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# Land use effects on pesticides in sediments of prairie pothole wetlands in North and South Dakota

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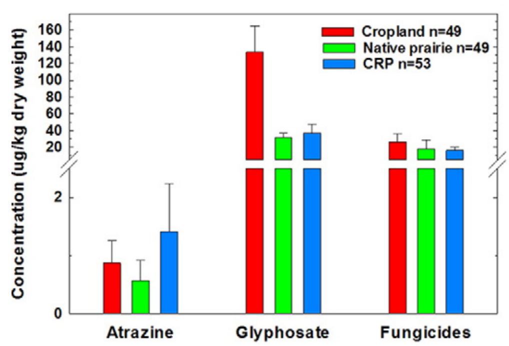
## HIGHLIGHTS

- Herbicides and fungicides, but not insecticides, were found in wetland sediments.
- Upland land use had minimal effect on overall presence of some pesticides.
- Conservation Reserve Program uplands protected wetlands from glyphosate input.

## GRAPHICAL ABSTRACT

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## ABSTRACT

Prairie potholes are the dominant wetland type in the intensively cultivated northern Great Plains of North America, and thus have the potential to receive pesticide runoff and drift. We examined the presence of pesticides in sediments of 151 wetlands split among the three dominant land use types, Conservation Reserve Program (CRP), cropland, and native prairie, in North and South Dakota in 2011. Herbicides (glyphosate and atrazine) and fungicides were detected regularly, with no insecticide detections. Glyphosate was the most detected pesticide, occurring in 61% of all wetlands, with atrazine in only 8% of wetlands. Pyraclostrobin was one of five fungicides detected, but the only one of significance, being detected in 31% of wetlands. Glyphosate was the only pesticide that differed by land use, with concentrations in cropland over four-times that in either native prairie or CRP, which were equal in concentration and frequency of detection. Despite examining several landscape variables, such as wetland proximity to specific crop types, watershed size, and others, land use was the best variable explaining pesticide concentrations in potholes. CRP ameliorated glyphosate in wetlands at concentrations comparable to native prairie and thereby provides another ecosystem service from this expansive program.


## 1. Introduction

Over 15 million ha of grassland in the Great Plains have been converted to support production agriculture (Samson and Knopf, 1994; Smith, 2003), which frequently have significant fertilizer and pesticide

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input. Pesticides have been reported to commonly occur in streams and rivers throughout agricultural intensive regions in the United States (Gilliom, 2007). In addition, cultivation increases the potential of soil erosion, which may result in increased transport of pesticides. Thus, depressional wetlands, which are common to the intensively cultivated regions of the Great Plains (Smith et al., 2008), are likely to receive agricultural contaminants via drift, overspray and overland flow in water or sediment (Belden et al., 2012).

To protect fragile uplands, wetlands, and their services throughout the United States, federal funds have been put into various programs administered through the United States Department of Agriculture (USDA), such as the Wetland Reserve Program (WRP) and the Conservation Reserve Program (CRP). The CRP is the largest federal conservation program in the United States; designed to retire private lands from agricultural production as both a commodity management strategy and as a means to increase environmental benefits provided to people (USDA, 2013). Indeed, the recreational value alone provided by increased wildlife habitat on CRP acres has been estimated to be worth about $963 million/year (Sullivan et al., 2004; Wu and Weber, 2012). Ecosystem services potentially improved by implementing conservation programs and practices include improving habitat, water quality, flood water storage, groundwater recharge, nutrient cycling, and reducing input of sediment and chemicals/nutrients (Euliss et al., 2011; Smith et al., 2011). Recent studies have demonstrated the ability of CRP to reduce sediment and pesticide concentrations in depressional wetlands throughout the Southern Great Plains (Belden et al., 2012; Daniel et al., 2014). Currently, CRP enrollment cap is scheduled to drop from nearly 13 million ha to around 9.7 million ha by 2018, as outlined by the 2014 Farm Bill (Stubbs, 2013), which may have implications for ecosystem service provisioning in regions with high densities of CRP lands.

