goes bankrupt and agreements are dissolved)	low to **high**	low to **high**
Socio-Economic	Higher-value alternative land uses, and rising opportunity costs can lead to a change of management activity or plans.	**high**	**high**

* This table is adapted from C-AGG (2010) and attempts to illustrate the limitations of the technical potential described here-in.

Standards define the things that will be measured to gain market entry and how they will be measured. A highly measurable, verifiable, real, and permanent mitigation practice will have greater value and be easier to track. A practice that is less measurable, more difficult to verify, with potential reversibility will be more difficult and costly to track. The desire to maximize crediting farm practices must be weighed against the costs of implementation and the accounting burdens of verification. Likewise, upfront costs/crediting needs to be balanced with assessing risks into the future to ensure against future reversals for a specified period of time (sometimes called a permanence or a liability period).

Below in Table B2 is a list of mechanisms for addressing risk from an insufficient ability to measure, track and verify and/or accommodate conditions that may cause a reversal of mitigation.

TABLE B2. Managing risk to permanence of GHG mitigation practices

Mechanism for Averting Risk*	Description	Consideration
Discounting	Discounting the potential mitigating potential by using a risk value to address the probability of carbon loss or reversal over a timeframe.	The disadvantage is certain projects may outperform but receive no credit, not rewarding innovative project managers.
Buffering	A portion of mitigation potential may be placed into a buffer reserve established over the term of the project and if no loss or reversal has occurred at the end of the term, the project manager is awarded the buffer. For example, if a project is quantified to address 100 Mg CO_2e over 4 years, a portion (say 20 Mg CO_2e) could be set aside, resulting in the landowner receiving payment of 20 Mg CO_2e per year (instead of 25 Mg CO_2e/yr). At the end of the 4th year, if all went as planned and the buffer was not needed to ensure project effectiveness, the landowner receives a final payment of 20 Mg CO_2e. If, however, the project did not meet its mitigation potential, the buffer is not converted to a payment.	Assessing risk and assigning a required buffer value on a project-by-project basis may be time-consuming and burdensome for project owners and system administrators.
Pooling of similar practices	A program-wide pooled buffer account is maintained at all times by an administrator. All projects submit the same relative amount to the pool. All projects receive an average benefit at the end of the pooling period. Benefits and liabilities are thus shared among participants.	Regular monitoring and recalibration of buffer withholding percentages can be used to adjust the size of the pooled buffer account based on actual loss experience.
Pooling of diverse practices	A farm-scale or regional portfolio of different GHG mitigation opportunities is pooled (for discounting, buffering or self-insuring purposes), diversifying the risk of reversal by any one type of project in the portfolio.	As above.
Insurance	A farm or group of landowners may purchase private insurance to cover the risk of loss or reversal of GHG mitigation.	Assessing risk and underwriting the insurance mechanisms on a project-by-

		project basis could be costly and time-consuming.
Temporary Liability	Easements or project implementation agreements may legally require landowners to take actions that maintain carbon stocks or mitigation rates over a predefined time period.	A long-term easement may offer the best chance to maximize project crediting while ensuring that no intentional reversals occur. But few landowners may be willing to make long-term agreements.
Setting Term Credits	A commitment period ("term") is defined for maintaining carbon stocks. At the end of the term, the project landowner must either renew the commitment for another term or the credits issued to the project must be replaced.	Responsibility for replacing the credits at the end of the term is generally assigned to the final buyer of the credits. Liability for any reversals that occur prior to the end of a term is generally assigned to the landowner.

* Adapted from C-AGG (2010)

While Table B2 suggests a number of ways to reduce the risk of reversal by natural and human activities, an underlying concept to defining each of these issues is the timeframe of the accruing benefits and the timeframe of reversibility. For example, it can take 30 years to reach a new steady-state value of soil carbon after implementing a practice and that gain can be reversed in just a few years of tillage. Additionally, one should consider the timeframe of the GWP potency such as short-lived methane or long-lived nitrous oxide, relative to carbon sequestration. These things taken together inform prioritization of activities to advance Real, Measurable, Verifiable, and Permanent mitigation, anticipating intentional (socio-economic conditions) and unintentional (extreme weather) reversals.

Verification: Thinking about rigor for GHG accounting as well as other state goals

Verification is intended to help assure that practices are both Real and Permanent (see definitions above). Verification is defined as the "GHG emission reductions must result from projects whose performance can be readily and accurately quantified, monitored, and verified."

The point of verification is accurate accounting from implemented activities. Verification upholds the integrity and quality of the data reported. Standardizing verification procedures promotes relevance, completeness, consistency, accuracy, and transparency of emissions reductions data reported by project developers. Transparent processes ensure projects are real, additional, permanent, verifiable and enforceable, compatible with other types of projects, support on-going monitoring, and minimize risk of invalid or double accounting. In this report, we apply the term *Verifiable* to practices that have robust and practical verification tools and methodologies. As mentioned above, one example is a manure storage unit cover and flare system equipped with a meter and temperature sensor that measures the gas flow and the flare effectiveness for documenting permanent destruction of methane. Another example is a forest management project with healthy growing trees that can be visually verified overtime for permanence or quantified by measuring tree diameter and height and using standard published allometric equations and factors to estimate stand volume and carbon content.

However, not all practices on farms have such a straightforward method for being 'readily and accurately quantified, monitored and verified'. Farms are complex living systems and greenhouse gases move in all directions making accurate and complete assessment of all GHG difficult to accurately monitor. We ranked activities as "verifiable" if their verification methods were direct and likely cost-effective. The second highest ranking term we use is *Reliable*. *Reliable* practices reliably reduce GHG emissions but may either be calculated indirectly, or across a large number of steps in a supply chain requiring much work to quantitatively verify, or may be a small but certain practice that can be evaluated simply with a site visit (trees planted as a riparian buffer can be visually verified to be healthy and growing). The lowest ranking term for verification is

Directionally Beneficial. Directionally Beneficial is applied to practices for which the benefit is too small or uncertain to merit the costs of formal verification, or verification is too onerous and therefore too costly, or a practice is easily reversible and potentially not a permanent practice (see also the discussion on Permanence in this Appendix). For example, no-till and reduced tillage have many benefits for soil health, with a small technical potential for increased soil carbon if performed continuously over the long term in careful combination with residue management, fertilizer management, and crop rotations, but it is not permanent and is very difficult to verify. However, as verification methods and tools develop in the future, the current ranking of practices in Table 3 could change.

A highly verifiable practice is a suitable candidate for state supported initiatives to support the GHG mitigation goals. A large and highly verifiable category offers a meaningful state-scale GHG mitigation opportunity. In contrast, a directionally beneficial practice is most likely best considered a GHG-mitigating co-benefit of some other state initiative. For example, no-till might best be considered a water quality initiative or soil health initiative with a possible small or impermanent co-benefit of GHG mitigation. Remember, verification is an accounting tool to support progress towards meeting a particular GHG mitigation goal. Verification costs money to implement and NYS should consider how it wants to prioritize spending. NYS may decide to support only highly verifiable and permanent GHG practices or direct money on implementing more directionally beneficial (not currently verifiable) practices that may also help meet other environmental goals such as clean air and clean water.

Additionality

Additionality is defined as "the project-based GHG emission reductions must be beyond what would have happened anyway or in a business-as-usual scenario". To discuss additionality we need to define subsidies, offsets, baseline and 'business as usual'. The following text combines ideas from several key sources (Gillenwater 2012, UNFCCC CDM Methodological Tool Version 7 2017, Claassen 2014).

A subsidy is intended to influence behavior but does not guarantee that a practice would not have occurred without the subsidy. An offset is intended to reduce GHG by some mechanism in one location to make up for GHG emissions elsewhere. An advantage of offsets is that markets can be used to help implement the most cost-effective reduction of GHG emissions. Offsets allow for trading credits to achieve compliance in emission limits. However, for an offset to achieve its purpose, in must be Extra, Surplus, or Additional – in other words, it must be done specifically for the purpose of reducing GHG emissions that would not have happened anyway. This 'extra/surplus/additional' value must be relative to a baseline or reference scenario and it must account for the differences in regulations and baseline requirements across sectors (for example, agriculture vs. electric) to ensure a net reduction from the system as a whole.

