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Natural Resources Conservation Service

Conservation Effects Assessment Project (CEAP)
CEAP-Wetlands Science Note

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Estimating the Effects of Wetland Conservation Practices in Croplands

Approaches for Modeling in the CEAP-Cropland Assessment

Summary of Findings

Quantifying the current and potential benefits of conservation practices can be a valuable tool for encouraging greater practice adoption on agricultural lands. A goal of the CEAP-Cropland Assessment is to estimate the environmental effects of conservation practices that reduce losses (exports) of soil, nutrients, and pesticides from farmlands to streams and rivers. The assessment approach combines empirical data on reported cropland practices with simulation modeling that compares field-level exports for scenarios “with practices” and “without practices.”

Conserved, restored, and created wetlands collectively represent conservation practices that can influence sediment and nutrient exports from croplands. However, modeling the role of wetlands within croplands presents some challenges, including the potential for negative impacts of sediment and nutrient inputs on wetland functions.

This Science Note outlines some preliminary solutions for incorporating wetlands and wetland practices into the CEAP-Cropland modeling framework. First, modeling the effects of wetland practices requires identifying wetland hydrogeomorphic type and accounting for the condition of both the wetland and an adjacent upland zone. Second, modeling is facilitated by classifying wetland-related practices into two functional categories (wetland and upland buffer). Third, simulating practice effects requires alternative field configurations to account for hydrological differences among wetland types. These ideas are illustrated for two contrasting wetland types (riparian and depressional).

Background

Aquatic contamination caused by loss of soil, nutrients, and pesticides from farm fields is a significant resource concern for the nation’s croplands. To address this concern, the CEAP–Cropland Assessment combines sampling and modeling approaches to estimate the environmental effects of conservation practices that can reduce soil erosion and nutrient export from croplands to streams and aquifers. The assessment uses empirical data on farming and conservation practices for a large representative sample of cropland field points from the National Resources Inventory (NRI) within the framework of the physical-process model, APEX (Agricultural Policy/ Environmental eXtender).

Model simulations compare the soil and nutrient exports expected under a scenario of “no conservation practices used” to the reduced outputs expected from the practices actually in use on each sample field. The field-level differences estimate the conservation benefits, which can be scaled up to regional or national levels (Duriancik et al. 2008). For example, simulations for the Chesapeake Bay region estimated that current conservation practices reduce annual sediment loss from cultivated croplands by 57%, and that greater practice use could potentially achieve 84% annual reductions in some areas relative to if no practices were in place (NRCS 2011).

Wetlands can provide multiple benefits (“ecosystem services”) that include reduction of contaminants, floodwater storage, soil carbon storage, and wildlife enhancement. These benefits are recognized in protective rules such as the Farm Bill “Swampbuster” provision, and in USDA programs that restore or create wetlands on agricultural lands (e.g., Wetlands Reserve Program [WRP], now part of the Agricultural Conservation Easements Program [ACEP]). While wetlands can contribute to improving stream and aquifer water quality in wetlands and croplands, there are challenges to modeling their role as a conservation practice within the CEAP–Cropland framework. Excessive sediment and nutrient inputs can have negative feedbacks on wetland functions and, consequently, on the ability of wetlands to provide other ecosystem services in the landscape.

All modeling requires some simplification and abstraction. The CEAP–Cropland modeling approach is based on a standardized field-unit area, which allows for simulating practices as sub-area effects. Steps in model design include: a) grouping cropland practices into functional categories, b) developing rule sets for co-occurring practices so that practice effects are not overestimated, and c) defining field-unit configurations for different practice types and scenarios (Potter et al. 2009). Modeling wetlands as a conservation practice will require similar design steps. This Science Note highlights key considerations for incorporating wetlands into the CEAP–Cropland Assessment and addresses three model-design issues: 1) linking practice effects to wetland type and condition, 2) defining practice types and rule sets, and 3) designing appropriate field-unit configurations. Further model-development needs are also discussed.

Assessment Partnership and Approach

This Science Note is based on collaborative work among researchers from the CEAP–Wetlands Assessment and the CEAP–Cropland Modeling Team.

