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George N. Zaimes
University of Kavala Institute of Technology

Richard C. Schultz
Iowa State University, rschultz@iastate.edu

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Keywords

non-point source pollutants, sediment, phosphorus, riparian land-uses, conservation land-uses

Disciplines

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Comments

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Original Research

Do Randomly Placed Riparian Conservation Land-Uses Improve Stream Water Quality in Iowa, USA?

George N. Zaimes[1,2]*, Richard C. Schultz[3]

[1]Department of Forestry and Management of Natural Resources, University of Kavala Institute of Technology (UKIT),
1 km Mikrohoriou, Drama, 66100 Greece
[2]School of Natural Resources and Environment, University of Arizona,
325 Bio Sciences East, P.O. Box 210043, Tucson, 85721 Arizona, USA
[3]Department of Natural Resource Ecology and Management, Iowa State University, Ames, Iowa, USA

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Abstract

To improve stream water quality in the United States, government programs subsidize farmers to establish riparian conservation land-uses in agricultural landscapes. This study compared sediment and phosphorus water concentrations from stream reaches adjacent to riparian forest buffers, grass filters, row-cropped fields, pastures with cattle fenced out of the stream, and continuous, rotational and intensive rotational pastures in Iowa. In some cases agricultural land-uses had significantly higher sediment and phosphorus concentrations, while in others the conservation land-uses were higher. The few significant differences between conservation and agricultural land-uses suggest that the random placement of conservation land-uses is an inefficient way to improve water quality.

Keywords: non-point source pollutants, sediment, phosphorus, riparian land-uses, conservation land-uses

Introduction

Improving stream water quality is a priority in most agricultural watersheds. Agricultural watersheds have higher sediment and nutrient stream water concentrations compared to watersheds with undeveloped forest [1]. As the percentage of row-crop agriculture [2] or pasture land [3] in the watershed increases, so does the phosphorus (P) concentration of its streams. In contrast, increasing the forested land of a watershed is negatively correlated with degraded stream water quality [4].

Traditional agricultural land-uses, such as row-cropping and continuous grazing, decrease the overall vegetation cover of the watershed for significant periods of time. In addition, these land-uses decrease surface roughness, infiltration, and evapotranspiration that lead to increased overland flow and soil losses [5]. Reduced vegetation cover also decreases root length and mass in the soil that makes stream banks more susceptible to erosion [6]. Overland flow [7] and stream bank erosion [8] are major transport pathways of sediment and P to streams. Sediment is the number one water quality problem in the United States [9] and P is the main limiting nutrient for eutrophication of surface waters [10].

To improve the degraded water quality of their streams, Iowa and other agricultural states in the United States are promoting conservation land-uses for riparian areas such as riparian forest buffers [11] and grass filters [12]. Research at the field scale has found that riparian forest buffers and grass filters can significantly reduce sediment and P from overland flow [13, 14] and stream bank erosion [15-17].

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*e-mail: zaimesgeorge@gmail.com

In addition, by focusing on the riparian areas of the watershed, stream water quality can improve while maintaining the largest area of the watershed in agricultural production. This is supported by research that found stronger relationships between riparian land-use and water quality than watershed land-use [18, 19]. It must also be noted that other studies [20, 21] have found that watershed land-use and water quality have a stronger relationship than riparian land-use. This indicates that in some cases it is necessary to implement conservation land-uses in other parts of the watershed.

The placement of conservation land-uses in agricultural riparian areas is financially attractive to farmers in Iowa because the Conservation Reserve Program, part of the 1996 Farm Bill, subsidizes lost income. The state of Iowa has and is spending substantial amounts of money to subsidize agricultural riparian land. When this project started in 2002, 61,621 hectares of riparian agricultural land had been converted to grass filters and 19,423 hectares to riparian forest buffers [22]. The riparian conservation land-uses are being placed randomly because this is a voluntary program. This leads to only portions of the riparian area of the entire watershed being placed in conservation land-use. So it is important to evaluate if this random placement of conservation practices is really improving stream water quality or if there should be more strategic planning of the placement of the riparian conservation practices in order to improve stream water quality. This is especially important today with funds for conservation practices continuously shrinking throughout the United States.