Developing a meaningful baseline or reference scenario is challenging for several reasons. First, a change in behavior in the future can happen for all kinds of reasons, not just the policy being evaluated (for example, a government policy could provide cost-share to afforest abandoned agricultural land. Alternatively, a 3rd party investor might approach that same landowner to lease the abandoned agricultural land to grown short rotation willow for a local bioenergy plant). Second, actors may provide misinformation in order to qualify or increase the benefits (gaming the system, free riders). Third, actors that have already begun a practice may not get credit. Fourth, a single behavior may be influenced by multiple factors, many of which are independent of the specific policy initiative. For example, a farmer might install a manure cover and flare system on a liquid storage unit to reduce odors specifically to improve neighbor relations, independent of the GHG mitigation benefit. Fifth, if a historical baseline is used, such as the year 1990, it is not possible to determine changes that would have happened anyway from changes that may have occurred in response to a GHG policy. Sixth, if a future business-as-usual scenario is used, it must make many assumptions about future behavior, land use, and economic conditions.

A 1990 baseline is used by the national reporting under the United Nations Framework Climate Convention (UNFCC) as well as NYS's recently enacted Climate Leadership and Community Protection Act (CLCPA). In such cases, any changes in GHG emissions are compared to the 1990 baseline. However, comparison to such a historical year baseline does not distinguish between reductions that would have occurred without any policy or management interventions from those that would not. For example, since 1990 there have been increases in the efficiency of both crop and livestock production, so that fewer GHG emissions occur for a given amount of food produced. However, these changes are due to market forces and ongoing efforts by farmers and others to improve production practices and improve economic returns, not to reduce GHG emissions. Thus, they happened anyway, not due to any GHG policy or management.

In this way, a practice that improves profitability may not be considered additional, since it might happen anyway. That is, a farm might implement a practice because it makes good financial sense through market-based mechanisms and therefore does not need State support to implement. Many of the GHG mitigation practices outlined in this report are now being done by some landowners/farmers in the State for reasons other than GHG mitigation. Such practices include improved N-use efficiency or managing woodlands/forests for high quality timber production in the future. The State could incentivize these practices for rural economic development and conservation purposes. The column "Achievable" in Table 3 is intended to illustrate the financial elements of implementing a practice in the current context.

New York has a long history of providing various forms of support to landowners to improve rural livelihoods, ensure healthy products, and protect air and water quality. To increase greenhouse gas mitigation, NYS could facilitate peer-to-peer training – taking advantage of the small percentage of farms that have already implemented a practice. Support for peer-to-peer training may be all that is required to achieve wider adoption of the practice throughout the state. NYS could also consider bundling or stacking multiple benefits together. However, when GHG benefits are bundled with other benefits, it can be much harder to determine that they are additional since the main benefit may be for water quality or some other purpose. In such cases, GHG benefits might best be viewed as co-benefits to some other main benefit. For this reason, in this report, the first column labeled "Services" in Table 3 provides a list of co-benefits associated with practices to help guide these kinds of bundled initiatives.

Many factors make it difficult to define agricultural practices as additional in NYS and elsewhere. For example, New York has supported farmer adoption of many Best Management Practices to achieve water quality improvements. Such support has included education and outreach, incentives, and cost-sharing. These practices have had both positive and negative impacts on GHG emissions. Below are 2 examples illustrating the complexity for determining the Additionality.

> **Example 1**: The "Trees for Tributaries" program is designed to improve water quality but may also have reduced net GHG emissions by sequestering carbon in trees. However, if it removes agricultural land from production, it may also cause land elsewhere to be converted to agricultural production, which may cause GHG emissions elsewhere due to indirect land use change (detrimental leakage). Plus, because riparian buffers are already being supported to improve water quality, the concomitant GHG mitigation from the growing trees may not be considered 'additional' GHG mitigation.
>
> **Example 2:** In recent decades, CAFO regulations to improve water quality have increased the number of long-term liquid manure storage units in NYS doubling the manure-based GHG emissions from the dairy herd. Covering the storage unit and flaring methane from currently uncovered liquid storage greatly reduces GHG emissions. There are benefits to simply covering liquid manure storage units including odor control, reduced rainwater hauling costs, and reduced SPDES overflow violations. If covered for these reasons, adding a flare and meter would likely be considered additional if implemented as a GHG mitigation strategy. However, if odor control, rainwater hauling, and SPDES violations are

not of particular concern for a farm and would not be adopted with a GHG policy, the entire manure cover+flare system could be considered additional. If however, one installed an Anaerobic Digester System (ADS) to generate electricity with the goal of maximizing methane production for maximal energy generation, this increased methane production and destruction should not be considered 'additional' GHG mitigation, because it is extra methane being produced to create electricity. This is important because if the digester system is not carefully designed and monitored for leaks and for emissions from digestate the net GHG emissions could actually increase rather than decrease compared to a baseline of a liquid storage unit and a baseline of GHG from current electricity production.

A rigorous definition of 'additionality' should be applied to any policy lever where a credit is given for supplying a public good or service to 'offset' a harm caused elsewhere. For example, if carbon sequestration in newly planted forests is to be used to offset GHG emissions from fossil fuel combustion for electricity generation, then the carbon sequestration should meet a rigorous definition of additionality. This report does not to specify whether or not a practice is "Additional" because it requires too many assumptions about the baseline and what constitutes "business as usual". Defining and quantifying additionality is fundamentally a policy decision. At this time, it is unclear how NYS will define additionality for agricultural GHG mitigation practices. Additionality is meant to be a companion to assist in the 'credibility' of an offset, ensuring the mitigation is a surplus from one sector making it a Real reduction. Evaluation of additionality is also important for conserving the limited funds available to implement GHG mitigation strategies that quantifiably deliver the publicly funded good of mitigating climate change.

Costs

The cost of mitigating a ton of CO_2e

Costs for implementing a practice that mitigates a ton of CO_2e are generally derived by estimates from Marginal Abatement Cost (MAC) curves constructed from the available information in the literature. A marginal abatement cost curve represents the monetary cost of achieving one additional ton of sequestered GHG or avoided GHG emissions and indicates the total quantity of net GHG reductions that can be achieved at different price points such as $10, $50 and $100 per metric ton CO_2e. It is a curve because there is usually a range of costs for implementing the same practice in different situations such as different farms. In this report, many such MAC estimates are from Fargione et al. (2018), which are national estimates down-scaled to the State level and are available online: https://nature4climate.org/u-s-carbon-mapper/.

The cost of damages from emitting a ton of CO_2e

The Social Cost of Carbon (SCC) "is a measure, in dollars of the long-term damage done by a ton of carbon dioxide emission in a given year. … [It] is meant to be a comprehensive estimate of climate change damages and includes changes in net agricultural productivity, human health, property damages from increased flood risk, and changes in energy system costs, such as reduced costs for heating and increased costs for air conditioning (US EPA 2017 from their discontinued web page). There is a very wide range of estimates for the social cost of carbon, and more recent literature that accounts for more factors finds higher values (for example Moore et al. 2015). The estimated price of $100 per ton of CO_2 is required to keep the 100-year average temperature from warming more than 2.5°C, and an even higher cost would be required to meet the Paris agreement goal of less than 2.0°C. Therefore, spending up to $100 per ton can be considered cost-effective for climate benefits alone (e.g. NAS 2017, Hsiang et al. 2017). Estimates can also be made of the social cost of methane and of nitrous oxide. However, these estimates are not as well developed as those for CO_2. Therefore we converted methane and nitrous oxide by their global warming potential (GWP) to CO_2e and frame estimates relative to the $100 per metric CO_2e.

New York will have to consider its own definition of 'affordability' for GHG mitigation practices across different GHG gases, sectors, and degrees of permanence and verifiability, etc. We have simply indicated whether we think this measurable technical potential is achievable within this cost range (ranging from saving money to spending $100 per metric ton CO_2e). Just as there are multiple impacts from CO_2, CH_4 and N_2O, there are multiple co-benefits from the proposed BMPs such as improved air quality, soil quality, and water quality. These activities have financial benefits that are often difficult to quantify. Just as we should aspire to account for the total costs of CO_2, CH_4 and N_2O, we should also aspire to account for the total benefits of implementing a practice (not just the GHG benefits).