Principal contributors were Diane De Steven (USDA Forest Service), David Mushet (U.S. Geological Survey), Kate Behrman (USDA Agricultural Research Service), and Mari-Vaughn Johnson (USDA NRCS). Information on wetland-related conservation practices was drawn from analyses of written conservation plans (e.g., De Steven and Gramling 2011) and practice databases (e.g., Gleason et al. 2011, Hively et al. 2013).

Issues for Modeling Wetland Practices

Linking Practice Effects to Wetland Type and Condition

Accounting for wetland hydrogeomorphic (HGM) type is key to estimating practice effects, because geomorphic form and topographic position influence how water and materials move in and out of wetlands (NRCS 2008). For example, two major HGM classes (riverine/riparian and depressional) occur frequently in agricultural landscapes, but they differ in their capacity to address soil and water-quality concerns owing to contrasting hydrologic regimes (Table 1). Sediment deposition and retention are natural processes on riverine floodplains, whereas chronic sediment inputs will degrade depressional wetland functions by reducing basin volume and water-storage capacity (e.g., Gleason et al. 2011, Smith et al. 2011). The flow-through hydrology of riparian systems promotes the nutrient transformations that improve downstream water quality, whereas hydrologically closed depressions may have finite capacity to remove nutrients owing to process-saturation and aging effects (Woltemade 2000, Fisher and Acreman 2004, Fennessy and Craft 2011).

Table 1. Capacity of two common HGM types to provide wetland ecosystem services on croplands.

Desired wetland service	Provided by riverine wetlands?	Provided by depressional wetlands?
Reduced soil/sediment export	yes	limited†
Reduced nutrient/pesticide export	yes	yes†
Increased soil-carbon storage	yes	yes
Increased surface-water storage	yes	yes
Increased biodiversity/wildlife habitat	yes	yes

†Optimal function with upland buffer practice to reduce negative effects of sediment/nutrient loading (see text).

There can be trade-offs between contaminant reduction and other services, particularly for depressional wetlands (Table 1). Depressions that are overloaded with sediment and nutrients from farmed uplands will lose functional capacity as a result of reduced surface-water storage, eutrophication, and altered biotic communities (Leibowitz 2003, Gleason et al. 2011). The functions of smaller riparian wetlands can sometimes be degraded by excess sediments as well (Walter and Merritts 2008). The contaminant-reduction services can be optimized by using upland buffer practices (e.g., unfarmed vegetated strips) adjacent to wetlands in order to intercept sediment and ameliorate excess nutrient inputs. Vegetative buffers can also positively enhance other services such as biodiversity/habitat support. Thus, estimating the effects of wetland practices requires modeling that can account for both the dynamics of wetlands and the effects of adjacent land use.

Defining Practice Types and Rule Sets

Classifying practice types is a necessary step because wetland-related practices are more generalized than most cropland practices. Conservation practices are broadly considered either structural (relatively permanent) or cultural (managed annually). Of five core wetland practices, three are structural for modeling purposes (Table 2). Wetland Restoration and Wetland Creation rehabilitate degraded wetlands or establish new wetlands for the goal of providing multiple ecosystem services, whereas a Constructed Wetland is created primarily for the service of treating agricultural contaminants. Wetland practices are applied mainly through WRP/ACEP and the CRP (Conservation Reserve Program), with Restoration being the most common (Brinson and Eckles 2011).

The three wetland structural practices are supported by associated practices (Table 2) that represent either various types of cultural management or constructional elements (e.g., dikes or tree planting). Wetland Wildlife Hab-

Table 2. Primary (core) wetland conservation practices and typical associated supporting practices.

Wetland Practice (NRCS No.)	Wetland Practice Type	Supporting Practices in Wetland †	Supporting Practices in Upland Buffer †
Wetland Restoration (657)	structural	356+587, 644, 659, 612	645, 612, 327, 391, 338
Wetland Creation (658)	structural	356+587, 644, 659, 612	645, 612, 327, 391, 338
Constructed Wetland (656)	structural	356+587, 658, 659, 612	645, 612, 327, 338
Wetland Wildlife Habitat Management (644)	cultural	356+587, 659, 612	645
Wetland Enhancement (659)	cultural (see text)	none	none

†Practice names: 356+587 = Dike and Water Control Structure; 612 = Tree Planting; 645 = Upland Wildlife Habitat Management; 327 = Conservation Cover (similar practices include Pasture and Hay Planting, Early Successional Habitat Development, or Riparian Herbaceous Cover); 391 = Riparian Forest Buffer; 338 = Prescribed Burning.