The objective of this study was to investigate if the random placement of conservation riparian land-uses can decrease stream water sediment and P concentrations during baseflow conditions in small streams. Small streams can have a substantial effect on water quality [23] because they provide better opportunities to intercept non-point source pollutants compared to larger streams. In addition to conservation land-uses, an emphasis was given to different grazing practices and complete exclosure of livestock from the stream. Rotationally and intensive rotationally grazed pastures are slowly replacing continuously grazed pastures in Iowa, because they can increase profitability [24]. Overall, it will be important to see if the random placement of the conservation and/or these new grazing practices are impacting stream water quality in the state of Iowa.

The hypothesis was that the stream water concentrations of sediment and P will increase in the following order: riparian forest buffers (RF), grass filters (GF), pastures with the cattle fenced out of the stream (FP), intensive rotational pastures (IP), rotational pastures (RP), continuous pastures (CP), and annual row-crop fields (RC). This was based on the potential intensity of the land-use on the riparian soil and vegetation and the stream banks.

Experimental Procedures

Study Regions

The research was conducted in central, northeastern, and southeastern Iowa (Fig. 1). These three regions are in different landforms that could influence the effectiveness of conservation land-uses in improving steam water quality. The Iowan Surface and the Paleozoic Plateau are the major landforms in the northeastern region [25]. The Iowan Surface has gently rolling terrain created by material moved by strong weathering events under permafrost conditions during Iowa's last glaciation (12,000-14,000 years before present). The Paleozoic Plateau is the oldest landscape in Iowa, with deeply incised narrow valleys and almost no glacial deposits. The Des Moines Lobe landform, in the central region, has poorly developed natural drainage, flat terrain with some broad ridges and small hills, and prairie wetlands because it is the most recently glaciated landscape of Iowa [25]. The Southern Iowa Drift Plain in southeastern Iowa has a highly developed drainage network with steeply rolling hills and valleys developed from incision through a loess cap into the glacial material deposited 500,000 ybp [25].

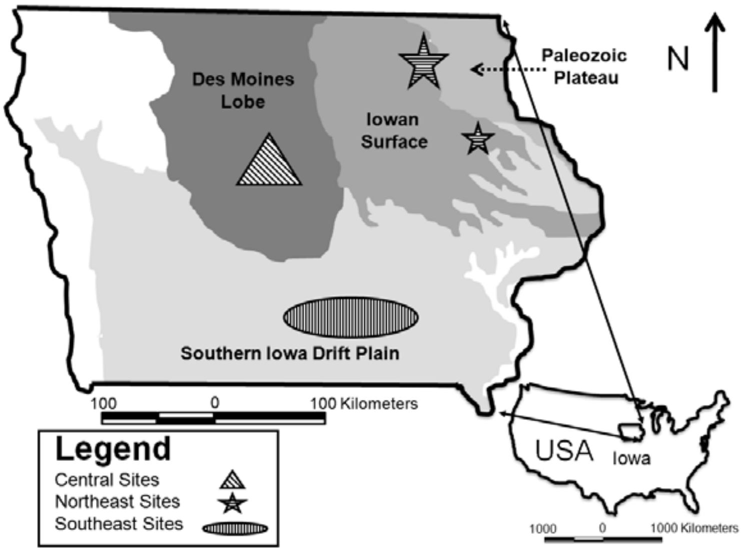

Fig. 1. The approximate location of the selected stream reaches in the three study regions of Iowa. The different gray colours indicate the different landform each region is in.

Selection of Stream Reaches

The stream water samples were collected from 1^{st}-3^{rd} order [26], incised, wadeable stream reaches (Fig. 2). Each stream reach selected had the same riparian land-use on both sides of the stream for at least 300 m. The riparian areas within each region also had similar soil textures (Table 1) [27]. In the northeastern and southeastern regions, the watershed area above each reach was <50 km^2, while the central region was <80 km^2. The topography of the watersheds in each region was similar with RC, the dominant land-use of the watershed that also included some pastures, homesteads, and the occasional small pockets of forests.

The study reaches were established on private farms to better evaluate the impacts of actual land-uses of Iowa farmers. Demonstrating the results on a neighbour's farm could also convince other local farmers to change their management. Over a six-month period, more than 120 stream reaches were visited in order to find reaches that were as as similar as possible to each other within each region. Unfortunately, it was not possible to find suitable stream reaches with all the riparian land uses of interest in all regions. The number of study reaches and the characteristics of their adjacent riparian areas in each region can be seen in Table 1. In these reaches the authors simultaneously conducted other studies on the impacts of riparian land-use on stream bank erosion and stream bed substrate [17, 28].

