June 7, 2024

Chief Terry Cosby
U.S. Department of Agriculture
NRCS Climate Office

Submitted via email to SM.FPAC.NRCS.CLIMATE@usda.gov

Re: Maintain and Simplify Irrigation Practices on the Climate Smart List for FY 25

Dear Chief Cosby:

The undersigned coalition of conservation and agricultural groups submits the following comments in response to NRCS' Climate Office solicitation for comment on its Climate-Smart Agriculture and Forestry Mitigation Activities List (CSAF List) for FY 2025. This submittal further responds to NRCS' specific request for relevant scientific literature supporting the climate change mitigation benefits of specific activities.

We appreciate NRCS' addition of irrigation practices 430 (irrigation pipeline), 441 (microirrigation), 442 (sprinkler system), and 533 (pumping plant) to the list of climate-smart mitigation activities eligible for funding under the Inflation Reduction Act (IRA) in FY 2024. We strongly encourage NRCS to keep those practices on the CSAF List for FY 2025, and to remove the "used to reduce energy use" qualifier associated with those practices. This limitation is unduly restrictive because it suggests that the only climate smart benefit associated with implementing irrigation practices is the result of reductions in energy use. The body of science says otherwise, and we encourage NRCS to follow that science.

As detailed in the technical compendium assembled by The Freshwater Trust (attached as Appendix A, and published in The Water Report), where an irrigation practice change makes sense for producers,[1]

[1] We recognize that GHG reduction benefits are one of many factors that need to be considered when making water on-farm management decisions. Other factors that need to be considered beyond GHG benefits include crop yield, affordability,

impactful climate smart benefits beyond reductions in energy use are produced. Specifically, a growing body of peer-reviewed studies demonstrate that converting gravity systems to pressurized pipe systems quantifiably reduces nitrous oxide (N2O) and methane (CH4) emissions[2]—both of which are climate smart greenhouse gas (GHG) parameters under the IRA. In short, these studies find that flood irrigation results in greater losses to seepage below the root zone compared to pressurized sprinkler and microirrigation/drip systems. Pressurized, more frequent, and targeted irrigation systems reduce GHG emissions through more consistent and direct watering of crop roots. This approach moderates the two major processes that drive GHG emissions in unpressurized systems: (1) soil wetting and drying cycles that increase N2O emissions and (2) soil anoxic conditions that increase methane emissions. Pressurized irrigation systems also improve uptake of nitrogen by plants (further reducing N2O) and decrease nitrogen runoff and leaching that cause indirect N2O emissions.

As further evidence of these benefits, TFT has applied NRCS-approved quantification methodologies (Nutrient Tracking Tool, COMET) to thousands of agricultural fields and consistently found that these models show quantifiable GHG reductions.

In addition to delivering climate smart benefits, irrigation upgrades improve water quality, and offer more precise water management options that can create more water system flexibility, drought resilience, and economic options for producers. As outlined in NRCS' Western Water and Working Lands Framework, it will be critical to protect surface water availability and sustain agricultural productivity in the face of unprecedented water scarcity challenges driven by climate change. Irrigation practices offer producers a critical tool in managing this uncertainty.

On a practical level, where supported by robust science, we encourage NRCS to publish a broader CSAF List, not a narrower one. All IRA funds must be obligated by 2026 and spent by 2031. This creates intense pressure to get money to projects right now even if additional scientific analysis could be useful. Paired with the IRA funding USDA secured to improve GHG quantification approaches, investment in and study of a more expansive list of practices will improve overall scientific rigor, and undoubtedly discover new things.

We believe that these factors overwhelmingly support an expanded role for irrigation practices on the CSAF List moving forward. We therefore recommend that NRCS: (1) keep these essential irrigation practices on the CSAF List, (2) remove the overly narrow energy use qualifier associated with irrigation practices 430, 441, 442, and 533, and (3) expand the explanatory guidance in the Crosswalk to include more scenarios. For example, the following sentence could be added to the beginning of the 442 guidance: "*Switching from flood irrigation to sprinklers where USDA-approved tools show quantifiable GHG reductions, where water is already delivered to fields with pressure, where water would be pumped with a renewable energy source, or where switching reduces the need for emission-producing field visits to open up headgates; or utilization of variable rate irrigation (VRI) technology … .*"

These modifications to the CSAF List will allow funding to flow to practices that reduce GHG emissions, improve water quality, and help build drought resiliency. All these outcomes benefit our environment and our communities.

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practicality, other benefits to the environment, and the economic bottom line. Accordingly, this analysis should not be read as a blanket statement that irrigation modernization is always the right choice, but rather that these practices should remain IRA-eligible "climate smart" practices available in the CSAF toolkit.

[2] While some like The Environmental Working Group have concluded that new irrigation systems likely do little or nothing to help in the climate fight, this conclusion appears publicly unsupported by data and peer-reviewed analysis.

Thank you in advance for considering our comments, and for your continued commitment to ensuring that IRA dollars can quickly make their way to the ground in communities. For follow-up, please contact Tim Wigington (tim@thefreshwatertrust.org) and Dan Keppen (dan@familyfarmalliance.org).

Sincerely,

- The Freshwater Trust
- Elephant Butte Irrigation District (NM)
- Family Farm Alliance
- Farmers Conservation Alliance
- Irrigation Association
- National Water Resources Association
- Netafim, Orbia Precision Agriculture
- Oregon Water Resources Congress

Attachment A: Scientific Basis and Quantification Approach to Support Adding Irrigation Modernization Practices to the Climate-Smart Mitigation Activities List

June 7, 2024

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EXECUTIVE SUMMARY

On August 16, 2022, President Biden signed the Inflation Reduction Act (IRA) into law. The IRA's substantial funding provides a significant opportunity to build critical natural resource-related infrastructure and implement climate-smart agriculture and renewable energy initiatives nationwide. Specific to working agricultural lands, the IRA instructs the Secretary of Agriculture to prioritize the $19 billion in new Farm Bill funding to agreements and projects that directly improve soil carbon, reduce nitrogen losses, or reduce, capture, avoid, or sequester carbon dioxide (CO2), methane (CH4), or nitrous oxide (N2O) emissions (collectively greenhouse gases, or GHGs). The NRCS *Climate-Smart Agriculture and Forestry Mitigation Activities List* (CSAF List) comprises the NRCS conservation practices that the agency considers "climate smart" and therefore eligible for priority IRA funding under EQIP and CSP.

The Freshwater Trust (TFT) and many other agricultural and conservation groups submitted comments to NRCS in late 2022 advocating for a more expansive CSAF List (see last document in this package) . We were heartened to see the FY 2024 CSAF List include new irrigation modernization practices (NRCS, 2023).

This technical document summarizes the body of science supporting finding irrigation modernization practices "climate smart" under the IRA. As a preface to this document, we want to emphasize that our suggestion to maintain/strengthen irrigation modernization practices on the CSAF List is not intended to imply that flood irrigators should choose irrigation modernization over the other practices on the CSAF List. Rather, this analysis is meant to illustrate that converting gravity systems to pressurized pipe systems can also quantifiably decrease GHG emissions. TFT recognizes that GHG reduction benefits are just one of many factors that need to be considered when making water management decisions. Other factors that need to be considered in addition to GHG benefits include crop yield, affordability, practicality, other benefits to the environment, and the economic bottom line. Accordingly, TFT's analysis should not be read as a blanket statement that irrigation modernization is always the right choice, but rather that these practices should remain IRA-eligible "climate smart" practices available in the CSAF toolkit in addition to those already available.