itat Management can refer to passive maintenance, or to active manipulation of water levels and vegetation. Wetland Enhancement can represent cultural management, but may also refer to small engineered features (excavated swales) within a wetland. Other practices such as Upland Wildlife Habitat Management (645), Conservation Cover (327), or Riparian Forest Buffer (391) are also structural, but they represent the establishment of an uncropped buffer area of perennial vegetation around or adjacent to a wetland. Upland buffer vegetation may be herbaceous or forested, and may be managed by cultural practices such as prescribed burning or grazing.

Modeling is simplified by grouping practices with similar environmental effects into functional categories (Potter et al. 2009). For wetland modeling, the important structural practices reduce to a minimum of two functional categories: wetland and upland buffer. A rule set is needed for any co-occurring wetland practices on a crop field to reduce the potential for over-estimating practice contributions. Table 3 illustrates a simple rule set whereby: a) any combination of Restoration, Creation, and Enhancement is simulated as the same practice (Restored Wetland) because the more intensive practices take precedence, and b) Constructed Wetland is simulated as a distinct practice owing to its different purpose. This example assumes that well-implemented restored and created wetlands provide similar contaminant-reduction functions. If Restoration and Creation were assumed to provide different levels of that function, then an expanded rule set would be needed.

While buffer is the only category of upland practice, the environmental effects may differ according to which supporting practices were used to establish the buffer vegetation. For example, planting non-native grasses has detrimental effects on playa wetland functions compared to planting native grasses (Smith et al. 2011), and forest buffers may perform differently than herbaceous buffers (Lee et al. 2003). If a field containing a wetland is retired from cropping into CRP or ACEP-WRE, the entire field effectively becomes the wetland "buffer."

Designing Field-Unit Configurations

CEAP-Cropland modeling simulates how conservation practices influence soil and nutrient exports at a single "edge-of-field" outlet from a basic 16-ha field unit (Fig. 1A). Simulated fields representing each field point are populated with NRI data (climate, slope, soil type, crop type, etc.) and with survey data on the agricultural management and structural conservation practices being used by the farmers. Model parameters are set according to how features of the applied practices are expected to affect exports from the field. The environmental effect is estimated by the difference in those exports relative to the higher losses that would occur without the practices. The basic configuration (Fig. 1A) is modified, as needed, to represent the contribution of some practices as sub-area or channel effects (Potter et al. 2009).

Wetlands represent a unique practice category, and simulating their effects requires field configurations with three potential sub-areas: crop field, upland buffer, and wetland. Possible configurations are illustrated for two contrasting HGM types: wetlands in "riparian" positions (Fig. 1B) and wetlands in "depressional" positions (Fig. 1C). In CEAP-Cropland modeling, buffer practices are simulated as fixed-

Table 3. Possible rule set for co-occurrences of wetland practices on a simulated cropland field.

Wetland Restoration	Wetland Creation	Wetland Enhancement	Constructed Wetland	Simulate as
present	present or absent	present or absent	absent	Restored Wetland
absent	present	present or absent	absent	Restored Wetland
absent	absent	present or absent	present	Constructed Wetland

Figure 1. Field configurations for simulating practice effects: A. the basic configuration for cropland practices; B. modified configuration for a riparian wetland; C. modified configuration for a depressional wetland.