As NYS develops its own 'social cost of carbon (or methane or nitrogen)' and the financial benefits of GHG-sensitive BMPs on working lands, NYS will also need to decide what proportion of available funds will be spent on implementing practices versus verifying and ensuring practices. Does NYS want to allocate spending to focus on improved verification, or to implement directionally beneficial practices that are less verifiable, but provide other benefits? Nearly all policies, programs, and practices cost money and if the SCC is $100, what percentage of that amount should be spent on drafting and implementing policies, educating and training, implementing and recording a practice on farm, verifying, ensuring permanence, and registering mitigation for accounting? As a project moves away from easily verifiable and permanent to directionally beneficial and reversible the costs of verification go up, reducing money available to implement new practices.

Abbreviations

ADS: Anaerobic Digester System
AEM: Agricultural Environmental Management (a program of NYS AGM)
BMP: Best Management Practice
C: carbon
CAFO: Concentrated Animal Feeding Operations
CAFRI: Climate and Applied Forestry Research Institute
CCE: Cornell Cooperative Extension
CH_4: methane
CHP: Combined Heat and Power
CLCPA: Climate Leadership and Community Protection Act
CNMP: Comprehensive Nutrient Management Plans
CO_2: carbon dioxide
CO_2e: carbon dioxide equivalent
CRF: Climate Resilient Farming
EPF: Environmental Protection Fund
g: gram
GHG: Greenhouse Gas
GWP: Global Warming Potential
IPCC: Intergovernmental Panel on Climate Change
Mg: Megagram = metric ton
MT: metric ton
MMt CO_2e y^{-1}: Million metric tons of CO_2equivalents per year
N: nitrogen
N_2O: nitrous oxide
NCS: Natural Climate Solutions
NGO: non-governmental organization
NRCS: Natural Resource Conservation Service
NWL: Natural and Working Lands
NYS: New York State
NYS AGM: New York State Department of Agriculture and Markets
NYS DEC: New York State Department of Environmental Conservation
NYS SWCC: New York State Soil and Water Conservation Committee

RGGI: Regional Greenhouse Gas Initiative
SLCP: Short-Lived Climate Pollutants
SWCD: Soil and Water Conservation Districts
Tg: Teragram = million metric tons
VOC: Volatile Organic Compound
VS: Volatile Solids

Appendix C: Charting A Path Forward

Vision

New York State is a recognized leader in agricultural production, water and air quality stewardship, and is leading on land-based climate change mitigation. To continue leading and protecting our strong and dynamic agricultural and forest economies, we imagine policy makers, academics, private companies, and citizens working together to protect natural resources and biodiversity, improve resilience to extreme weather, and mitigate greenhouses gas emissions that cause climate change.

Context & Definition: Following the NYS Department of Agriculture and Markets (AGM) mandate (2008 NYS Bill S8148/A10685), NYS fiscal year 2017-18 budget (S2004-D), and the Carbon Farming Act (A3281), this project, administered through NYS AGM, develops a scientifically based assessment of opportunities and barriers to support climate adaptation and mitigation practices on working NYS agricultural lands. Carbon Farming was defined as "the implementation of a land management strategy for the purposes of reducing, sequestering, and mitigating greenhouse gas emissions on land used in support of a farm operation and quantifying those greenhouse gas benefits".

Alignment of Terms: Comparison of Definitions of Practices Across Platforms

Table C1 combines three existing platforms to help integrate Best Management Practices (BMPs) for soil, water, and climate change. Specifically, it compiles the terms defined in (1) Natural Climate Solutions (NCS, Griscom et al. 2017, Fargione et al. 2018), (2) NRCS Field Office Technical Guides, and (3) the NYS Soil and Water Conservation Committee (SWCC) Agricultural Best Management Practice Systems Catalog (revised 2016). The objective of this table is to help leverage existing water quality and soil health practices to incorporate relevant GHG mitigation.

TABLE C1. Comparing Best Management Practice Definitions from different sources to help Integrate Climate Mitigation into Existing Agricultural Environmental Management Strategies.

SWCC Agricultural BMP Systems Catalog: Prescribed Rotational Grazing System A prescribed grazing management system using 5 or more paddocks for a grazing season, alternating paddocks to allow for forage vigor and re-growth. Livestock graze for no more than 7 days before they are rotated to another paddock.		
Source	**Name**	**Definition**
NCS	Grazing Optimization	Increase of soil carbon sequestration due to grazing optimization on rangeland and planted pastures. Grazing optimization prescribes a decrease in stocking rates in areas that are overgrazed and an increase in stocking rates in areas that are under-grazed, the net result of increased forage offtake and livestock production.
NRCS 528	Prescribed Grazing	Managing the harvest of vegetation with grazing and/or browsing animals with the intent to achieve specific ecological, economic, and management objectives. https://efotg.sc.egov.usda.gov/references/public/NY/nyps528.pdf

NRCS 512	Forage Biomass Planting	Establishing adapted and/or compatible species, varieties, or cultivars of herbaceous species suitable for pasture, hay, or biomass production. https://efotg.sc.egov.usda.gov/references/public/NY/nyps512.pdf
SWCC Agricultural BMP Systems Catalog: Feed Management System The continual process of providing adequate, not excess, nutrients to dairy animals through the integration of feeding and crop management to reduce nutrient excretion in manure and nutrient accumulation in soil, lower potential pollution risks to water and air resources, and improve farm profitability.		
Source	**Name**	**Definition**
NRCS 592	Feed Management	Manipulating and controlling the quantity and quality of available nutrients, feedstuffs, or additives fed to livestock and poultry. https://efotg.sc.egov.usda.gov/references/public/NY/nyps592.pdf
SWCC Agricultural BMP Systems Catalog: Manure & Agricultural Waste Treatment System A system for the mechanical, chemical or biological treatment of agricultural wastes. or **SWCC Agricultural BMP Systems Catalog: Waste Storage & Transfer System** A system design for the collection, transfer, and/or storage of agricultural livestock and recognizable process waste.		
Source	**Name**	**Definition**
NCS	Improved Manure Management	Avoided CH_4 emissions from dairy and hog manure. Emissions reductions were estimated for improved manure management on dairy farms with over 300 cows and hog farms with over 825 hogs.
NRCS 317	Composting Facility	A structure or device to contain and facilitate an aerobic microbial ecosystem for the decomposition of manure and/or other organic material into a final product sufficiently stable for storage, on farm use and application to land as a soil amendment. https://efotg.sc.egov.usda.gov/references/public/NY/nyps317.pdf
NRCS 590	Nutrient Management	Managing the amount (rate), source, placement (method of application), and timing of plant nutrients and soil amendments. https://efotg.sc.egov.usda.gov/references/public/NY/nyps590.pdf
NRCS 367	Roofs and Covers	A rigid, semi rigid, or flexible manufactured membrane, composite material, or roof structure placed over a waste management facility, agrichemical handling facility, or an on-farm secondary containment facility. https://efotg.sc.egov.usda.gov/references/public/NY/nyps367.pdf
NRCS 313	Waste Storage Facility	An agricultural waste storage impoundment or containment made by constructing an embankment, excavating a pit or dugout, or by fabricating a structure. https://efotg.sc.egov.usda.gov/references/public/NY/nyps313.pdf
NRCS 632	Waste Separation Facility	A filtration or screening device, settling tank, settling basin, or settling channel used to partition solids and/or nutrients from a waste stream. https://efotg.sc.egov.usda.gov/references/public/NY/nyps632.pdf
NRCS 629	Waste Treatment	The use of unique or innovative mechanical, chemical or biological technologies that change the characteristics of manure and agricultural waste. https://efotg.sc.egov.usda.gov/references/public/NY/nyps629.pdf
SWCC Agricultural BMP Systems Catalog: Nutrient Management System - Cultural Managing the amount (rate), source, placement (method of application), and timing of plant nutrient and soil amendment applications for efficient use by crops and reduced losses to the environment. If applicable, this can include addressing the issues from farmstead areas as it relates to non-point sources of pollutants.		
Source	**Name**	**Definition**