Following the **Introduction** below, **Section 2** of this document lays out the strong evidence showing how irrigation modernization practices can reduce nitrous oxide (N2O) and methane (CH4) emissions similar to practices already on the CSAF List. As seen in Figure 1, just under half (49%) of agriculture's GHG emissions in 2018 were N2O and CH4 emissions from cropland soils and grazing lands (United States Department of Agriculture et al., 2022). **Section 3** of the document details the scientifically robust, existing methods available to quantify the GHG emission reduction benefits generated by these irrigation modernization practices, utilizing some of the same methods that support practices already on the CSAF List. **Section 4** demonstrates how irrigation modernization also facilitates other climate-smart practices.

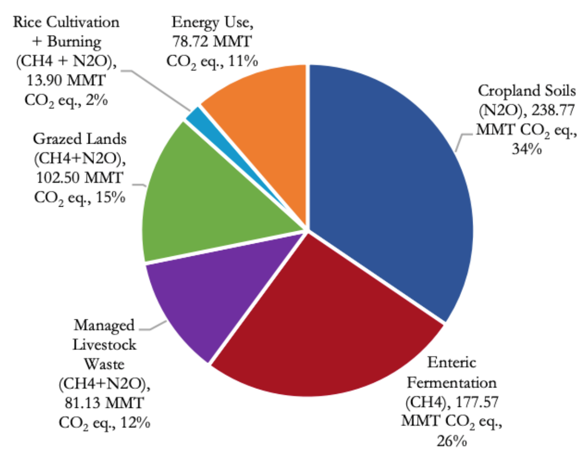

Figure 1. Agricultural Sources of GHG in 2018. MMT CO_2 eq is million metric tons of carbon dioxide equivalent.

SECTION 1: INTRODUCTION

For the purposes of this document, TFT defines “irrigation modernization” as *the improvement of water use efficiency via pressurization of irrigation systems on currently irrigated agricultural lands*, through the adoption of NRCS practices for irrigation pipeline (430), microirrigation systems (441), sprinkler systems (442), and irrigation water management (449) (NRCS, 2020a, 2020b, 2020c, 2021). This definition does not include irrigating previously non-irrigated lands, changing water management practices while maintaining unpressurized (flood) irrigation systems, or installing an unpressurized subirrigation system. Irrigation modernization does include converting unpressurized irrigation to pressurized sprinkler or microirrigation, as well as upgrading already pressurized systems from sprinklers to microirrigation.

The USDA report on *Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory* (Eve et al., 2014) provides the scientific foundation for the NRCS conservation practices included on the CSAF List, which states that "listed practices have quantifiable carbon sequestration and/or GHG reduction methodologies described in COMET-Planner." NRCS Conservation Practices and GHG quantification methods used in COMET-Planner, in turn, are closely aligned with those identified in the USDA's *Methods for Entity-Scale Inventory.* In the 2014 report, USDA (a) designates irrigation as one of ten “management practices impacting GHG emissions from croplands and grazing lands,” (b) outlines evidence in the literature for reductions in soil emissions resulting from irrigation modernization (described in **Section 2** below, along with more recent supporting science), and (c) provides scientifically defensible methods for the quantification of changes in N2O and CH4 with implementation of irrigation and water management practices (described in **Section 3**).

Unfortunately, the 2014 USDA report did not explicitly include any GHG quantification methods for irrigation modernization practices on croplands or grazing lands. In recent years, quantification methods have been developed for irrigation modernization, particularly the Daily Century (DayCent) and Denitrification-Decomposition (DNDC) models. These methods provide scientifically defensible options for quantifying GHG effects from irrigation modernization and have been used in multiple studies (described in **Section 3** below). With these advances, it’s now possible to fully quantify the GHG-related benefits from irrigation modernization. With the information in sections 2 and 3, NRCS should have all the information needed to add these as stand-alone practices to the CSAF List, or at a minimum, add these practices as facilitating practices.

The CSAF List also states that “conservation practices that facilitate the management or the function of a CSAF mitigation activity but may not achieve the desired effects on their own (and may not have a quantifiable benefit) may be planned as applicable.” These “facilitating practices” can be supported through Climate-Smart programs in conjunction with CSAF mitigation activities. While Conservation Practices 430, 441, 442, and 449 have their own GHG reduction benefits which support inclusion on the CSAF List as stand-alone practices, they also qualify as significant facilitating practices for multiple listed CSAF mitigation activities, including nitrogen management and reduced tillage (described in **Section 4** below).

SECTION 2: EVIDENCE OF LOWER GHG EMISSIONS FROM IRRIGATION MODERNIZATION

This section outlines the evidence for reduced GHG emissions from irrigation modernization. As is the case with all conservation practices, environmental benefits are generated following implementation. Here, TFT focuses just on the relevant GHG reduction benefits and quantification science of irrigation modernization because that is the filter for CSAF List inclusion. However, while flood irrigation may lead to GHG emissions, it may sometimes provide other benefits such as wildlife habitat, ecosystem function, aquifer recharge, enhanced stream baseflow, and other societal benefits. Alternative CSAF practices can be adopted to maintain those benefits while still investing in the enhancement of an operation. Ranchers and farmers will be the experts on their own operations and will consider carefully all these elements when making specific implementation choices.

Chapter 3.2.1.4 ("Irrigation") of USDA's 2014 *Methods for Entity-Scale Inventory* summarizes research and science that drive GHG emissions under various forms of irrigation. USDA provides reasoning and evidence for higher N2O (and in some cases CH4) emissions in unpressurized systems compared to pressurized systems[1]. Key statements (beginning on p. 3-19) include:

- **Unpressurized flood:** "Flood irrigation involves flooding the entire field with water. Under continuously flooded conditions, soils are highly anoxic, thus facilitating high methanogenesis and denitrification[2] rates (Mosier et al., 2006)."
- **Unpressurized furrow:** "The impact of furrow irrigation on GHG emissions depends on how often and the extent to which furrows are filled with water. Wetting and drying cycles are likely to emit large pulses of NO and N2O (Davidson, 1992)."
- **Pressurized sprinkler:** "During and shortly after [sprinkler] irrigation events, soil may become saturated and emit pulses of N2O, but because the soil is not continuously saturated, N2O emissions are expected to be lower compared with surface [furrow] irrigation (Nelson & Terry, 1996)."
- **Pressurized surface drip:** "The impacts of surface drip irrigation on GHG fluxes are expected to be similar to those of sprinkler systems, [...] there is early evidence that both surface and subsurface drip irrigation leads to less emissions of CH4 and N2O (Kallenbach et al., 2010; Kennedy et al., 2013)."
- **Pressurized subsurface drip:** "Soil water content has less temporal variation with subsurface drip irrigation compared with sprinkler and surface systems, so pulses of N2O [...] emissions are also expected to be of smaller magnitude (Kallenbach et al., 2010). Similarly, subsurface drip irrigation/fertigation of high value crops, such as tomatoes, has been shown to reduce N2O emissions compared with furrow irrigation (Kennedy et al., 2013)."

The following subsections present findings related to irrigation modernization and nitrous oxide (N20) emissions and methane (CH4) emissions.

