United States Department of Agriculture

CEAP Science Note

Natural Resources Conservation Service
Conservation Effects Assessment Project

Assessing the Effects of Wetland Practices in Agricultural Landscapes: A Conceptual Model for Wetland Plant Diversity

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Summary of Findings

Wetland conservation practices can enhance the provisioning of desirable ecosystem services in agricultural landscapes. The potential for trade-offs in services should be recognized when planning and implementing wetland practices. Conceptual models are useful tools for identifying the expected practice benefits and trade-offs.

Plant-diversity attributes are an indicator of wetland functional condition and thus of a wetland's capacity to provide other valued services. A conceptual model for wetland plant diversity was developed to assist in planning and assessment of wetland conservation practices.

Wetland plant diversity reflects complex vegetation dynamics that are regulated by hydrology, geomorphic settings, and biotic interactions. These dynamics are also affected by external factors such as upland land use and the extent of wetlands in the landscape.

In agricultural landscapes, three driving factors influence plant diversity within wetlands. Inter-annual climate variation is a natural driver that shifts plant community composition by changing wetland hydroperiods. Non-conserving agricultural practices tend to degrade diversity through disturbances or unsustainable loading of sediment and nutrients. Conservation practices are expected to enhance diversity through improvements in hydrologic function and upland buffer condition.

The model illustrates process linkages between agricultural practices, wetland functional condition, and plant-diversity attributes. It can be adapted to guide regional assessments of practice effectiveness in conserved or constructed wetlands, and it can aid in landscape-level modeling of alternative practice-use scenarios.

Introduction

USDA conservation programs and practices seek to address societal resource concerns that arise from intensive agricultural production. These concerns include degradation of water quality and soils, and loss of valued ecological services provided by natural ecosystems.

Within agricultural landscapes, wetlands are important contributors of ecosystem services that include:

- improving water quality
- sustaining water quantity
- mitigating runoff and flooding
- regulating greenhouse gases
- providing wildlife habitats and native biodiversity

Biodiversity (whether considered a direct service or not) can reflect habitat functional condition and thus the capacity of an ecosystem to provide other services.

Wetland conservation practices (protection and restoration) have the potential to maintain desirable services in agricultural landscapes. However, estimating the effects of wetland practices requires an understanding of some inherent trade-offs (Brinson and Eckles 2011, Euliss et al. 2013). Conserved wetlands can reduce sediment and nutrient pollution in downstream waters, but excess loading will degrade wetland habitat quality and biodiversity (e.g., Daniel et al. 2014). Constructed treatment wetlands are an alternative practice for maximizing pollutant-reduction services, but even those wetlands can exceed capacity if not designed effectively (O'Geen et al. 2010).