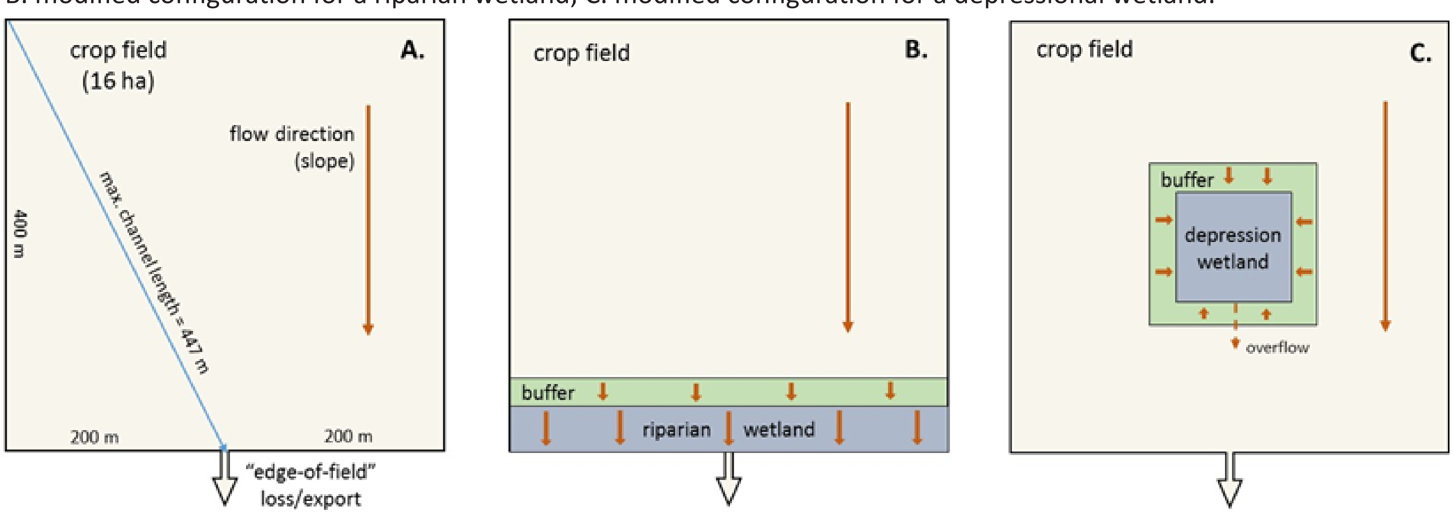

Table 4. Scenarios for estimating wetland practice effects within cropland fields.

Wetland Practice	Supporting Buffer Practice	Wetland Practice Effect (P-Factor)
none (or unrestored)	none (cropped)	1.0
restored wetland	none (cropped)	0.x
restored wetland	perennial cover (various)	0.y

width vegetated strips (10 m for Grass Filter Strips and 30 m for Riparian Forest Buffers) through which flows from the crop field are spread before leaving the outlet. Restored riparian wetlands could be simulated in a similar way (Fig. 1B), where flows are routed through a buffer strip (if present) and then through the riparian wetland. Constructed Wetlands might also be simulated with this configuration, since they are designed as flow-through systems. Wetland and buffer widths could be specified based on the typical or average size of such practices for a given region.

In contrast to the riparian situation, a depressional wetland is a localized within-field elevation minimum, often with a relatively restricted contributing watershed. It is an endpoint of sediment and water runoffs except when there are occasional (or managed) outflows (Fig. 1C). The edge-of-field environmental effect accrues from the routing and retention of some exports to the wetland area instead of directly to the field outlet, the wetland's contaminant-processing capacity, and the presence/absence of a buffer practice that affects inputs to the wetland. The "reservoir" feature of APEX might be used to simulate this configuration, with modifications to account for the hydrodynamic processes of basin filling, below-ground infiltration, and surface overflow (Mushet and Scherff 2016). To simplify estimation of practice effects, wetland area could be set to the typical aggregate size of regional depressions at the scale of the simulated field area, and the buffer zone could be set to a width having the average extent and slope of the typical localized watershed area that contributes to basin inflow.

Each configuration allows for simulating practice/no practice scenarios for: 1) the crop field, 2) an upland buffer with defined width and vegetation cover, and 3) a functioning wetland area. Table 4 illustrates three possible scenarios, where an edge-of-field practice effect is represented conceptually by the ratio ("P-factor") of expected exports with/without the practices. A non-functioning wetland (i.e., drained and cropped) with no uncropped buffer contributes little to no reduction of contaminant loss from the crop field, thus the P-factor would be 1.0 for that scenario. Presence of a wetland alone might lower the output ratio by some amount (P-factor = 0.x); however, that benefit would be limited without the presence of a vegetated buffer to ameliorate the negative feedback of excessive inputs (i.e., P-factor with a buffer reduces to 0.y, where y < x). Model parameters for these effects might be based on empirical data or values from published literature. Synergistic effects would also be expected from the use of crop-field conservation practices that reduce inputs to the buffer-wetland complex, so that its functional capacities can be maintained over time.