Nitrous Oxide (N2O)

In addition to that USDA report, TFT gathered independent evidence that reached similar conclusions. For example, Sapkota et al. (2020) reviewed empirical field studies related to irrigation modernization and GHG emissions in a meta-analysis. They concluded that (1) in arid regions, high intensity irrigation methods (defined as high volume and more intermittent applications) showed the greatest N2O production and (2) the maximum N2O flux from unpressurized irrigated fields was higher than the maximum on pressurized irrigated fields. However, a caveat to this meta-analysis was that it was difficult to isolate the impacts of irrigation modernization from changes to fertilizer application, cover cropping, and tillage practices, which often varied between the studies' treatments. Therefore, TFT

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[1] Evidence cited by USDA indicating that more efficient irrigation leads to *increased* N2O or CH4 emissions referred to either subirrigation or intermittent irrigation events. Neither of these cases are included in TFT's definition of irrigation modernization so they were not included here.

[2] According to the USDA report from which this quote was taken, "it remains difficult to predict the relative portion of denitrified nitrogen that is emitted as N2O relative to N2."

isolated studies that align with the irrigation modernization practices excluded from the CSAF List, which are summarized in Table 1 below.

The studies in Table 1 consistently show reduced N2O emissions from high efficiency pressurized irrigation systems when compared to unpressurized systems. Most relevant are the studies where irrigation was varied on non-rice crops grown in arid or semi-arid regions of the US, including hay and alfalfa in southern California (Andrews et al., 2022); cotton in Arizona (Bronson et al., 2018), and tomatoes in northern California (Kennedy et al., 2013) and California's Central Valley (Kallenbach et al., 2010). In each case, N2O emissions were 25% to 75% lower in the pressurized systems when compared to unpressurized systems. Similar results were found in studies of cropping systems in arid and semi-arid regions outside the US, including in Spain and northern China (see Table 1).

Most studies compared unpressurized systems to high efficiency systems; TFT found only three studies that compared N2O emissions between unpressurized and sprinkler systems. Of these three, Fangueiro et al. (2017) saw 40% lower N2O emissions on sprinkler irrigation fields relative to flooding. The other two studies saw no significant difference in N2O from sprinklers relative to unpressurized methods (Bronson et al., 2018; Wang et al., 2016). While sprinkler irrigation conversions were less conclusive with respect to N2O reductions, this practice does provide other GHG reduction benefits as outlined in the CH4 subsection below.

Table 1. Literature review of N2O flux from irrigation modernization. All references were field experiments.

Reference	Location	Crops	Irrigation Scenario	N2O reduction or flux
Bronson et al., 2018	Arizona	Cotton	Furrow	Efficiency factor[3] (EF) < 0.5%
			Sprinkler	EF < 1.1%
			Subsurface drip	EF < 0.1%
Andrews et al., 2022	Southern California	Alfalfa	Furrow	Baseline
			Drip	Reduction by 38%
		Sudangrass	Furrow	Baseline
			Subsurface drip	Reduction by 59%
Kennedy et al., 2013	Northern California	Tomato	Furrow	2.01±0.19 kg N2O-N/ha
			Drip	0.58±0.06 kg N2O-N/ha
Kallenbach et al., 2010	California Central Valley	Tomato	Furrow	0.02 kg N2O-N/ha/d
			Subsurface drip	0.005 kg N2O-N/ha/d

[3] Efficiency factor (EF) is the percentage of applied nitrogen fertilizer emitted as N2O and can therefore be used to standardize application rates. Since the application rates varied under the treatments, it's likely that the modernized irrigation systems produced lower absolute N2O emissions than the furrow baseline, but these values were not provided in the study.

Wu et al., 2014	Xinjiang, China	Cotton	Furrow	1.71 kg/ha
			Drip	1.09 kg/ha
Sanchez-Martin et al., 2010	Spain	Melon	Furrow	Baseline
			Drip	Reduction by 75% and 28%
Maris et al., 2015	Spain	Olive	Drip	0.07 kg/ha
			Subsurface drip	0.02 kg/ha
Fangueiro et al., 2017	Southwest Spain	Rice	Flood	Baseline
			Sprinkler	Reduction by 40%
Wang et al., 2016	North China	Winter wheat	Flood	Baseline
			Sprinkler	Insignificant change
			Drip	Reduction by 14.6%
Ye et al., 2020	Shenyang, China	Tomato	Flood	25.33 ± 3.94 kg N/ha
			Mulched drip	23.87 ± 2.23 kg N/ha
			Drip filtration	10.04 ± 1.05 kg N/ha

Methane (CH4)

Irrigation management systems affect oxygen availability in soil, and methanogenic microbes are most competitive in anoxic conditions; therefore, irrigation efficiency is well correlated to methane emission reductions (Nguyen et al., 2015). Flood irrigation systems saturate soils deeply and lower soil oxygen levels, causing anaerobic conditions that favor methanogens (Eagle & Olander, 2012) and ultimately produce CH4 emissions (Eve et al., 2014; Nelson & Terry, 1996). Pressurized irrigation more precisely and uniformly distributes water to root zones, which can interrupt anerobic microbial processes such as methanogenesis. High efficiency systems lead to even fewer emissions of CH4 than sprinkler and surface irrigations because drip irrigation reduces evaporative loss and avoids full saturation of soil pores (Del Grosso et al., 2000; Kallenbach et al., 2010; Kennedy et al., 2013).

Table 2 summarizes multiple published studies that showed methane reductions from irrigation modernization on agricultural fields without negative yield effects (Nie et al., 2023; Sapkota et al., 2020; Zschornack et al., 2016). A three-year rice study in southwest Spain found that sprinkler irrigation decreased CH4 emission by 99% relative to flood irrigation (Fangueiro et al., 2017). A winter wheat study in a semi-arid region of northern China showed that CH4 uptake in high efficiency irrigation systems increased more than 20% compared to flood irrigation fields due to the lower frequency wetting/drying cycles, lower soil moisture, improved oxygen diffusion, and increased CH4 oxidation (Wang et al., 2016). It is hypothesized in the literature that under the aerobic soil conditions common in modernized irrigation methods, a high redox potential prevents the formation of CH4, or permits its oxidation by methanotrophic bacteria (Aulakh et al., 2001).

Table 2. Literature review of CH4 flux from irrigation modernization. All references were field experiments.

Reference	Location	Crops	Irrigation Scenario	CH4 Flux
Wang et al., 2016	North China	Winter wheat	Flood	−40.19±2.61 (ug m−2 h−1)
			Sprinkler	−37.63±2.30 (ug m−2 h−1)
			Surface drip	−49.41±1.46 (ug m−2 h−1)
Maris et al., 2015	Spain	Olive	Surface drip	-48 kg/ha
			Subsurface drip	-63 kg/ha
		Cotton	Furrow	-3 kg/ha

Wu et al., 2014	Xinjiang, China		Surface drip	-9 kg/ha
Ye et al., 2020	Shenyang, China	Tomato	Flood	− 0.71 ± 0.11 kg C/ha
			Mulched drip	− 0.93 ± 0.20 kg C/ha
			Drip filtration	− 1.98 ± 0.34 kg C/ha
Fangueiro et al., 2017	Spain	Rice	Flood	Baseline
			Sprinkler	Reduction by 99%

SECTION 3: GHG QUANTIFICATION METHODS FOR IRRIGATION MODERNIZATION

Using unpressurized irrigation methods, a significant volume of water is applied to an entire field every few days, with greater losses to seepage below the root zone compared to pressurized sprinkler and microirrigation systems (Ross et al., 1997). As described in **Section 2**, pressurized, more frequent, and targeted irrigation systems reduce GHG emissions through more consistent and targeted watering of crop roots, which moderates the two major processes that drive GHG emissions in unpressurized systems: (1) soil wetting and drying cycles that increase N2O emissions and (2) soil anoxic conditions that increase CH4 emissions. Pressurized and managed irrigation systems also improve uptake of nitrogen by plants (further reducing N2O) and decrease nitrogen runoff and leaching that cause indirect N2O emissions.