Riparian Land-Uses

The two main riparian conservation land-uses of Iowa are RF and GF (Figs. 2 a and b). Reaches adjacent to these land-uses were only selected if these had been established for at least 5 years, prior to the start of the study. In addition, all selected RF and GF had at least a 20 m width on both sides of the stream reach. Most RF and GF were relatively young when this project started, because these land-uses became available for cost-share in 1996 with the Conservation Reserve Program. The RF consisted of tree, shrub, and warm-season grass zones [11], while the GF consisted of cool-season grasses [12].

Annual RC and CP are the traditional agricultural land-uses in Iowa (Figs. 2 c, d, and e). Corn (*Zea mays* L.) and soybean (*Glycine max* (L.) Merr.) were the crops grown in alternating years adjacent to the study reaches. While some stream banks of the reaches had narrow strips (<4 m) of

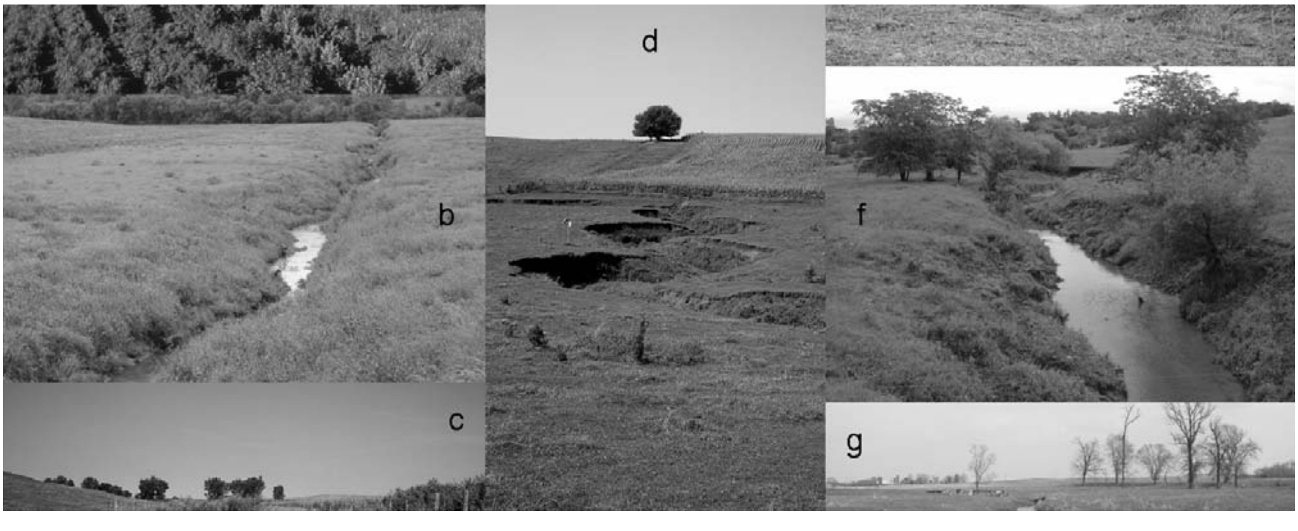

Fig. 2. Typical stream reaches from which water grab samples were collected. The adjacent riparian land-uses were: a) riparian forest buffers (RF), b) grass filters (GF), c) the front sub-reach is a continuous pasture (CP) while in the sub-reach in the background cattle are completely fenced out of the stream (FP), d) continuous pastures (CP), e) row-crop fields (RC), f) rotational pastures (RP), and g) intensive rotational pastures (IP).

Table 1. The land-use and soil characteristics of the riparian areas adjacent to the selected stream reaches in the three study regions of Iowa.