Conclusions and Additional Considerations

With appropriate simplification and conceptualization, there is promise for integrating wetland effects on soil and water-quality services into the CEAP–Cropland Assessment framework. This Science Note is a preliminary step to resolve some basic model-design issues. Efforts are underway to improve the APEX model to better simulate wetland hydrodynamics (Mushet and Scherff 2016), while further refinements may be needed to address the potential effects of cultural management (e.g., in managed wetlands with active water-level control; see Duffy and Kahara 2011).

A distinctive case for assessment is posed by the HGM class of wetland flats. This wetland type may occur in headwater landscape positions, extend over large areas, and need substantial drainage networks to convert to agriculture (Rheinhardt et al. 2002). Converted flats can become significant sources of nutrient export; notable examples occur in the Atlantic Coast lowlands and the Florida rangelands (De Steven and Lowrance 2011). Achieving nutrient-reduction services in agricultural wetland flats may require distinctive cultural practices (e.g., Drainage-Water Management) as well as unique field configurations for modeling.

The CEAP–Cropland Assessment focuses on conservation practices that influence edge-of-field effects on soil and water quality. However, wetlands in agricultural fields also provide other services of value to society, such as providing critical habitat for crop pollinators and support of important wildlife populations. These types of services are not readily quantifiable as edge-of-field effects. Consequently, novel extensions of the modeling framework will be needed to estimate the "internal effects" of cropland and upland buffer practices on wetland capacity to provide other services (Mushet and Scherff 2016).

Once the basic design and parameterization issues are resolved, simple quantifications for wetland and buffer areas may provide a starting point for estimating these added benefits. For example, use of cropland and buffer conservation practices to reduce sediment and nutrient inputs will extend the life expectancy and functional capacity of a depressional wetland, which in turn will enhance the provision of biodiversity and habitat services within cropland settings.

A practical issue for integrated assessment is the ability to detect the presence of wetlands within cropland settings. The Cropland approach selects a sample of points classified by the NRI as "cropland and CRP land" from the larger population of all NRI points. The actual fields associated with each point are then identified and delineated for purposes of compiling data on the practices in use. If restored/created wetlands associated with these fields are not recorded, then wetland practices could be under-detected; likewise, conserved natural wetlands may also be unrecorded because there is no explicit “protected wetland” practice. If the presence of wetlands within sample fields is not documented, their influence on edge-of-field outputs and on internal wetland benefits will be difficult to estimate. Finally, an NRI point which coincides with an ACEP-WRE tract is likely classed into a different land use and would be unavailable for sample selection, even though the tract represents long-term cropland retirement and wetland restoration. In a region where ACEP-WRE tracts have considerable extent (e.g., the Mississippi Alluvial Valley; Faulkner et al. 2011), scaling up the model results using only CRP wetlands could underestimate the effects of regional conservation programs. Improving field delineations and practice-use surveys to better capture wetland-related data could help to address this issue.

Modeling the current and potential benefits of conservation practices on agricultural lands is an important tool to raise conservation awareness and encourage greater practice adoption. USDA programs such as the CRP and ACEP-WRE achieve gains in wetland ecosystem services by protecting and restoring wetlands on crop fields that are withdrawn from farming, either temporarily or permanently. However, there is a conservation need to improve the condition and functioning of wetlands on working lands where retirement from active cropping is not an option. Successful incorporation of wetland practices into the CEAP-Cropland Assessment modeling approach could provide information on how use of appropriate upland buffer practices (e.g., in programs such as the Environmental Quality Incentives Program, EQIP) can enhance the ability of wetland practices to provide multiple ecosystem services within active croplands.

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Conservation Effects Assessment Project: Translating Science into Practice

The Conservation Effects Assessment Project (CEAP) is a multi-agency effort to build the science base for conservation. Project findings will help to guide USDA conservation policy and program development and help farmers and ranchers make informed conservation choices.

One of CEAP's objectives is to quantify the environmental benefits of conservation practices for reporting at national and regional levels. Because wetlands are affected by conservation actions taken on a variety of landscapes, the Wetlands National Component complements the national assessments for cropland, wildlife, and grazing lands. The wetlands national assessment works through numerous partnerships to support relevant assessments and address regional scientific priorities.

This Science Note was written by Drs. Diane De Steven (USDA Forest Service) and David Mushet (U.S. Geological Survey). Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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