Two biogeochemical models, Denitrification-Decomposition (DNDC) and Daily Century (DayCent), are the most widely used models to quantify GHG emissions from agricultural soils (Inst. for Study of Earth, Oceans and Space, 2012Li, 2012; Li et al., 2005; Parton et al., 2001; Wang et al., 2021). Both DNDC and DayCent are simulation tools to predict soil fluxes of N2O, CH4, and CO2 with various farm management practices, such as irrigation, cropping, tillage, fertilization, and grazing (del Grosso et al., 2000; Deng et al., 2018, 2020; Inst. for Study of Earth, Oceans and Space, 2012Li, 2012; Necpálová et al., 2015; Parton et al., 2001).

Previous studies have used the DNDC model to evaluate the impacts of conversion from unpressurized to pressurized irrigation on N2O and CH4 emissions, which are summarized below in Table 3. A study using the DNDC model simulated cropping systems in California from 2001 to 2010 and found that drip irrigation is predicted to reduce N2O emissions by 55-67% relative to unpressurized irrigation (Deng et al., 2018). In another study, the DNDC model was used to simulate soil fluxes for cropland in California’s San Joaquin Valley from 2011 to 2013, and the results indicate that sprinkler, surface drip, and subsurface drip irrigation systems are predicted to decrease N2O emission by 29%, 58%, and 78%, respectively, relative to unpressurized irrigation (Guo et al., 2020).

Outside the US, the DNDC model has been used to assess effects of irrigation modernization on soil fluxes in China (Table 3), including a study for vineyards in Ningxia that indicated drip irrigation is predicted to reduce N2O emission by 72.5% in 2012 and by 52.4% in 2013, relative to unpressurized irrigation (Zhang et al., 2016). DNDC model simulations for cucumber and tomato production in Beijing, China during 2017 and 2018 indicate that drip irrigation is predicted to reduce N2O emissions by 31.7%, relative to unpressurized irrigation (Huadong et al., 2022Ke et al., 2022).

DayCent does not use specific irrigation types as inputs, such as flood, sprinkler, and drip, but DayCent does allow other relevant inputs that approximate irrigation modernization, such as irrigation intensity (low, medium, or high), volume, frequency, and timing (Olander et al., 2011). DayCent has been used widely for simulating N2O emissions from agricultural soils from various irrigation, cropping systems, and fertilization (Del Grosso et al., 2012; Eve et al., 2014).

Recent research calibrated and validated both DayCent and DNDC models using measured data from a turfgrass field experiment with medium and low irrigation in Kansas (Hong et al., 2023). The study concluded that DayCent model results were accurate ranging -54% to 14% and therefore *adequately* estimated N2O emission reductions from soils with low and medium irrigation and N-fertilization treatments, while DNDC model results ranged from -24% to -85% and therefore *underestimated* N2O emission reductions from the tested practices (Hong et al., 2023). This underestimation by DNDC could be addressed by incorporating empirical data into quantification methods for irrigation modernization.

The DayCent or DNDC methods can be used at the farm or regional scale throughout the US to simulate irrigation modernization practices. Irrigation method, application, and frequency are key inputs to both models, which account for changes in soil microbial activity and plant growth rates that impact net GHG flux. These process-based models facilitate scaling and account for spatial heterogeneity at the farm scale, while available empirical data (described in **Section 2**) can be used to quantify and address model uncertainty. Where field-based measurement validation is lacking for the N2O and CH4 estimates from process-based models, empirical data are available (or can be gathered) to produce "emissions factors" for simpler or more accurate quantification methods.

The 2014 USDA *Methods for Entity-Scale Inventory* already describe DNDC and DayCent as quantification methods for multiple practices included on the CSAF List (including forms of irrigation and water management). These existing quantification frameworks used in COMET-Planner can also be applied to irrigation modernization practices. Table 4 on the following page describes how quantification methods used for other CSAF Listed management practices, particularly those that involve irrigation or water management, can be easily adapted or applied to irrigation modernization.

Table 3. Summary of studies using the DNDC model to evaluate the impacts of conversion from unpressurized to pressurized irrigation on N2O and CH4 emissions.

Reference	Location	Crops	Irrigation Scenario	N2O Flux
Deng et al., 2018	California	Varying cropping systems	Unpressurized	Baseline
			Sprinkler	Reduction by 37%
			Drip	Reduction by 55%
			Subsurface drip	Reduction by 67%
Guo et al., 2020	San Joaquin Valley, California	Cropland, grassland, urban turf, and forest	Flood	9,688 t
			Sprinkler	6,837 t
			Surface drip	4,030 t
			Subsurface drip	2,093 t
Zhang et al., 2016	Ningxia, China	Vineyards	Furrow	Baseline
			Drip	Reduction by 72.5% and 52.4%
Huadong et al., 2022	Beijing, China	Cucumber, tomato	Flood	Baseline
			Drip	Reduction by 31.7%

Table 4: Demonstration of how the USDA GHG quantification methods developed for other practices can be applied to irrigation modernization practices, as defined in this document. The first three columns summarize information on currently listed CSAF activities and GHG quantification methods in Table ES-2 in the USDA's *Methods for Entity-Scale Inventory Quantification*; the fourth column describes how these methods can be applied or adapted for quantifying changes in GHG emissions associated with irrigation modernization.

GHG & source	CSAF Listed practice(s)	Quantification methods overview (quoting the USDA's *Methods for Entity-Scale Inventory* Table ES-2)	Application and/or relevance of methods to quantifying GHG emissions associated with irrigation modernization practices (not currently CSAF Listed)
Direct N2O emissions from mineral soils	Tillage and nitrogen application	DayCent and DNDC are used to derive expected base emission rates [... which] are scaled with practice-based scaling factors to estimate the influence of management changes. [...] Scaling factors related to specific [...] management practices [...] are derived from experimental data.	This method is directly applicable for quantifying changes in N2O and CH4 resulting from irrigation modernization on crop/grazing lands. DayCent and DNDC use irrigation methods, application rate, and frequency as inputs. DNDC allows the user to specific irrigation equipment, while DayCent does not. See Section 3 for examples from literature. Section 2 provides literature from which scaling factors can be derived.
Soil organic carbon stocks for mineral soils	Irrigation effects on decomposition in cropland and grazing land	The DayCent model is used to estimate the soil organic carbon at the beginning and end of the year for mineral soils. The stocks are entered into the [relevant] IPCC equations [...] to estimate carbon stock changes.	DayCent uses irrigation method, application rate, and timing as inputs and can be used for evaluation of N2O flux, as it is for CO2 flux here. Sections 2 and 3 provide documentation of empirical data that can be used to quantify uncertainty of modeled data, as well as examples of studies that used DayCent for this purpose.
Soil organic carbon stocks, N2O and CH4 emissions in wetlands	Water management	The DNDC process-based biogeochemical model is [...] used for estimating [...] N2O and CH4 emissions from wetlands. Process based model is used; hence, no emissions factors are used in this method.	Although applied for wetland practices here, this method is directly applicable for quantifying changes in N2O and CH4 resulting from irrigation modernization on crop/grazing lands. DNDC uses irrigation methods, application rate, and frequency as inputs; therefore, changes to irrigation practices associated with modernization can be simulated. See Section 3 for examples from scientific literature of DNDC simulations of irrigation modernization to quantify changes in GHG emissions.
CH4 & N2O emissions from rice cultivation	Cultivation period flooding regime; time since last flooding	A basic estimation equation (cf., IPCC Tier 1) is used to estimate CH4, and an inference (cf., IPCC Tier 2) method is used for N2O emissions from flooded rice production	USDA states the DayCent or DNDC model was not used because it has been evaluated for rice cultivation in Asia but not in the US where rice cultivation differs significantly. They also state that these models will likely be adopted for this quantification method in the future when additional testing has occurred. Differences in cultivation between the US and Asia is not as much of a factor for non-rice crops.