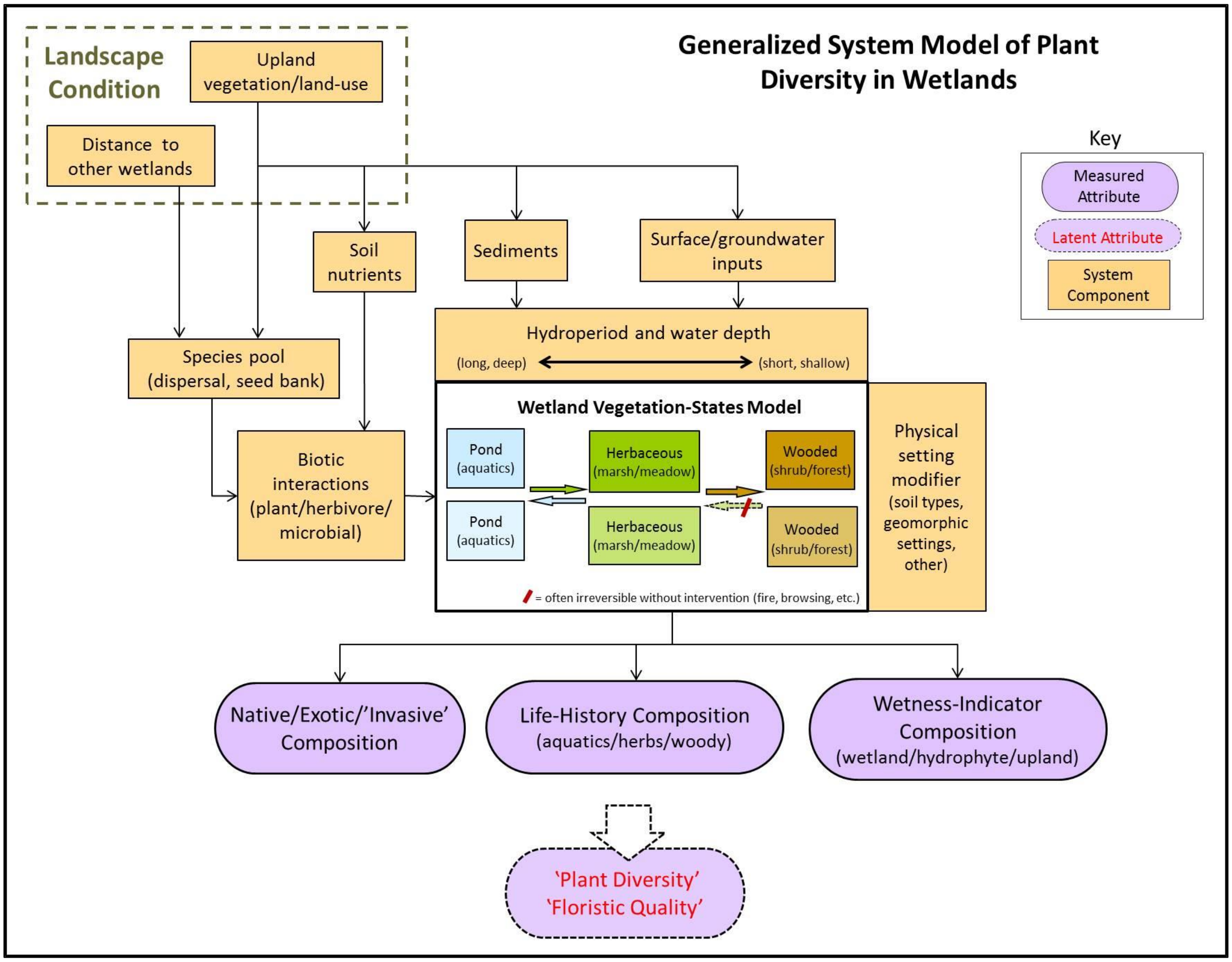
Plant-diversity attributes can be indicators of practice effects on wetland condition. A first step for understanding how such attributes are linked to practices is through a conceptual model. The purpose of conceptual models is to identify important pathways of influence between key system components and the outcomes of interest to managers (Gross 2009).

To assist in assessments of wetland practices, a CEAP–Wetlands Plant Working Group developed a two-phase conceptual model for wetland plant diversity, following the formats of Mushet et al. 2012. First, a system model describes the main factors and processes that affect plant species composition. Second, a driver-stressor-effects model illustrates how changes in natural and anthropogenic forces will alter the vegetation attributes that represent plant diversity. The overall model is a tool for communicating the expected benefits of conservation practices and the potential trade-offs between alternative practices.

System Model for Wetland Plant Diversity

Plant diversity is a conceptual ("latent") trait that is represented by multiple attributes (cf. Grace and Pugesek 1997). Three quantifiable attributes that describe community composition and quality are the relative representation of wetland vs. upland species, native vs. exotic species, and different life-history forms. The general system model (Fig. 1) describes the main factors that influence these attributes in naturally-occurring wetlands.

Figure 1. System model for local and landscape factors that influence plant-diversity attributes in natural wetlands.



The core of the system model is a vegetation state-change sub-model, where the composition attributes describe the plant diversity of any state. Conceptually, wetland plant communities are dynamic among three basic states (aquatic, herbaceous-emergent, wooded) whose species composition (floristic quality) is regulated by hydrological regimes and physico-chemical conditions (Smith et al. 2008). Individual wetlands may be temporally stable in one state or may shift between states. The plant species composition of these states can vary in different physical settings (e.g., topographic positions or soil types).

The specific form of the dynamic sub-model will vary by geographic region because of differences in climates, landform settings, and types of wetlands. For example, the wooded state is an integral model component for wetlands throughout the Eastern and Southern U.S., but not for prairie-potholes or playas of the Central Plains. Community dynamics may be driven generally by hydroperiod variability and geomorphic controls, but in some regions the fire regime may be an important driver (cf. De Steven and Lowrance 2011).

Additional factors act as constraints or modifiers on the core dynamic system (Fig. 1). Plant diversity in a given wetland is constrained by the pool of species that is present *in situ* or that colonizes by dispersal. That species pool is influenced by conditions in the landscape. The number and spatial distribution of wetlands determine the distances to other wetlands that are sources of colonizing plants (e.g., O'Connell et al. 2013). Upland land use affects composition of the vegetation surrounding a wetland. Condition of the adjacent uplands also influences sediment, water, and nutrient inputs to wetlands. Sediment and water inputs directly affect the hydrologic regime, whereas nutrients affect biotic processes such as plant competition and productivity. Finally, other biotic interactions (e.g., grazing by herbivores) may also influence plant composition.