NCS	Cropland Nutrient Management	Avoided N_2O emissions due to more efficient use of nitrogen fertilizers and avoided upstream emissions from fertilizer manufacture. Four improved management practices were considered: 1) reduced whole-field application rate, 2) switching from anhydrous ammonia to urea, 3) improved timing of fertilizer application, and 4) variable application rate within field.
NRCS 590	Nutrient Management	Managing the amount (rate), source, placement (method of application), and timing of plant nutrients and soil amendments. https://efotg.sc.egov.usda.gov/references/public/NY/nyps590.pdf
SWCC Agricultural BMP Systems Catalog: Soil Conservation System - Cultural Cultural soil conservation systems employ management-based measures such as crop rotation, tillage, mulching, cover cropping, and/or other practices according to a soil conservation plan to control soil erosion, reduce run-off and enhance soil health.		
Source	**Name**	**Definition**
NCS	Cover Crops	Soil carbon sequestration gained by growing a cover crop in the fallow season between main crops. The benefit of using cover crops on the five major crops in the U.S. (corn, soy, wheat, rice, and cotton) that are not already growing cover crops was quantified.
NCS	Alley Cropping	Carbon sequestration gained by planting wide rows of trees with a companion crop grown in the alleyways between the rows (applicable to <10% of cropland).
Wightman & Woodbury	Replace Annuals with Perennials	Replacement of annual crops with perennial crops will increase soil carbon and increase N use efficiency but may affect yields and value of the harvested crop and so the cropping systems must be carefully selected.
NCS	Legumes in Pastures	Increase of soil carbon sequestration due to sowing legumes in planted pastures. Restricted to planted pastures and to where sowing legumes would result in net sequestration after taking into account potential increases in N_2O emissions from the planted legumes.
NCS	Biochar	Increased soil carbon sequestration by amending agricultural soils with biochar, which converts non-recalcitrant carbon (crop residue biomass) to recalcitrant carbon (charcoal) through pyrolysis. The source of biochar production was limited to crop residue that can be sustainably harvested. It was assumed that 79.6% of biochar carbon persists on a time scale of >100 years and that there are no effects of biochar on emissions of N_2O or CH_4.
NRCS 340	Cover Crops	Grasses, legumes, and forbs planted for seasonal vegetative cover. https://efotg.sc.egov.usda.gov/references/public/NY/nyps340.pdf
NRCS 585	Strip Cropping	Growing planned rotations of erosion-resistant and erosion-susceptible crops or fallow in a systematic arrangement of strips across a field. https://efotg.sc.egov.usda.gov/references/public/NY/585_NY_CPS_Stripcropping_2019.pdf
NRCS 512	Forage and Biomass Planting	Establishing adapted and/or compatible species, varieties, or cultivars of herbaceous species suitable for pasture, hay, or biomass production. https://efotg.sc.egov.usda.gov/references/public/NY/nyps512.pdf
NRCS 329	Residue and Tillage Management (No-Till)	Limiting soil disturbance to manage the amount, orientation and distribution of crop and plant residue on the soil surface year around. https://efotg.sc.egov.usda.gov/references/public/NY/nyps329.pdf
NRCS 345	Residue and Tillage	Managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round while limiting soil-disturbing activities

	Management (Reduced Till)	used to grow and harvest crops in systems where the field surface is tilled prior to planting. https://efotg.sc.egov.usda.gov/references/public/NY/345_NY_CPS_Residue_and_Tillage_Management-Reduced_Till_2017.pdf
SWCC Agricultural BMP Systems Catalog: Riparian Buffer System An area of grasses, sedges, rushes, ferns, legumes, forbs, shrubs, and/or trees tolerant of intermittent flooding or saturated soils located adjacent to and up-gradient from waterbodies.		
Source	**Name**	**Definition**
NRCS 391	Riparian Forest Buffer	An area of predominantly trees and/or shrubs located adjacent to and up-gradient from watercourses or water bodies. https://efotg.sc.egov.usda.gov/references/public/NY/nyps391.pdf
NRCS 342	Critical Area Planting	Establishing permanent vegetation on sites that have, or expected to have, high erosion rates, and on sites that have physical, chemical, or biological conditions that prevent the establishment of vegetation with normal seeding/planting methods. https://efotg.sc.egov.usda.gov/references/public/NY/nyps342.pdf
NRCS 390	Riparian Herbaceous Cover	Grasses, sedges, rushes, ferns, legumes, and forbs tolerant of intermittent flooding or saturated soils, established or managed as the dominant vegetation in the transitional zone between upland and aquatic habitats. https://efotg.sc.egov.usda.gov/references/public/NY/nyps390.pdf
NRCS 612	Tree and Shrub Establishment	Establishing woody plants by planting seedlings or cuttings, by direct seeding, and/or through natural regeneration. https://efotg.sc.egov.usda.gov/references/public/NY/nyps612.pdf
NRCS 490	Tree and Shrub Site Preparation	Treatment of areas to improve site conditions for establishing trees and/or shrubs. https://efotg.sc.egov.usda.gov/references/public/NY/nyps490.pdf
Suggested category to add to the SWCC Agricultural BMP Systems Catalog: Woodland Management Not currently listed in the NYS Soil and Water Conservation Committee Agricultural Best Management Practice Systems Catalog (revised 2016)		
Source	**Name**	**Definition**
NCS	Afforestation	Increase of carbon sequestration in above and belowground biomass and soils gained by converting non-forest (<25% tree cover) to forest [>25% tree cover] in areas of the conterminous U.S. where forests are the native cover type. To safeguard food production, most cropland and pasture was not included. The carbon sequestration mitigation benefit in conifer-dominated forests was reduced to account for albedo effects.
NCS	Natural Forest Management	Changes in timber management practices to increase net forest carbon sequestration (mixed native species forests under private ownership).
NCS	Avoided Forest Conversion	Emissions of CO_2 avoided by avoiding anthropogenic forest conversion. To estimate the rate of conversion (i.e. to another land use), forest clearing in the conterminous U.S. from 2000 to 2010 was calculated and then avoided carbon emissions from above and below ground biomass that are specific to each region and forest type was calculated. Forest loss due to fire or pests was not included. The benefit of avoided conversion in conifer-dominated forests was reduced to account for their albedo effects.
NRCS 666	Forest Stand Improvement	The manipulation of species composition, stand structure, or stand density by cutting or killing selected trees or understory vegetation to achieve desired forest conditions or obtain ecosystem services. https://efotg.sc.egov.usda.gov/references/public/NY/nyps666.pdf

Opportunities to Expand Working Land's Role in Climate Mitigation

Table C2 is a preliminary listing of existing opportunities and methodologies identified by a wide range of stakeholders and agencies with respect to climate change mitigation opportunities for agriculture. This listing provides resources for identifying new policy options or expanding existing policies based on what has been done in other states or sectors. Additionally, this listing can stimulate ideas for how mitigation opportunities could be implemented (e.g. an equipment sharing program). A recent publication about innovations by State Governments using funding sources and finance tools regarding land conservation practices might help inform what financial levers are appropriate for specific practices (see Feldman et al. 2019).