SECTION 4: IRRIGATION MODERNIZATION FACILITATES CLIMATE-SMART ACTIVITIES

The CSAF List includes the following direction: “In addition to the designated CSAF mitigation activities listed, conservation practices that facilitate the management or the function of a CSAF mitigation activity but may not achieve the desired effects on their own (and may not have a quantifiable benefit) may be planned as applicable.” The sections above demonstrate that irrigation modernization does “achieve the desired effects” on its own, and clearly has substantial quantifiable benefits; but irrigation modernization has also been shown to facilitate other CSAF mitigation activities.

For example, in the *Methods for Entity-Scale Inventory*, USDA states that “optimizing other practices—including tillage and the management of soil pH, pests, irrigation, drainage, and other factors—will tend to increase nitrogen fertilizer uptake by the crop and therefore reduce N2O emissions” (Chapter 3.2.1.2; page 3-16). Indeed, fertilizer management is a suite of agricultural practices that strongly control soil mineral nitrogen availability for the nitrification and denitrification process in which N2O emissions are produced in soils (Abbasi & Adams, 2000). N2O emission is positively correlated with nitrogen fertilizer application rates, which in turn are affected by irrigation efficiency and the potential for fertigation (Akiyama et al., 2004).

A recent paper analyzed the extent to which the adoption of efficient irrigation practices mediated the adoption of climate-smart soil health practices in diverse cropping systems in California. The analysis demonstrated that pressurized irrigation systems are an especially important farm operation characteristic for the adoption of many nitrogen management and soil health practices (Rudnick et al., 2021). This is particularly relevant to the CSAF List because a significant portion of the eligible practices fall under the categories of soil health or nitrogen management. This is further exemplified by a University of Colorado Boulder report showing how irrigation modernization provides Colorado farmers with the ability to adopt zero and reduced tillage practices. The authors state that sprinkler and microirrigation systems do not compact the soil like many flood irrigation systems and, therefore, “expand options for zero-tillage and safeguard soil health” (UC Boulder, 2020). This means that adding irrigation modernization to the CSAF List of eligible practices is likely to facilitate the adoption of additional CSAF-eligible practices by the same producer, multiplying GHG-emission reduction benefits while investing in a producer’s operation and creating other co-benefits including water quality improvement and soil health.

REFERENCES

Abbasi, M. K., & Adams, W. A. (2000). Gaseous N emission during simultaneous nitrification- denitrification associated with mineral N fertilization to a grassland soil under field conditions. *Soil Biology and Biochemistry*, *32*, 1251–1259. www.elsevier.com/locate/soilbio

Akiyama, H., Mctaggart, I. P., Ball, B. C., & Scott, A. (2004). N2O, NO, and NH3 Emissions from Soil after the Application of Organic Fertilizers, Urea, and Water. *Water, Air, and Soil Pollution*, *156*, 113–129.

Andrews, H. M., Homyak, P. M., Oikawa, P. Y., Wang, J., & Jenerette, G. D. (2022). Water-conscious management strategies reduce per-yield irrigation and soil emissions of CO2, N2O, and NO in high-temperature forage cropping systems. *Agriculture, Ecosystems and Environment*, *332*. https://doi.org/10.1016/j.agee.2022.107944

Aulakh, M. S., Wassmann, R., & Rennen, H. (2001). Methane Emissions from Rice Fields — Quantification, Mechanisms, Role of Management, and Mitigation Options. *Advances in Agronomy*, *70*, 193-260. https://doi.org/10.1016/S0065-2113(01)70006-5

Bronson, K. F., Hunsaker, D. J., Williams, C. F., Thorp, K. R., Rockholt, S. M., Grosso, S. J. Del, Venterea, R. T., & Barnes, E. M. (2018). Nitrogen Management Affects Nitrous Oxide Emissions under Varying Cotton Irrigation Systems in the Desert Southwest, USA. *Journal of Environmental Quality*, *47*, 70–78. https://doi.org/10.2134/jeq2017.10.0389

Davidson, E. A. (1992). Sources of nitric oxide and nitrous oxide following wetting of dry soil. *Soil Science Society of America Journal*, *56*(1), 95–102. https://doi.org/10.2136/sssaj1992.03615995005600010015x

Del Grosso, S. J., Mosier, A. R., Parton, W. J., & Ojima, D. S. (2005). DAYCENT model analysis of past and contemporary soil N2O and net greenhouse gas flux for major crops in the USA. *Soil and Tillage Research*, *83*(1), 9–24. https://doi.org/10.1016/j.still.2005.02.007

Del Grosso, S. J., Parton, W. J., Mosier, A. R., Ojima, D. S., Potter, C. S., Borken, W., Brumme, R., Butterbach-Bahl, K., Crill, P. M., Dobbie, K., & Smith, K. A. (2000). General CH4 Oxidation Model and Comparisons of CH4 Oxidation in Natural and Managed Systems. *Global Biogeochemical Cycles*, *14*(4), 999–1019. https://doi.org/10.1029/1999GB001226

Deng, J., Guo, L., Salas, W., Ingraham, P., Charrier-Klobas, J. G., Frolking, S., & Li, C. (2018). Changes in Irrigation Practices Likely Mitigate Nitrous Oxide Emissions From California Cropland. *Global Biogeochemical Cycles*, *32*(10), 1514–1527. https://doi.org/10.1029/2018GB005961

Deng, J., Xiao, J., Ouimette, A., Zhang, Y., Sanders-DeMott, R., Frolking, S., & Li, C. (2020). Improving a Biogeochemical Model to Simulate Surface Energy, Greenhouse Gas Fluxes, and Radiative Forcing for Different Land Use Types in Northeastern United States. *Global Biogeochemical Cycles*, *34*(8). https://doi.org/10.1029/2019GB006520

Driscoll, A. W., Conant, R. T., Marston, L. T., Choi, E., & Mueller, N. D. (2024). Greenhouse gas emissions from US irrigation pumping and implications for climate-smart irrigation policy. *Nature Communications*, *15*(1). https://doi.org/10.1038/s41467-024-44920-0

Eagle, A. J., & Olander, L. P. (2012). Greenhouse gas mitigation with agricultural land management activities in the United States: a side-by-side comparison of biophysical potential. In *Advances in Agronomy 115*, 79–179. https://doi.org/10.1016/B978-0-12-394276-0.00003-2

Eve, M., Page, D., Flugge, M., Steele, R., Man, D., Riley-Gilbert, M., & Biggar, S. (2014). *Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory. USDA Technical Bulletin 1939*. https://www.usda.gov/sites/default/files/documents/USDATB1939_07072014.pdf