Riparian land-use	Reaches (#)	Soil series[1]	Soil texture[1]	Stocking rate (cow-calf ha^{-1})
Central region				
Row-cropped fields (RC)	2	Spillville-Coland complex	Clay loam, Loam	NA[2]
Continuous pastures (CP)	2	Coland, Colo, Spillville-Coland complex	Silt loam, Clay loam, Loam	1.5-2.0
Rotational pastures (RP)	2	Coland, Coland-Terrill complex	Clay loam	1.0-2.5
Grass filters (GF)	2	Spillville, Spillville-Coland complex	Clay loam, Loam	NA[2]
Riparian forest buffers (RF)	2[3]	Coland, Hanlon-Spillville and Spillville-Coland complexes	Clay loam, Loam	NA[2]
Northeastern region				
Continuous pastures (CP)	2	Dorchester, Radford, Otter-Ossian complex	Silt loam	1.2-2.0
Intensive rotational pastures (IP)	3	Dorchester, Dorchester-Chaeseburge-Viney and Dorchester-Chaeseburge complexes	Silt loam	1.0-1.7
Pastures, cattle fenced out of the stream (FP)	2	Radford, Spillville	Silt loam	NA[2]
Riparian forest buffers (RF)	1	Colo-Otter-Ossian complex, Spillville	Silt loam, Loam	NA[2]
Southeastern region				
Continuous pastures (CP)	3	Nodaway, Nodaway-Cantril complex	Silt loam, Loam	1.2-2.2
Rotational pastures (RP)	2	Nodaway	Silt loam	0.7-2.4
Intensive rotational pastures (IP)	2	Nodaway, Nodaway-Cantril complex	Silt loam, Loam	0.7-1.2
Pastures, cattle fenced out of the stream (FP)	1	Nodaway	Silt loam	NA[2]
Grass filters (GF)	2	Amana, Nodaway	Silt loam	NA[2]

[1] From [27].

[2] Not applicable.

[3] In this region a natural forest was used as a riparian forest buffer reach.

grasses or weeds, many others were cropped to the edge. In the reaches adjacent to the CP, cattle had full access to the stream throughout the grazing season. In the northeastern and central regions, grazing started in early May and ended in early November. In the southeastern region, one of the CPs followed similar dates as the other regions, while in the other two CPs the cattle grazed year-round with supplemental feed provided during the winter.

The reaches adjacent to the IP and RP were only selected if these land-uses had been established for at least 3 yrs., prior to the start of the study (Figs. 2 f and g). Older IP and RP were difficult to find when this project started because only recently had farmers in Iowa started adopting these practices for pastures with beef cattle. In the RP, the pasture was divided into 2-3 paddocks, with each paddock grazed 15-30 days and rested for about 30 days. In the IP, the pasture was divided into more than 6 paddocks. Each paddock was grazed 1-7 days and rested for 30-45 days. In all regions the grazing period for both the IP and RP started in early May and ended in early November. All pastures had primarily cool-season grasses that were grazed by beef cattle.

Finally, the reaches selected adjacent to the FP also had been established for at least 3 yrs., prior to the start of the study (Fig. 2c). Previously in these reaches, cattle had full access to the stream channel. This is a practice that many farmers in Iowa are reluctant to accept because the stream is the main water source for the cattle and the fencing along the stream banks requires frequent maintenance because of the many flash floods that happen in low-order streams.

Collection of the Stream Water Grab Samples

Samples were collected for seven different seasons: summer 2002, fall 2002, spring 2003, summer 2003, fall 2003, spring 2004, and summer 2004; no samples were collected during winter. In each sampling season, one grab sample (250 ml) from each study reach was collected by the same person. The sampling location was the furthest downstream point of the study reach in the middle of its wetted cross-sectional area. The collection was done during baseflow conditions; no significant precipitation events had occurred at least 3 days prior to collection. Every sampling season, the collection of all the samples for each region was completed within two days. The reaches of each region were relatively close to each other and received similar precipitation amounts [29, 30] indicating similar hydrologic conditions. Once collected, the samples were preserved in a cooler until they were analyzed in the laboratory.

Laboratory Analysis of the Stream Water Grab Samples

The samples were analyzed for total suspended sediments (TSS) and total and dissolved phosphorus (TP and DP, respectively). The analysis was conducted, at the latest, 48 hr after their collection from the field.