The Prairie Pothole Region (PPR) extends from the north central United States to southern Canada, and represents the northern extent of the Great Plains. Covering approximately 900,000 $km^2$, the PPR constitutes a major physiographic region, with CRP on over 2 million ha. Originally composed primarily of short to tall grass prairie with interspersed wetlands (prairie potholes) and river systems, the PPR has experienced significant changes over the past 200 years, as agriculture has become the dominant land use practice in the region, which along with widespread drainage of wetlands has resulted in significant loss of wetlands and their associated biodiversity and ecosystem services (Dahl, 2014; Johnston, 2013). Regardless, prairie pothole wetlands are still a major feature of the region and characterized as depressional wetlands of glacial origin that can range from a few hectares to tens of hectares in size. These wetlands are subject to continued pressure from agriculture, including sedimentation, altered hydrology and subsequent effects on biota and abiotic processes, and fertilizer and pesticide input originating from upland cultivation that can extend to the edge of the wetland (Euliss et al., 2011).

Previous work has documented pesticide contamination in depressional wetlands (playas) ranging from the Southern High Plains through the Rainwater Basin of Nebraska (Belden et al., 2012). That study demonstrated the ability of two conservation programs (CRP and WRP) to mitigate pesticide contamination in wetlands. Given the extensive use of CRP in the intensely cultivated PPR, the main goal of this study was to examine if the presence of CRP in the upland influenced pesticide contamination in sediments relative to the other dominant land use types; cropland and native prairie. Further, we evaluated a variety of other landscape level factors (e.g., crop type, distance to fields, etc.) as predictors of pesticides in sediments. Pesticide contamination has been reported in wetland water in the northern portion of the Prairie Pothole region (Donald et al., 1999; Messing et al., 2011). However, these studies did not measure several important current-use pesticides, focused on water, and did not differentiate contamination based on land-use around wetlands. Our study was conducted in North and South Dakota, where we sampled wetlands from the three land use types and screened for commonly used pesticides. Our sampling regime focused on sediments as the primary sink for many pesticides. Dissipation half-lives in sediment are also typically longer than water, increasing our chances of detecting contamination. We report the presence of pesticides and their concentrations and frequency of occurrence relative to land use. In addition, we discuss the relationship between pesticide endpoints and surrounding crop types.

## 2. Materials and methods

### 2.1 materials

Neat standards (>98% purity) of all analytes were purchased from Sigma-Aldrich (St. Louis, MO). All solvents and reagents were pesticide or GC/MS grade.

### 2.2 site selection

A total of 151 wetlands (49 cropland, 49 native prairie, and 53 restored) were sampled late June and early July 2011. This sampling period was likely effective for pesticides applied at planting and early life stages as most field crops are planted in May or Early June in the region (http://www.rma.usda.gov/fields/mt_rso/2015/final/). However, it may have missed later season applications of some pesticides such as fungicides and insecticides applied at the tassle stage in corn. Wetlands were located within the Glaciated Plains and Missouri Coteau portions of the PPR of North and South Dakota (Fig. 1; Gleason et al., 2011). This region receives an average range of 5–10 cm of precipitation per month from May to July (http://www.usclimatedata.com). Native prairie and cropland wetlands were classified according to the dominant land use type in their immediate upland watershed. For cropland wetlands, crop type in the immediate watershed was determined during sampling. The most common crop type was soybeans (34%) followed by corn (32%) and wheat (18%). Less common crop types included canola and millet. For this study, restored wetlands were those historically embedded in active cropland but since removed from cultivation. Some restored wetlands had hydrological restoration work implemented within basin (drain plugging, pit filling), but all wetlands had immediate watersheds replanted to grass cover through the CRP. Sampled wetlands were also classified by water regime (temporary, seasonal, or semi-permanent) following Cowardin et al. (1979) and provided by USGS Northern Prairie Wildlife Research Center. Mean (±SD) percent organic matter in sediments was similar among land use types, ranging from $0.07 \pm 0.02$ in CRP wetlands to $0.08 \pm 0.03$ and $0.11 \pm 0.07$ in cropland and native grassland wetlands, respectively (loss on ignition method).

### 2.3 Sediment sampling

Wetland sediments were sampled from the wetland center and then five equidistant points within the wetland, surrounding the center, ranging from about 10 to 30 m from shore depending on wetland size and configuration. Equal amounts of sediment (80 mls) were collected from the top 5 cm at each sample location and combined in a single 500 mL sample jar for each wetland (Shelton and Capel, 1995). The top 5 cm was sampled to account for any mixing and because many organisms move throughout the top few centimeters of sediment. Prior to sample analysis, all sediment samples were homogenized and subsampled for the required testing procedure.

### 2.4 Pesticide extraction and analysis

Eighteen pesticides were chosen as analytes based on usage data for the region obtained from the US Department of Agriculture National Agricultural Statistics Statistic Service (http://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Chemical_Use/), feasibility for