Fangueiro, D., Becerra, D., Albarrán, Á., Peña, D., Sanchez-Llerena, J., Rato-Nunes, J. M., & López-Piñeiro, A. (2017). Effect of tillage and water management on GHG emissions from Mediterranean rice growing ecosystems. *Atmospheric Environment*, *150*, 303–312. https://doi.org/10.1016/j.atmosenv.2016.11.020

Guo, L., Chen, J., Luo, D., Liu, S., Lee, H. J., Motallebi, N., Fong, A., Deng, J., Rasool, Q. Z., Avise, J. C., Kuwayama, T., Croes, B. E., & FitzGibbon, M. (2020). Assessment of Nitrogen Oxide Emissions and San Joaquin Valley PM2.5 Impacts From Soils in California. *Journal of Geophysical Research: Atmospheres*, *125*(24). https://doi.org/10.1029/2020JD033304

Hong, M., Zhang, Y., Braun, R. C., & Bremer, D. J. (2023). Simulations of nitrous oxide emissions and global warming potential in a C4 turfgrass system using process-based models. *European Journal of Agronomy*, *142*. https://doi.org/10.1016/j.eja.2022.126668

Huadong, K., Kong, C., Lei, H., Ding, W., & Li, H. (2022). Assessment of the N2O emission reduction potential in greenhouse vegetable fields based on the DNDC model. *Chinese Journal of Eco-Agriculture*, *30*(8), 1269–1282. https://doi.org/10.12357/cjea.20210735

Institute for the Study of Earth, Oceans and Space. (2012). *User's Guide for the DNDC Model (Version 9.5)*. University of New Hampshire. https://www.dndc.sr.unh.edu/model/GuideDNDC95.pdf

Kallenbach, C. M., Rolston, D. E., & Horwath, W. R. (2010). Cover cropping affects soil N2O and CO2 emissions differently depending on type of irrigation. *Agriculture, Ecosystems & Environment*, *137*(3–4), 251–260. https://doi.org/10.1016/J.AGEE.2010.02.010

Kennedy, T. L., Suddick, E. C., & Six, J. (2013). Reduced nitrous oxide emissions and increased yields in California tomato cropping systems under drip irrigation and fertigation. *Agriculture, Ecosystems and Environment*, *170*, 16–27. https://doi.org/10.1016/j.agee.2013.02.002

Li, Y., Chen, D., Zhang, Y., Edis, R., & Ding, H. (2005). Comparison of three modeling approaches for simulating denitrification and nitrous oxide emissions from loam-textured arable soils. *Global Biogeochemical Cycles*, *19*(3), 1–15. https://doi.org/10.1029/2004GB002392

Maris, S.C., Teira-Esmatges, M.R., Arbonés, A., & Rufat, J. (2015). Effect of irrigation, nitrogen application, and a nitrification inhibitor on nitrous oxide, carbon dioxide and methane emissions from an olive (Olea europaea L.) orchard. *Science of the Total Environment, 538*, 966-978. https://www.sciencedirect.com/science/article/abs/pii/S0048969715305441?via%3Dihub

Mosier, A. R., Halvorson, A. D., Reule, C. A., & Liu, X. J. (2006). Net Global Warming Potential and Greenhouse Gas Intensity in Irrigated Cropping Systems in Northeastern Colorado. *Journal of Environmental Quality*, *35*(4), 1584–1598. https://doi.org/10.2134/jeq2005.0232

Natural Resources Conservation Service. (2020a). *Conservation Practice Standard Irrigation Pipeline (Code 430)*. https://www.nrcs.usda.gov/

Natural Resources Conservation Service. (2020b). *Conservation Practice Standard Irrigation System, Microirrigation (Code 441)*. https://www.nrcs.usda.gov/

Natural Resources Conservation Service. (2020c). *Conservation Practice Standard Irrigation Water Management (Code 449)*. https://www.nrcs.usda.gov/

Natural Resources Conservation Service. (2021). *Conservation Practice Standard Sprinkler System (Code 442)*. https://www.nrcs.usda.gov/

Natural Resources Conservation Service. (2023). *Climate-Smart Agriculture and Forestry (CSAF) Mitigation Activities List FY2023*. https://www.nrcs.usda.gov/sites/default/files/2023-01/CSAF%20Mitigation%20Activities_2023.pdf

Necpálová, M., Anex, R. P., Fienen, M. N., del Grosso, S. J., Castellano, M. J., Sawyer, J. E., Iqbal, J., Pantoja, J. L., & Barker, D. W. (2015). Understanding the DayCent model: Calibration, sensitivity, and identifiability through inverse modeling. *Environmental Modelling and Software*, *66*, 110–130. https://doi.org/10.1016/j.envsoft.2014.12.011

Nelson, S. D., & Terry, R. E. (1996). The effects of soil physical properties and irrigation method on denitrification. *Soil Science*, *161*(4), 242–249.

Nguyen, S. G., Guevarra, R. B., Kim, J., Ho, C. T., Trinh, M. V., & Unno, T. (2015). Impacts of Initial Fertilizers and Irrigation Systems on Paddy Methanogens and Methane Emission. *Water, Air, and Soil Pollution*, *226*(9). https://doi.org/10.1007/s11270-015-2501-8

Nie, T., Huang, J., Zhang, Z., Chen, P., Li, T., & Dai, C. (2023). The inhibitory effect of a water-saving irrigation regime on CH4 emission in Mollisols under straw incorporation for 5 consecutive years. *Agricultural Water Management*, *278*. https://doi.org/10.1016/j.agwat.2023.108163

Olander, L. P., Del Grosso, S., Haugen-Kozyra, K., César Izaurralde, R., Malin, D., Paustian, K., & Salas, W. (2011). Using biogeochemical process models to quantify greenhouse gas mitigation from agricultural management. In E. Wollenberg (Ed.) *Climate Change Mitigation and Agriculture*. London: Routledge. https://doi.org/10.4324/9780203144510

Parton, W. J., Holland, E. A., del Grosso, S. J., Hartman, M. D., Martin, R. E., Mosier, A. R., Ojima, D. S., & Schimel, D. S. (2001). Generalized model for NOx and N2O emissions from soils. *Journal of Geophysical Research Atmospheres*, *106*(D15), 17403–17419. https://doi.org/10.1029/2001JD900101

Ross, E. A., Hardy, L. A., Brenner, J., Walker, J., Gustafson, C., Nelson, D., Dalton, J., & Suit, J. (1997). *National Engineering Handbook: Irrigation Guide, Part 652*. United States Department of Agriculture. https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17837.wba

Rudnick, J., Lubell, M., Khalsa, S. D. S., Tatge, S., Wood, L., Sears, M., & Brown, P. H. (2021). A farm systems approach to the adoption of sustainable nitrogen management practices in California. *Agriculture and Human Values*, *38*(3), 783–801. https://doi.org/10.1007/s10460-021-10190-5

Sanchez-Martín, L., Meijide, A., Garcia-Torres, L., & Vallejo, A. (2010). Combination of drip irrigation and organic fertilizer for mitigating emissions of nitrogen oxides in semiarid climate. *Agriculture, Ecosystems & Environment, 137*(1-2), 99-107. https://doi.org/10.1016/j.agee.2010.01.006