Driver-Stressor-Effects Model for Plant Diversity Attributes

The system model is the basis for the second-phase model (Fig. 2) that links diversity responses to environmental change and human actions. In this second model, changes in "drivers" produce "stressor" conditions that have ecological effects on the system components, which result in changes to the attributes of interest.

A body of research suggests that three major drivers affect the plant diversity of wetlands in agricultural landscapes (Fig. 2). Short-term climate variation is a natural driver, "non-conserving" practices tend to degrade plant diversity, and conservation practices are expected to improve diversity. The model distinguishes between conservation practices applied in a wetland versus those applied to an upland buffer, since both can affect wetland functioning. As an over-arching factor, long-term climate change is likely to affect all drivers and stressors in the future.

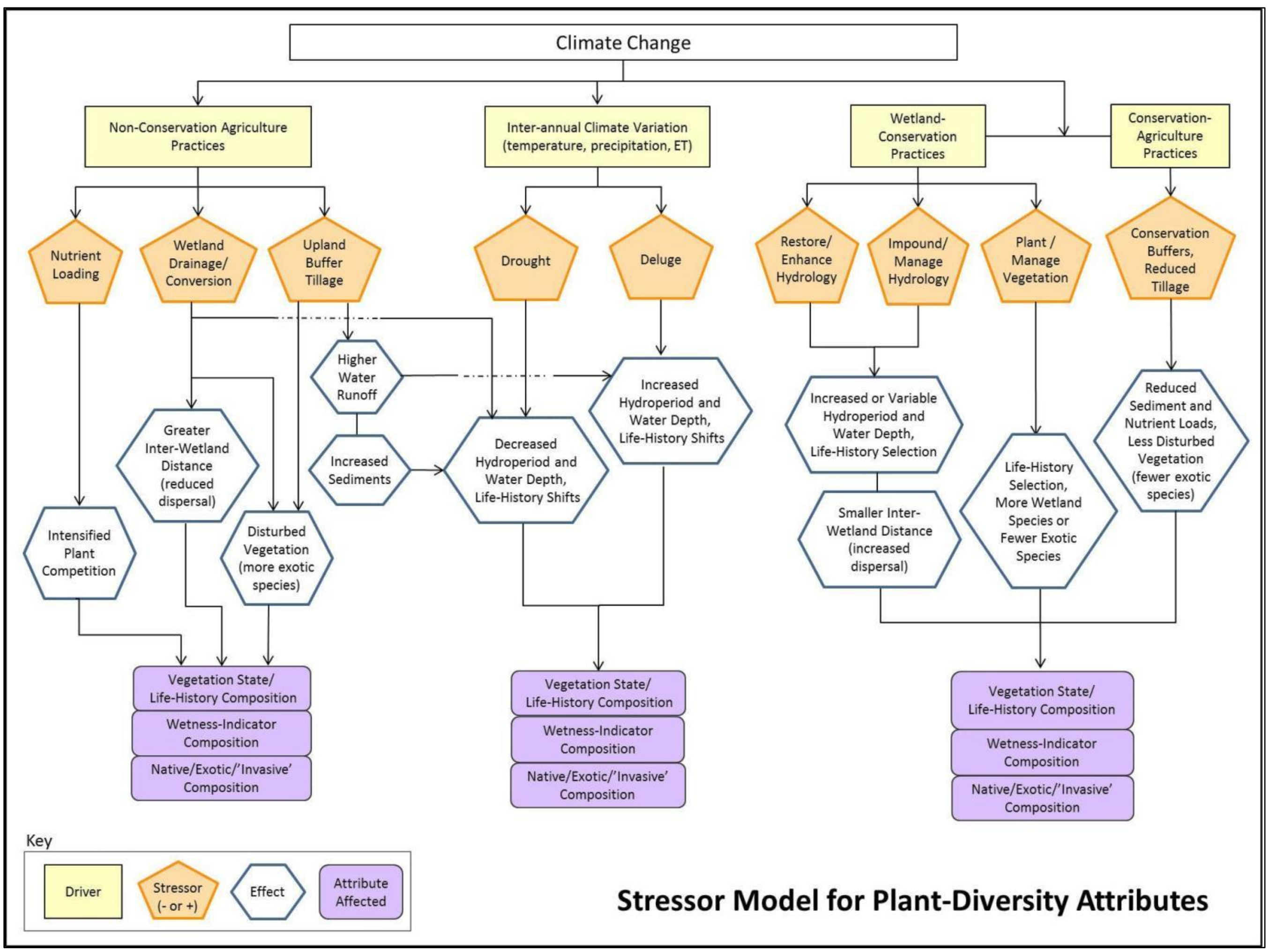
Drivers are linked to particular stressors and effects. The principal pathways for each driver are as follows:

1. *Inter-annual climate variation* affects community states and plant-diversity attributes through changes in hydroperiod and water depth during dry or wet periods. Droughts favor shifts toward upland species and transitions to herbaceous or woody communities. Return of wetter conditions can reverse the changes, but in some cases succession to the wooded state may not be reversible without management intervention.

2. *"Non-conserving" agricultural practices* generally degrade plant diversity through: a) higher nutrient loading that intensifies plant competition and reduces species richness; b) wetland drainage that causes shifts to upland species, or wetland conversion (loss) that results in greater inter-wetland distances; and c) intensive tillage of adjacent uplands that results in greater runoff and sediment loading plus higher incidence of exotic or invasive plants.

3. *Conservation practices* are expected to have positive effects

Figure 2. Conceptual model of environmental and practice effects on the plant-diversity attributes of wetlands within agricultural landscapes.



on plant-diversity attributes through: a) passive hydrology restoration or active hydrologic management that increases dominance by wetland species; b) planting that introduces desirable species or vegetation management that removes undesirable species; and c) practices that reduce or remove agricultural impacts in an upland buffer.

Directions of attribute change (increase/decrease) are specified in relation to the particular pathway and measure of interest. Criteria for desirable or target attribute values may be based on reference sites (e.g., Hopple and Craft 2013, Yepson et al. 2014) or on functional benchmarks (cf. De Steven et al. 2015).

The overall model represents a balance between broad generality and mechanistic detail. As such, it is a tool for illustrating the linkages between plant diversity and functional processes in wetlands. The model could be adapted to describe stressor effects at finer levels, such as for a particular community state or species group.

Application

Modeling the ecosystem services gained from wetland practices is especially challenging because of the complex interactions among wetland type, climate, topography, land use, and dynamic vegetation. Similar to managed rangelands, conserved wetlands on agricultural lands must provide environmental-quality services yet maintain their ecological integrity as natural ecosystems. Constructed treatment wetlands can diverge from natural conditions but still must sustain the biological health necessary for efficient functioning.

The conceptual model provides a starting point by identifying the wetland, upland, and landscape conditions that contribute to sustaining functional, diverse wetland vegetation. It also highlights some of the feedbacks and tradeoffs between practices and services. Further quantification of practice effects will require more detailed modeling approaches at landscape and field scales.

This model was developed to support landscape assessments of wetland services based on land-condition indicators (cf. Eckles 2006). Mushet et al. (2014) provide an example for amphibian diversity using the InVEST spatial modeling platform (Integrated Valuation of Environmental Services and Tradeoffs; Natural Capital Project, www.naturalcapitalproject.org). InVEST estimates biodiversity effects from proxy relationships between land-use coverages and indicators of habitat quality, which allows scaling up to landscapes and exploring alternative scenarios (e.g., with or without conservation practices). The proxy relationships are needed because biodiversity attributes are not directly detectable by the remote sensing methods that produce land-cover data.

At field scales, further work will be needed to quantify relationships between diversity attributes and changes in the functional processes that provide other ecosystem services. Wetland practices, particularly hydrology restoration, are not always implemented successfully (e.g., Duffy et al. 2011, chapter A). Plant diversity indicators may prove most useful for field-scale validation of how and where the applied wetland practices are most effective, potentially allowing incorporation into more detailed process-based models.

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The 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 the 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 focuses on regional scientific priorities.

The CEAP–Wetlands Plant Working Group (PWG) was chaired by Andrew Baldwin (University of Maryland) and included members Diane De Steven (USDA Forest Service), David Mushet (U.S. Geological Survey), Greg McCarty (USDA Agricultural Research Service), Dennis Whigham (Smithsonian Environmental Research Center), Megan Lang (University of Maryland), Mari-Vaughn Johnson (USDA-Natural Resources Conservation Service), Jim Kiniry (USDA-ARS), and Liza McFarland (Univ. of Maryland). Diane De Steven wrote this summary, with input from PWG members. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

For more information, see http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap, or contact Bill Effland (william.effland@wdc.usda.gov) or Mari-Vaughn Johnson (mjohnson@brc.tamus.edu)

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