TABLE C2. Existing NYS Policies and Ideas from other Leaders, States, Organizations

Resource Type	**Name of Organization/ Opportunity**	**Description and URL**
General Resources		
Organization	North East USDA Climate Hub	<https://www.climatehubs.oce.usda.gov/hubs/northeast>
Organization	NE Climate Adaptation Science Center	<https://necsc.umass.edu/northeast-climate>
Technical Assistance	NRCS	Technical Assistance for mitigation projects (NRCS Technical Standards and Tools are relevant and available for most areas of management listed throughout this Table) <https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/technical/>
Education Materials	NYS AEM Tier II worksheet	Tier 2 Environmental Assessment Worksheets, including Greenhouse Gas Mitigation Opportunities | pdf
Education Materials	NYS AEM GHG Information Sheets	#1 **Introduction** to Farm & Forest GHG Mitigation | pdf #2 **Dairy Manure Storage** & GHG Mitigation | pdf #3 Liquid Manure Quantitative **Methane Destruction**|pdf #4 **Energy Efficiency** & GHG Mitigation | pdf #5 **Nitrogen Fertilizer** Management & GHG Mitigation | pdf #6 **Soil Carbon** Management & GHG Mitigation | pdf #7 **Forest Management** & GHG Mitigation | pdf #8 **Glossary** of GHG Mitigation Terms | pdf
Education/outreach materials	Agricultural carbon trading	Somewhat outdated but still informative tools on carbon-credits http://agcarbontrading.org/learn/ Climate Action Reserve - http://www.climateactionreserve.org
Education/outreach materials	Wightman & Woodbury	The authors articles, presentations, and outreach materials. <http://blogs.cornell.edu/woodbury/>
Education/outreach materials	CSF – climate smart farming	Technical assistance, decision support tools http://climatesmartfarming.org/
Education	Small farms program	Agroforestry, reduced tillage, clean energy <http://smallfarms.cornell.edu/>
NYS grants	NYS Climate Resilient	The goal of the Climate Resilient Farming Program is to reduce the impact of agriculture on climate change (mitigation) and to

	Farming (CRF) Program	increase the resiliency of New York State farms in the face of a changing climate (adaptation). Soil and Water Conservation Districts use the Agricultural Environmental Management (AEM) Framework to plan and assess their environmental risks. <https://www.nys-soilandwater.org/programs/crf.html>
NYS grants	NYS Climate Resilient Farming, Round 5	The fifth round of grants are funded through the State's Environmental Protection Fund (EPF). The EPF for Fiscal Year 2019-2020 has $4.5 million for Climate Resilient Farming program projects. Contact NYS AGM for the schedule of the next round of proposals. Through the Climate Resilient Farming grant program, County Soil and Water Conservation Districts apply for the competitive grants on behalf of farmers. Projects can focus on reducing carbon footprints, saving energy, improving soil health, increasing irrigation capacity, and emphasizing water management to mitigate the effects of drought as well as heavy rainfall and flooding on crops and livestock. Examples of projects eligible for funding are: • **Methane reduction tactics**, such as using manure storage cover and methane flare systems. • **Water management** practices, such as stream bank stabilization, streamside forested buffers, and irrigation water systems. • **Soil health practice** systems, including cover crop planting, conservation tillage and managed rotational grazing.
NYS grants	Empire State Development (ESD, new farmer grants)	Keeping land in agriculture requires new farmers taking over from farmers that are retiring. This grant fund helps beginning farmers improve farm profitability through one or both of the following goals: (1) Expanding agricultural production, diversifying agricultural production, and/or extending the agricultural season; (2) Advancing innovative agricultural techniques that increase sustainable practices such as organic farming, food safety, reduction of farm waste, and/or water use. Grants range from 150k to 500k. The program has provided more than $4.19 million to farmers since 2014. <https://esd.ny.gov/new-farmers-grant-fund-program>
NYS grant	Open Space Funding from the Environmental Protection Fund (EPF)	Created in 1993, the New York State Environmental Protection Fund (EPF) provides mechanisms for open space conservation and land acquisition. • ***Title 7*** allocates funds to the Department of Environmental Conservation and the Office of Parks, Recreation and Historic Preservation for purchase of land to be included in the Forest Preserve, State Parks, the State Nature and Historical Preserve, State Historic Sites, Unique Areas and other categories. • ***Title 9*** provides funds for local governments and not-for-profit organizations to purchase park lands or historic resources as well to develop and preserve these resources. Within the Adirondack and Catskill Parks the Department of

		Environmental Conservation administers the Title 9 grant program through the Division of Lands and Forests, Bureau of Public Lands. <https://www.dec.ny.gov/lands/5071.html>
NYS grants, general	Environmental Protection Fund (EPF) general grants page	Competitive grants for environmental protection and improvement are available for municipalities, community organizations, not-for-profit organizations and others. EPF budget is historically at the highest level of $300 million. <https://www.dec.ny.gov/pubs/grants.html>
NYS municipality grants	Climate Smart Communities (CSC)	The Climate Smart Communities (CSC) Grant program was established in 2016 to provide 50/50 matching grants to cities, towns, villages and counties of the State of New York and boroughs of New York City for eligible climate adaptation and mitigation projects. <http://www.dec.ny.gov/energy/109181.html#CSC>
NYS field trials/pilot projects		
Soil C	Carbon farming trials (Hudson)	Hudson Carbon established 13 testing sites at three farms in the Hudson Valley <https://www.hudsoncarbon.com/>
Biochar	Biochar and compost	Cornell Biochar and compost facility: <https://www.climatehubs.oce.usda.gov/hubs/northeast/project/cornell-biochar-and-compost-facilities>
Forest Management	NYS forest experiment station	Arnot Forest trials and teaching station, <http://blogs.cornell.edu/arnotforest/>
Perennial Grain	Kernza Perennial Grain Trials (NYS)	Intermediate wheatgrass is a long-lived, rhizomatous perennial grass. The Cornell Sustainable Cropping Systems Lab initiated a long-term experiment in August 2014 at the Cornell Musgrave Research Farm in Aurora, NY in collaboration other researchers across the US. The objectives of this experiment are to: 1) determine the effects of harvesting forage on Kernza grain yields and profitability, and 2) evaluate Kernza grain and forage yields over time across multiple environments. <https://blogs.cornell.edu/whatscroppingup/2016/12/05/perennial-grain-crop-production-in-new-york-state/>
Perennial bioenergy	Perennial grass (bioenergy)	Yield trials: <https://plbrgen.cals.cornell.edu/research-extension/forage-project/multistate-project-ne-1010/>
Bioenergy case study	Biomass energy case studies	Case studies from around NYS. <http://ccetompkins.org/energy/renewable-energy/biomass/biomass-energy-case-studies-1>
Perennial willow	SUNY ESF - willow	Short rotation woody crops (willow) biomass trials and information <https://www.esf.edu/willow/projects.htm>
Field Crop Nutrient Management (including nitrogen) Research	Cornell University Nutrient Management Spear Program	The vision of the Cornell University's Nutrient Management Spear Program is to assess current knowledge, identify research and educational needs, conduct applied, field and laboratory-based research, facilitate technology and knowledge transfer, and aid in the on-farm implementation of beneficial strategies for field crop

		nutrient management, including timely application of organic and inorganic nutrient sources to improve profitability and competitiveness of New York State farms while protecting the environment. <http://nmsp.cals.cornell.edu/>
Nitrogen Management		
See Cornell Spear Program, above		
Precision Adaptive N Management Tool	Adapt-N	An example of an online tool for precision nutrient management <http://www.adapt-n.com/>
Implementation Protocol	Climate Action Reserve	Nitrogen Management Project Protocol to provide guidance on how to quantify, monitor, and verify greenhouse gas emission reductions from improving nitrogen use efficiency in crop production. <https://www.climateactionreserve.org/how/protocols/nitrogen-management/>
Agricultural Retailer and Service Provider Certification Program for Nutrient Management	NY 4R Nutrient Stewardship Program	This 4R Nutrient Stewardship Certification Program encourages agricultural retailers, service providers and other certified professionals to adopt proven best practices through the 4Rs, which refers to using the Right Source of Nutrients at the Right Rate and Right Time in the Right Place. < https://www.nysaba.com/4r-ny>
NYS legislation		
	2008 NY State Bill S8148/A10685	Section 1. Subdivisions 3 and 4 of section 150 of the agriculture and markets law, as added by chapter 136 of the laws of 2000, are amended to read as follows: "AEM (Agricultural Environmental Management) plan" means a document prepared or approved by a certified AEM planner and accepted by a participating farmer which documents a course of action for the environmental management of a farm operation, including, but not limited to, measures to abate and control agricultural nonpoint source water pollution, air pollution and other adverse environmental impacts from farm operations through the implementation of best management practices, in a way which maintains the viability of the farm operation. An AEM plan may also include measures to address greenhouse gas emissions, global warming and renewable energy related to farm operations.
	Climate Leadership and Community Protection Act (CLCPA) S6599/A8429	<https://www.nysenate.gov/legislation/bills/2019/s6599> Title: An act to amend the environmental conservation law, the public service law, the public authority law, the labor law and the community risk and resiliency act, in relation to establishing the New York state climate leadership and community protection act, signed 2019. **Purpose:** To establish the New York State Climate Leadership and Community Protection Act to adopt measures to put the state on a path to reduce statewide greenhouse gas emissions by 85% by 2050.
	Food Donation and Food	Effective January 2022, large generators of food scraps (on average 2 tons per week or more) must donate excess edible food and