Sapkota, A., Haghverdi, A., Avila, C. C. E., & Ying, S. C. (2020). Irrigation and greenhouse gas emissions: A review of field-based studies. *Soil Systems 4*(2), 1–21. MDPI AG. https://doi.org/10.3390/soilsystems4020020

UC Boulder. (2020). *2020 Trends Report: Tillage practices linked to poor soil health and reduced soil carbon*. https://cslc.colorado.edu/2020-trends/conventional-tillage-practices-linked-to-poor-soil-health

United States Department of Agriculture, Office of the Chief Economist, & Office of Energy and Environmental Policy. (2022). *US Agriculture and Forestry Greenhouse Gas Inventory 1990-2018: Technical Bulletin 1957*. https://data.nal.usda.gov/dataset/data-us-agriculture-and-forestry-greenhouse-gas-inventory -1990-2018

Wang, C., Amon, B., Schulz, K., & Mehdi, B. (2021). Factors that influence nitrous oxide emissions from agricultural soils as well as their representation in simulation models: A review. *Agronomy 11*(4), 770. MDPI AG. https://doi.org/10.3390/agronomy11040770

Wang, G., Liang, Y., Zhang, Q., Jha, S. K., Gao, Y., Shen, X., Sun, J., & Duan, A. (2016). Mitigated CH4 and N2O emissions and improved irrigation water use efficiency in winter wheat field with surface drip irrigation in the North China Plain. *Agricultural Water Management*, *163*, 403–407. https://doi.org/10.1016/j.agwat.2015.10.012

Ye, X., Liu, H., Zhang, X., Ma, J., Han, B., Li, W., Zou, H., Zhang, Y., & Lin, X. (2020). Impacts of irrigation methods on greenhouse gas emissions/absorptions from vegetable soils. *Journal of Soils and Sediments*, *20*, 723-733. https://doi.org/10.1007/s11368-019-02422-3/Published

Zhang, Y., Niu, H., Wang, S., Xu, K., & Wang, R. (2016). Application of the DNDC model to estimate N2O emissions under different types of irrigation in vineyards in Ningxia, China. *Agricultural Water Management*, *163*, 295–304.

Zschornack, T., da Rosa, C. M., Pedroso, G. M., Marcolin, E., da Silva, P. R. F., & Bayer, C. (2016). Mitigation of yield-scaled greenhouse gas emissions in subtropical paddy rice under alternative irrigation systems. *Nutrient Cycling in Agroecosystems*, *105*(1), 61–73. https://doi.org/10.1007/s10705-016-9775-0

December 21, 2022

Mr. Terry Cosby, Chief
Natural Resources Conservation Service
U.S. Department of Agriculture
1400 Independence Ave., SW
Washington, D.C. 20250

Submitted via Federal eRulemaking Portal http://www.regulations.gov/

Re: Docket #: NRCS-2022-0015 Use of IRA funds to deploy climate-smart practices

Dear Chief Cosby:

On behalf of the agriculture, conservation, and water organizations below, please accept these comments, intended to provide constructive feedback on the recent Natural Resources Conservation

Service (NRCS) proposal to implement funds received under the Inflation Reduction Act (IRA) to fund the deployment of climate-smart practices on US farms, ranches, and forestlands through four Farm Bill conservation programs. We believe the feedback will help NRCS better achieve its goals related to climate-smart agriculture.

Background

On August 12, 2022, President Biden signed the IRA into law. The substantial funding included in the IRA provides a significant opportunity to build critical resource-related infrastructure, protect communities from wildfire and extreme heat, and implement climate-smart agriculture and renewable energy initiatives nationwide. Specific to working agricultural lands, the IRA instructs the Secretary to prioritize the $19B in new Farm Bill program funding to agreements and projects that directly improve soil carbon, reduce nitrogen losses, or reduce, capture, avoid, or sequester carbon dioxide (CO_2), methane, or nitrous oxide (N_2O) emissions. NRCS has requested input on how NRCS regulations, policies, forms, or program processes should be modified, streamlined, expanded, or removed to increase benefits achievable through IRA funding.

The purpose of our letter is to urge NRCS to seek ways to simultaneously address other conservation challenges by adding key practices to its climate-smart agriculture and forestry (CSAF) list of mitigation activities for IRA funding. These practices will meet the IRA's climate-smart objectives while simultaneously responding to other pressing resource challenges in the West. Adding and prioritizing these multi-benefit practices will also help ensure that western states receive IRA resources consistent with the recent request from 16 western Senators.[i]

Recommendations for Activities to Add to the CSAF List

As the NRCS works to specifically incentivize the adoption of conservation practices that combat climate change, we urge the NRCS to consider practices that will help meet climate goals while simultaneously helping Western farmers and water managers currently facing significant water shortages. Accordingly, we request that the NRCS include the following activities on the CSAF list so that they are eligible for IRA funding:

1. Irrigation infrastructure and efficiency

Conservation practices related to irrigation infrastructure and water efficiency should be eligible for funding under the IRA. Aside from a narrow application on rice fields for irrigation water management (449), irrigation infrastructure and efficiency practices such as irrigation pipeline (430), micro-irrigation systems (441), sprinkler systems (442), and irrigation water management (449) are currently excluded from the CSAF list.

These exclusions miss key greenhouse gas (GHG) reduction benefits associated with these practices and will therefore hinder the immensely successful and ongoing efforts to use NRCS funding to develop and implement comprehensive irrigation modernization strategies in many parts of the West. In addition to securing GHG reduction benefits consistent with IRA objectives, irrigation modernization positions rural communities for long-term water resilience from the impacts of climate change, enhances our domestic food supply, and supports a healthy environment for generations to come. In short, these practices not only help address the causes of climate change but can also be implemented in a way that helps mitigate the severe water-related impacts being experienced in the West and should therefore be added to the CSAF list.

Modernizing irrigation systems often results in moving irrigation pumping systems off of diesel-powered generators, thereby releasing fewer GHGs into the atmosphere.[ii] Moreover, as large-diameter pipes replace leaky, gravity-fed open canal systems, the resulting conversion to a pressurized distribution system reduces on-farm and district fossil fuel consumption and directly reduces CO2 emissions. Further, installing in-conduit hydroelectric generation in these modernized irrigation district systems can generate clean electricity using pressurized water flowing through a closed-pipe system to spin a turbine (irrigation districts can also sell the power generated to local utilities, providing the district with an additional revenue stream that they can use to accelerate investment in modernization projects).

Additionally, upgrading irrigation systems can significantly reduce N2O emissions, reduce nitrogen losses, increase soil carbon, and generate energy savings (plus avoided GHG emissions), in addition to providing nutrient- and sediment-related water quality benefits. In arid and semi-arid regions like the western United States, irrigation management improvements can result in more than 50% reductions in average cumulative N20 emissions.[iii] Further, upgrading irrigation systems can also improve soil organic carbon, soil quality, and erosion control.[iv] Though careful consideration must be afforded to impacts on adjacent streams and wetlands, irrigation infrastructure modernization can also help producers adapt to drought conditions.

Keeping land in arid areas in-production through more flexible and effificient irrigation management will also preserve a major carbon sink. For example, one irrigation district in Central Oregon saw roughly 50% of its agricultural land go fallow this past year due to the drought, with 750,000 acres of California farmland fallowed this year as well. These, and many other examples across the West, represent vast swaths of farmland, all of which provide a carbon uptake value. Significant carbon sequestration opportunities are lost when insuffficent water supplies create barren patches of soil.