	Scrap Recycling Act 2019	recycle all remaining food scraps if they are within 25 miles of an organic material recycler.
Soil Health		
NYS Roadmap	New York Soil Health Roadmap	"Identifies key policy, research and education efforts to overcome barriers to adoption of soil health practices by farmers." The Roadmap was developed by New York Soil Health, an initiative coordinated by Cornell University. The Roadmap also "identifies strategies for integrating soil health goals with state priorities focused on environmental issues such as climate change and water quality." (IWLA 2019) <http://bit.ly/NYsoilhealth>
Cornell Soil Health Testing Laboratory	Soil Health Training Manual and Testing Services	The Comprehensive Assessment of Soil Health (CASH) manual identifies constraints to biological and physical soil functioning. This information then guides land managers in making targeted management decisions to plan and implement systems of soil health management practices to alleviate identified constraints and maintain healthier soils. <https://soilhealth.cals.cornell.edu/> For a fee, the lab also offers comprehensive soil health testing services and provides field-specific information on constraints in biological and physical processes, in addition to standard soil nutrient analysis <https://soilhealth.cals.cornell.edu/testing-services/>
Tool	Cover Crop Decision Tool	Online tool to help you quickly narrow the choices of cover crop < http://covercrop.org/cover-crop-decision-tool>
Education materials	NE cover crop council	Specific to NYS <http://northeastcovercrops.com/states/new-york/>
Riparian Buffers		Key Source materials: https://www.dec.ny.gov/chemical/106345.html
NYS Financing	State: Agricultural Nonpoint Source Abatement and Control Program (AgNPS)	NYS Department of Agriculture and Markets' competitive grant program helps farmers reduce water pollution by providing technical and financial assistance to implement best management practices. Projects incorporating riparian buffers receive priority scoring.
NYS Financing	State: Green Innovation Grant Program (GIGP)	NYS Environmental Facilities Corporation's program provides funding for municipal green infrastructure practices, including riparian buffers.
NYS Financing	State: Trees for Tributaries	DEC's Saratoga Tree Nursery program provides landowners, municipalities and conservation organizations with free technical assistance and low- or no-cost native trees and shrubs to plant along streams.
NYS Financing	Water Quality Improvement Program	DEC's competitive grant program funds municipal projects that reduce polluted runoff, improve water quality, and restore aquatic

	(WQIP)	habitats. Riparian buffers on non-agricultural land are a priority practice eligible for funding.
NYS Financing	Local: Catskill Stream Buffer Initiative (CSBI)	Providing private landowners throughout the west of Hudson River watershed with individualized assistance and financial support to protect and improve streamside properties.
NYS Financing	Local: Upper Susquehanna Coalition (USC) Riparian Buffer Program	Providing technical assistance and funding to landowners in the NY headwaters of the Chesapeake Bay watershed for conservation practices, including riparian buffers.
Federal Financing	Conservation Reserve Enhancement Program (CREP)	Agricultural landowners are eligible to receive financial payments from U.S. Department of Agriculture's (USDA) Farm Service Agency (FSA) to remove streamside farmland from production and plant forests or grass buffers.
Federal Financing	Debt for Nature (DFN) Program	Farmers with loans from the USDA-FSA may qualify for loan cancellation in exchange for implementing conservation practices, like riparian buffers.
Federal Financing	Environmental Quality Improvement Program (EQIP)	USDA's Natural Resources Conservation Service (NRCS) EQIP program providing financial and technical assistance to farmers to implement conservation practices, including riparian buffers, on farmland and non-industrial (not used for wood products) private forestland.
Forest Management		
Communication Tools	Tools for Engaging Landowners Effectively (TELE)	TELE can help you convince more landowners to adopt a desired behavior, whether that's harvesting timber, permanently conserving land, or anything in between. <https://www.engaginglandowners.org/>
	All NYS families with at least 10 acres of woodland	197,000 Private woodland owners steward 9.3 million acres in NYS, of which 27% are associated with farms or ranches. 96% of these landowners are considered Prime Prospects (have good stewardship attitudes but are not highly engaged in managing). 16% say they plan to sell their land in 5 years or at any time if the price is right. <https://www.engaginglandowners.org/landowner-data/find-profiles?region=97>
Pilot/Demonstration site	NYS Forest Experiment station	Arnot Forest trials and teaching station, <http://blogs.cornell.edu/arnotforest/>
Education	Forest Connect	Connect woodland users to the knowledge and resources needed to ensure sustainable production and ecological function on private woodlands. <http://blogs.cornell.edu/cceforestconnect/>

Tax Exemption	NYS DEC Forest Tax Law-480a	Any owner of forest land and any tract of forest land is eligible if it consists of at least 50 contiguous acres. An owner must first decide if he or she is willing to commit land to the production of forest crops and to follow a management plan, prepared by a forester and approved DEC, for the next succeeding ten years beginning each year that they receive a tax exemption. This decision can be made only after an analysis of the investments required by the plan, income from forest product sales, and associated stumpage. <https://www.dec.ny.gov/lands/5236.html>
Agroforestry Information	Cornell Small Farms	Tools and resources to help woodlot owners start farming their forests < https://smallfarms.cornell.edu/projects/agroforestry/>
Silvopasture	Silvopasture network	Network for sharing resources related to silvopasture <http://silvopasture.ning.com/>
Peer-to-peer training	Master Forest Owners (MFO) network	140 experienced and highly motivated volunteer MFOs are available statewide, ready to assist neighbor woodland owners with the information needed to start managing their woodlands, through free site visits to landowner properties. All MFOs are graduates of a 4-day training program, where they learn about sawtimber and wildlife management, woodland economics, and ecology. <http://blogs.cornell.edu/ccemfo/>
Implementation Protocol	Climate Action Reserve	The Forest Project Protocol (FPP) provides guidance for the development of forest carbon projects. The FPP addresses eligibility and accounting requirements for the calculation of emissions removals and reductions associated with reforestation, improved forest management, and avoided conversion projects. https://www.climateactionreserve.org/how/protocols/forest/
Offset	RGGI	"U.S. forest offset projects sequester carbon through three project types that increase and/or conserve forest carbon stocks, increasing the removal of CO_2 from the atmosphere, or reducing or preventing the emissions of CO_2 to the atmosphere." <https://www.rggi.org/allowance-tracking/offsets/offset-categories/forestry-afforestation>
Manure Management		
Educational Materials		**Dairy Manure Storage** & GHG Mitigation | pdf Liquid Manure Quantitative **Methane Capture/Destruction** | pdf
Implementation Protocol	Climate Action Reserve	The Livestock Project Protocol provides guidance to calculate, monitor, report, and verify GHG emission reductions associated with installing a manure biogas control system for livestock operations, such as dairy cattle and swine farms. <https://www.climateactionreserve.org/how/protocols/us-livestock/>
State plan	NYS methane reduction plan	Initiative to incorporate methane reduction into New York State programs related to manure management <https://www.dec.ny.gov/docs/administration_pdf/mrpfinal.pdf>
Offset	RGGI	Avoided Agricultural Methane by "projects (that) capture and destroy methane from animal manure and organic food waste using anaerobic digesters" <https://www.rggi.org/allowance-tracking/offsets/offset-categories/agricultural-methane>

Applied Research, Educational/Extension Materials, and Tools	Cornell PRO-DAIRY – Dairy Environmental Systems Program	Applied research, extension materials, and tools for dairy facility and manure management environmental engineering solutions <https://prodairy.cals.cornell.edu/environmental-systems/>
Applied Research, Educational/Extension Materials, Land Grant University Guidelines for Field Crops, and Tools	Cornell University Nutrient Management Spear Program	The vision of the Cornell University's Nutrient Management Spear Program is to assess current knowledge, identify research and educational needs, conduct applied, field and laboratory-based research, facilitate technology and knowledge transfer, and aid in the on-farm implementation of beneficial strategies for field crop nutrient management, including timely application of organic and inorganic nutrient sources to improve profitability and competitiveness of New York State farms while protecting the environment. <http://nmsp.cals.cornell.edu/>
Enteric Fermentation and Dairy Feed Management		
Case Study	Precision Feed Management Case study	Yates County, NY <https://projects.sare.org/sare_project/lne11-308/>
Information Sheet	Info Sheet	Feeding Strategies During Challenging Times <https://prodairy.cals.cornell.edu/sites/prodairy.cals.cornell.edu/files/shared/documents/Feeding%20Strategies%20During%20Challenging%20Times.pdf>
Fact Sheet	2008 fact sheet	General Concepts, but not specific to climate change, <https://ecommons.cornell.edu/bitstream/handle/1813/36721/dec15.pdf;sequence=1>
Forage Analysis	Dairy One	Forage Analysis, <https://dairyone.com/>
Renewable Energy		
NE and NYS	RGGI proceeds (Revenue is invested via NYSERDA, e.g. to support Clean Energy Fund and Clean Energy for Agriculture items)	The Regional Greenhouse Gas Initiative is the first market-based regulatory program in the United States to reduce greenhouse gas emissions. RGGI is a cooperative effort among the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont to cap and reduce CO_2 emissions from the power sector. Following a comprehensive 2012 Program Review, the RGGI states implemented a new 2014 RGGI cap of 91 million short tons. The RGGI CO_2 cap then declines 2.5 percent each year from 2015 to 2020. The RGGI CO_2 cap represents a regional budget for CO_2 emissions from the power sector. Pursuant to rules and regulations promulgated by NYSERDA and the NYS DEC, NYSERDA is responsible for administering periodic auctions for the sale of the emissions allowances. The proceeds from the sales of these allowances will be used by NYSERDA to administer energy efficiency, renewable energy,

		and/or innovative carbon abatement programs, and to cover the costs to administer such programs.
NYS	NYSERDA clean energy fund (CEF)	Supporting farms, for example greenhouse lighting efficiency. <https://www.nyserda.ny.gov/About/Clean-Energy-Fund>
NYS plan	NYSERDA, Clean Energy for Agriculture Task Force	The Clean Energy for Agriculture Task Force—an assembly of farmers, universities, agriculture organizations, and others—is helping identify and prioritize clean energy opportunities for New York State's agriculture sector. The resulting *Clean Energy for Agriculture Task Force Strategic Plan* identifies initiatives to cut energy costs and accelerate the use of clean energy by the more than 35,000 farms across the State. <https://www.nyserda.ny.gov/About/Publications/Clean-Energy-for-Agriculture-Task-Force-Strategic-Plan>
NYS policy/research need	Solar contracting	Achieving Large-Scale Solar in New York State: What are the Research & Information Needs? <https://cardi.cals.cornell.edu/sites/cardi.cals.cornell.edu/files/shared/RPB-April2018.pdf>
Grant	USDA- Rural Development	Rural Energy for America Program Renewable Energy Systems & Energy Efficiency Improvement Guaranteed Loans & Grants. Grants of $20,000 or less for renewable energy project or efficiency projects. Applicants must be "Agricultural producers with at least 50% of gross income coming from agricultural operations, or Small businesses in eligible rural areas. <https://www.rd.usda.gov/programs-services/rural-energy-america-program-renewable-energy-systems-energy-efficiency>
Grass Bioenergy	Grass pellet field research and appliance testing	Grass pellets as a low-tech, small-scale, environmentally friendly, renewable energy system that can be locally produced, locally processed and locally consumed. <http://forages.org/index.php/grass-biofuels>
Developing Markets		
Federal	Office of Environmental Markets	Carbon markets <https://www.usda.gov/oce/environmental_markets/carbon.htm>
CA Offset Registry	Climate Action Reserve (CAR)	<https://www.climateactionreserve.org/how/california-compliance-projects/>
Voluntary Offset Registry	Climate Action Reserve (CAR)	<https://www.climateactionreserve.org/about-us/voluntary-offsets/>
Carbon Market	IndigoAg	Soil carbon market, <https://www.indigoag.com/for-growers/indigo-carbon>
Carbon Market	Nori	Carbon marketplace (launching 2020) < https://nori.com/about>

Other State/Organization Initiatives		
State Initiative	California Healthy Soils Initiative	"launched by then Governor Jerry Brown in his 2015 inaugural address and recognized and funded by the legislature in 2016 with enactment of Senate Bill 859. The initiative includes 7 state agencies addressing different aspects of healthy soils on the state's public lands, private farms and ranches, and in programs ranging from composting and water management to carbon storage for green-house gas mitigation. The California initiative is a comprehensive approach to implementing a soil health strategy." (IWLA 2019) <http://bit.ly/CAinitiative>
State Initiative	Hawaii Carbon Farming Task Force	"In 2017, Hawaii enacted HB 1578, which created a Carbon Farming Task Force to identify agriculture or aquaculture activities and best practices that provide soil health and carbon sequestration benefits and could be used to establish a carbon farming certification. The 13-member Task Force is to make recommendations to the legislature including pro-posed legislation. The Task Force has until December 2022, to provide a preliminary report to the legislature." (IWLA 2019) <http://bit.ly/HItaskforce>
State Initiative	Nebraska Healthy Soils Task Force	"Legislative Bill 243 (2019) was enacted to create a Healthy Soils Task Force appointed by the Governor to "develop a comprehensive healthy soils initiative for the State of Nebraska," develop a comprehensive action plan to carry out the initiative, and develop a timeline to improve soil health in Nebraska within five years of the completion of the action plan. The legislation gives the Task Force until January 2021 to complete its work. The new law includes components of the action plan, including consideration of outreach and financial incentives needed. The bill passed on a 43-0 vote in April 2019." (IWLA 2019) <http://bit.ly/NEtaskforce>
Agency Programs	Maryland Healthy Soils Program	"Maryland House Bill 1063 was enacted in 2017, establishing the Maryland Healthy Soils Program to increase biological activity and carbon sequestration in the state's soils by promoting practices based on emerging soil science. It requires the Maryland Department of Agriculture (MDA) to provide farmers with education, technical assistance and, subject to available funding, financial incentives to implement farm management practices that contribute to healthy soils. The bill did not include additional funding, but the Department has implemented the new law with existing resources, building on the Department's support of Maryland's soil conservation districts. The Department collaborated with the Healthy Soils Consortium to identify practices that are most effective in improving soil health and building soil carbon stocks. MDA will create a menu of Maryland-specific practices, determine metrics and tools to quantify soil carbon, and provide incentives to encourage climate friendly soil practices. The Department is also examining existing programs to find ways to promote soil health co-benefits. The bill was passed

		by overwhelming votes in the Senate and House of Delegates." (IWLA 2019) <http://bit.ly/MDhealthysoils>
Agency Programs	New Mexico Healthy Soil Program	"New Mexico HB 204, enacted in 2019, creates the Healthy Soil Program in the state Department of Agriculture "to promote and support farming and ranching systems and other forms of land management that increase soil organic matter, aggregate stability, microbiology and water retention to improve the health, yield and profitability of the soils of the state." The new program includes a healthy soil assessment and education program, and a grants program. The assessment and education program provide education and outreach to farmers, a baseline soil health assessment, development of a network of soil health champions, and public education. Grants may help cooperative extension, soil and water conservation districts, Indian tribes, and local governments provide technical assistance to producers and landowners. The legislature provided $455,000 to implement the bill and for research on soil health monitoring." (IWLA 2019) <http://bit.ly/NMhealthysoil>
Agency Programs	Connecticut Regenerative Agriculture Program	"Connecticut Committee Bill 6647 (2019) would require the Commissioner of Agriculture to establish a regenerative agriculture program, adopt rules to define "regenerative agriculture," and provide state standards for minimum carbon and water content that would apply to grants awarded by the Commissioner to encourage regenerative agriculture. As of April 2019, the bill remained in committee." (IWLA 2019) < bit.ly/CTRegen>
Agency Programs	Massachusetts Healthy Soils Program	"Massachusetts bill S.438 (2019) would establish a healthy soils program that would optimize climate benefits by providing loans, grants, research, technical assistance, educational material, and outreach to farmers whose management practices will contribute to healthy soils and result in net long-term on-farm greenhouse gas benefits. The bill would establish a Massachusetts Healthy Soils Program Fund, and provide funding for the program. The bill would also incorporate soil health concepts into several other sections of statute, and includes definitions for "healthy soils" and "healthy soils practices". As of April 2019, the bill remained in committee." (IWLA 2019) <http://bit.ly/MAhealthysoils>
Agency Programs	Iowa Soil Health Monitoring	"Iowa HF 102 (2019) would establish a statewide soil resource health and recovery monitoring system to collect data on soil health parameters like nutrient retention capacity, structure, stability, erosion, water retention, and habitat for earthworms and soil microbes. The system would be housed in the state Department of Agriculture and Land Stewardship, in cooperation with Iowa State University. The Department and University would submit a report to the legislature every two years on the state of Iowa's soils, including recommendations to sustain and improve soil resources and proposed legislation or rules changes. As of April 2019, the bill remained in committee." (IWLA 2019) <http://bit.ly/IAmonitoring>
Agency Programs	Illinois Sustainable	5 Year Farmer Transition Program STAR Program