In addition to improving the resilience of rural economies, advancing irrigation management also improves the surrounding environments. Modernization of irrigation systems, particularly through piping open canals, reduces systems water loss. The resulting saved water improves water supply reliability for water users and presents an opportunity to increase instream flows in rivers and streams, while additional modernization activities can increase fish passage. Augmented instream flows benefit protected species and improve water quality, allowing these aquatic ecosystems to continue providing crucial ecosystem services to surrounding farms, communities, and economies.

Excluding Irrigation Water Management from the list of CSAF practices also means that NRCS will be unable to utilize any IRA funds on irrigated wet meadow systems with deep-rooted wetland vegetation such as sedges, rushes, and grasses. This will trigger missed opportunities for conservation that sustain carbon stocks and a wide array of ecosystem services provided by these ecologically important meadow systems.

2. Vegetation Management in the Western Sagebrush Biome

The conservation practices associated with sagebrush conservation—as defined in the NRCS Sagebrush Biome Framework and Western Association of Fish & Wildlife Agencies (WAFWA) Sagebrush Conservation Design—are truly the key to minimizing the massive rangeland fires that have been a major source of GHG emissions in recent years. The NRCS Sagebrush Biome Framework for Conservation Action is science-based and clearly prioritizes conservation to address the most pressing issues in the sage – invasive annual grasses, woodland expansion, riparian and wet meadow degradation, and land use conversion. This has been the focus of the Working Lands for Wildlife (WLWF) Sage Grouse Initiative (SGI) for the last five years. By all accounts, this work has been extremely successful and should be eligible for expanded IRA funding given the potential for implement these conservation treatments in ways that also achieve quantifiable carbon sequestration and/or GHG reductions.

The current set of CSAF practices as proposed would greatly restrict NRCS' ability to utilize IRA funds in addressing the massive challenge of invasive annual grasses and fire in the sagebrush ecosystem and the conservation of irrigated lands for wildlife in the West. The CSAF list includes only three practices that address sagebrush rangelands—Prescribed Grazing (528), Range Planting (550), and Pasture and Hay Planting (512). Missing are practices such as Brush Management (314), Herbaceous Weed Treatment (315), and Restoration of Rare of Declining Natural Communities (643). Collectively these practices are key to addressing woodland expansion, invasive annual grasses, and mesic habitat degradation.

Strategically addressing the true challenges in the sagebrush ecosystem in ways that also achieves quantifiable carbon sequestration and/or GHG reduction outcomes requires a systems-based approach with the full complement of available conservation practices.

Conclusion

NRCS' upcoming strategic investment of EQIP, RCPP, CSP and ACEP funds through the IRA represents an unprecedented opportunity to increase the pace and scale of conservation. Clearly, grand opportunities exist for innovative utilization of NRCS' full realm of conservation practices to achieve the IRA's carbon sequestration and/or GHG reduction objectives, while also helping to secure critical climate adaptation benefits in the face of drought in the west. Our organizations urge NRCS to fully exercise the authority afforded to it under the IRA and add these critical practices to the CSAF list so that they too are eligible for IRA funding.

We appreciate the opportunity to share our recommendations with you.

If you have any questions regarding this letter, please do not hesitate to contact Dan Keppen, executive director for Family Farm Alliance (dan@familyfarmalliance.org).

Sincerely,

California Farm Bureau
Colorado Farm Bureau
Dolores Water Conservancy District (CO)
Farmers Conservation Alliance
Family Water Alliance (CA)
Idaho Farm Bureau
Nevada Farm Bureau
Panoche Resource Conservation District (CA)
Truckee-Carson Irrigation District (NV)
Western Growers
California Farm Water Coalition
Deschutes Basin Board of Control (OR)
Elephant Butte Irrigation District (NM)
Family Farm Alliance
Fremont-Madison Irrigation District (ID)
Idaho Water Users Association
Oregon Farm Bureau
The Freshwater Trust
Washington State Potato Commission
Yuma Co. Agriculture Water Coalition (AZ)

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[i] Letter from 16 Western Senators to Secretary Tom Vilsack (Dec. 7, 2022), https://www.bennet.senate.gov/public/_cache/files/1/c/1cee131b-0844-4469-9efd-be2876fc5d97/D617B3AAF1878358F49194FD9FBF56D9.22.12.07-usda-western-drought-priority-letter-final.pdf?mc_cid=8e95aed930&mc_eid=95ce63cab6.

[ii] In a recent study, GHG emissions were shown to be reduced by upgrading to higher efficiency irrigation systemsii because as phase three power becomes increasingly available, growers convert from diesel pumps to the smaller electric pumps needed for higher efficiency systems. Mushtaq, S., Maraseni, T. N., & Reardon-Smith, K. (2013). Climate change and water security: Estimating the greenhouse gas costs of achieving water security through investments in modern irrigation technology. *Agricultural Systems*, 117, 78–89. https://doi.org/10.1016/j.agsy.2012.12.009.

[iii] For example, a recent study in Arizona found that overhead sprinkler irrigation and subsurface drip irrigation on cotton farms significantly reduced N2O emissions relative to furrow irrigation. Bronson, K.F., Hunsaker, D.J., Williams, C.F., Thorp, K.R., Rockholt, S.M., Del Grosso, S.J., Venterea, R.T., & Barnes, E.M. (2018). Nitrogen management affects nitrous oxide emissions under varying cotton irrigation systems in the Desert Southwest, USA. *Journal of Environmental Quality*, 47, 70-78. http://doi:10.2134/jeq2017.10.0389. Similarly, a Southern California study found that drip irrigation decreased N2O emissions by 59% for hay production and 38% for alfalfa; all while also reducing water demand by 49%. Andrews, H.M., Homyak, P.M., Oikawa, P.Y., Wang, J., & Jenerette, G.D. (2022). Water-conscious management strategies reduce per-yield irrigation and soil emissions of CO2, N2O, and NO in high-temperature forage cropping systems. *Agriculture, Ecosystems & Environment*, 332, 107944. https://doi.org/10.1016/j.agee.2022.107944. Earlier research confirms these findings. A 2010 study found drip irrigation reduced N2O emissions relative to furrow irrigation in California's Central Valley. Kallenbach, C.M., Rolston, D.E., & Horwath, W.R. (2010). Cover cropping affects soil N2O and CO2 emissions differently depending on type of irrigation. *Agriculture, Ecosystems & Environment*, 137, 3-4. https://doi.org/10.1016/j.agee.2010.02.010. Denitrification-Decomposition model simulations for California from 2001 to 2010 assessed that drip irrigation reduced (N2O) emissions by 55-67% relative to surface gravity irrigation. Deng, J., Guo, L., Salas, W., Ingraham, P., Charrier-Klobas, J.G., Frolking S., & Li, C. (2018). Changes in irrigation practices likely mitigate nitrous oxide emissions from California cropland. *Global Biogeochemical Cycles*, 32, 1514-1527. https://doi.org/10.1029/2018GB005961.

[iv] Emde, D., Hannam, K.D., Most, I. Nelson, L.M., & Jones, M.D. (2021). Soil organic carbon in irrigated agricultural systems: A meta-analysis. *Global Change Biology*, 27, 3898-3910. *See also* Ippolito, J.A., Bjorneberg D., Scott, D., & Karlen, D. (2018). Soil quality improvement through conversion to sprinkler irrigation. *Soil & Water Management & Conservation*, 81, 1505-1516. http://doi:10.2136/sssaj2017.03.0082.