	Agricultural Partnership	Precision Conservation Management Advanced Soil Health Training https://ilsustainableag.org
Soil Health Tools	Illinois STAR	"The Champaign County, Illinois, Soil and Water Conservation District created Saving Tomorrow's Agriculture Resources (STAR) as a free tool to help farmers and landowners assess their nutrient and soil loss practices at a field level. The STAR evaluation assigns points for each nutrient management, cropping, tillage, and soil conservation activity on each field. Each field earns one to five stars based on the points awarded, allowing farmers to see how their conservation system compares to other farmers and to best management practices. The District gives farmers and landowners a menu of strategies they can use to boost their STAR rating. Soil and water conservation districts in other Illinois counties and other states are adapting the STAR tool to their soils and circumstances". (IWLA 2019) <http://bit.ly/ILstar>
State Incentives $75/acre cover crop	Maryland Agricultural Water Quality Cost-Share Program	"Grants to farmers to offset seed, labor, and equipment costs associated with conservation practices, especially planting cover crops. Cost-share rates vary from year to year, but in recent years farmers have received up to $75 an acre to plant cover crops. Participating farmers can also receive attractive field signs to help educate the public on ways agriculture is protecting the Chesapeake Bay. The program is a major factor in cover crops being planted on more than half of eligible Maryland cropland, rates higher than any other state. Funding is provided by the Chesapeake Bay Restoration Fund and the Chesapeake and Atlantic Coastal Bays Trust Fund. Maryland provided $34 million in cost-share grants to farmers in FY 2017." (IWLA 2019) <http://bit.ly/MDcostshare>
State Incentives $25/acre 1st yr cover crop $15/acre 2nd yr cover crop	Iowa Cover Crop Cost Share	"The Iowa Department of Agriculture and Land Stewardship provides cost-share for farmers who adopt no-till, strip till, nitrogen inhibitor, or cover crop practices. $3.8 million in funding from the Iowa Water Quality Initiative was provided in fiscal year 2017, but demand for the cost-share far exceeds available funding. Farmers can receive $25 per acre for first-time users of cover crops, or $15 per acre for returning users." (IWLA 2019) <http://bit.ly/IAcostshare>
State Incentives $5 per acre discount on crop insurance for cover crops	Iowa Crop Insurance Discount	"The Iowa Department of Agriculture and Land Stewardship (IDALS) funds the $5 per acre discount on federal crop insurance for farmers who plant cover crops. Funds come from the Iowa Water Quality Initiative. The discount is provided through the crop insurance companies that service federally subsidized crop insurance policies in Iowa. It is not available to farmers who are receiving cost-share for planting cover crops through the USDA suite of conservation programs or Iowa's own state cost-share program. The discount (or lack of one) shows up on a line of the crop insurance invoice that farmers pay, which has helped stimulate interest in cover crops from farmers who view the invoice and see there is a discount they are not getting. IDALS

		reports that 700 farmers enrolled nearly 170,000 acres of cover crops in the program in the first year of the demonstration project." (IWLA 2019) <http://bit.ly/IAcovercropinsurance>
State Incentives $20 per acre for single species cover crops $45 per acre for multi-species cover crops	Nebraska Cover Crop Payments	"Nebraska LB 729 (2019) would provide incentives for farmers to plant cover crops of $20 per acre for single-species cover crops, or $45 per acre for multi-species cover crops. The funds would be made available in target watersheds, focusing first on watersheds with high nitrate runoff, and for farms within 2.5 miles of a waterway. The bill does not provide a specific funding source, but identifies federal, state, and local grants and other funds designated for the purpose. As of April 2019, the bill remained in committee." (IWLA 2019) <http://bit.ly/NEpayments>
50% property tax exemption for cropland planted to cover crops	Iowa Property Tax Exemption	"Iowa House Study Bill 78 (2019) would provide a 50% property tax exemption for cropland planted to cover crops. The exemption would be applied on an annual basis to the cropland planted to cover crops that year, and landowners could apply for the exemption every year. The Department of Agriculture and Land Stewardship would have authority to inspect property to ensure compliance with the law. In Iowa, property taxes fund schools and other local government entities. The bill remained in committee as of April 2019." (IWLA 2019) <http://bit.ly/IApropertytax>
Fertilizer 62¢ per ton fertilizer fee	Fertilizer and Pesticide Fees	"Wisconsin has a fertilizer tonnage fee charged for commercial fertilizers, currently 62¢ per ton. The proceeds support agrichemical management, fertilizer research, outreach, nutrient and pest management, and agricultural chemical cleanup. Iowa created a Groundwater Protection Fund in 1987 which receives money from pesticide dealer license fees, pesticide registration fees, and a fee for fertilizer sales based on the percentage of nitrogen in the product, using 75¢ per ton of 82% nitrogen fertilizer as the base. Nebraska has a state buffer strip program funded by proceeds from fees assessed on registered pesticides." (IWLA 2019)
Soil Health Initiative on Public Land	California Healthy Soils Initiative	"Through this initiative, California's Department of General Services is committed to improving soil health by demonstrating best practices in building soil organic matter in urban landscaping on state land, including the park grounds surrounding the State Capitol in Sacramento." (IWLA 2019)
Soil Health Initiative on Public Land	State Land Rented for Agricultural Purposes	"Illinois HB 2819 (2019) was introduced to allow the Illinois Department of Natural Resources to require the establishment of soil health practices on state-owned land used for agricultural purposes." (IWLA 2019) <http://bit.ly/ILlandrent>
Update Conservation District laws	Illinois Conservation District Authority	"Illinois Senate Bill 1980 (2019) would amend the state's Soil and Water Conservation Districts Act to add "soil health" to the declared purpose of the state's 97 soil and water conservation districts. It includes a definition of "soil health" and would allow districts to initiate and conduct soil health activities. Those powers include surveys, investigations, research, development of comprehensive plans, entering into agreements with other entities,

		and making machinery and equipment available to landowners or farmers within the district. As of April 2019, the legislation had passed the state Senate on a 56-0 vote and was pending in the House of Representatives." (IWLA 2019) <http://bit.ly/ILdistrict>
Soil health workshops	Connecticut RC&D Soil Health Initiative	"The Connecticut Resource Conservation & Development District has a long-running series of workshops on soil health, in partnership with the USDA Natural Resources Conservation Service. Held twice a year, the workshops include hands-on demonstrations, a soil pit, and a rainfall simulator. Conservation districts in other states host similar soil health workshops, featuring soil health experts, presentations from farmers, and tours of working farms using soil health practices." (IWLA 2019) <http://bit.ly/CTinitiative>
Equipment Sharing Cover crop Roller Crimper	South Jersey RC&D Roller Crimper	"South Jersey Resource Conservation & Development Council serving southern New Jersey acquired a roller-crimper which it loans out to area farmers who want to try it out as a method of terminating cover crops. Cover crops have typically been terminated using chemicals such as glyphosate, but that poses a problem for organic growers and substantial costs for other growers. Roller-crimpers, invented by the Rodale Institute (below), can be used as an alternative to (or in addition to) chemical burn-down. Agencies, organizations, or cooperatives could acquire and rent out or loan roller-crimpers to farmers to encourage the use of cover crops, as many have done with seed drills to encourage adoption of no-till farming." (IWLA 2019)

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