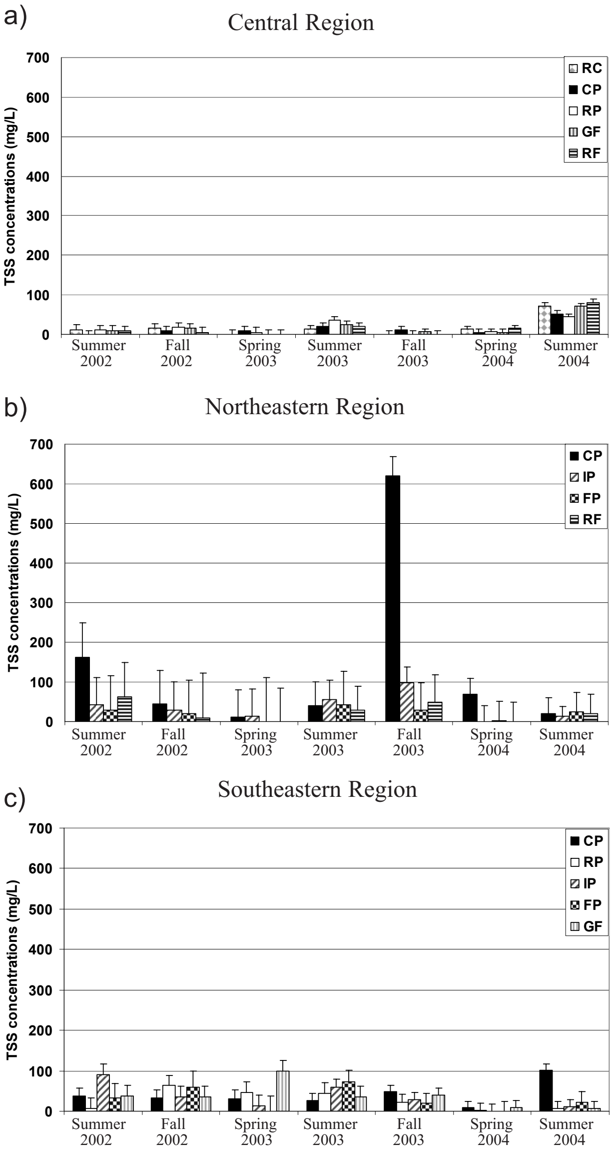

Fig. 3. Total suspended sediment (TSS) concentrations of the water grab samples collected seasonally (except winter) from the summer of 2002 until the summer of 2004 in three regions of Iowa: a) central, b) northeastern, and c) southeastern. The riparian land-uses adjacent to the sampled reaches were: riparian forest buffers (RF), grass filters (GF), pastures with the cattle completely fence out of the stream (FP), continuous pastures (CP), row-crop fields (RC), rotational pastures (RP), and intensive rotational pastures (IP).

The standard method of APHA [31] was used to estimate the TSS concentrations. Filter papers (0.45 µm) were placed in weighing tin boats, dried in the oven at 105ºC for 1 hr and 30 min, and afterward weighed with an analytical balance. Once the tin boats with the filter papers were weighed, one of the filter papers was placed on a vacuum pump assembly. Then a 25 mL stream water subsample was poured on the filter paper while the vacuum pump was on. The subsample was extracted with a serological pipette from the 250 mL stream water grab sample as it was being stirred by a bar on a magnetic stir plate to suspend all its sediment. Once the filtering process was done, the filter paper was placed in the same weighing tin boat. When all samples were filtered, the filter papers in the tin boats were dried in the oven at 105ºC for 1 hr and 30 min and then weighed again on the analytical balance. The weight differences of the tin boats with the filters (after and before filtering) along with the extracted volumes provided the TSS concentrations. Because the filtered water subsamples were also going to be analyzed for DP concentrations, they were collected in a clean glass vial. Three subsamples were analyzed for TSS for each stream water grab sample collected.

To estimate the TP concentrations, subsamples from the stream water grab samples were used while for the DP concentrations the stored filtered subsamples from the TSS analysis were used. Three subsamples for TP and three for DP concentrations were analyzed for each stream water grab sample collected. These subsamples were digested using heat and oxidizing reagents to break down all forms of P to orthophosphate [32]. Orthophosphate reacts with certain substances and produces a blue-violet color readable at a wavelength of 890 nm on a spectrophotometer [32]. Based on the color of the subsample, the P concentration can be estimated. In this study a Hach DR/3000 spectrophotometer (Loveland, CO) was used.

More specifically for this study, 5 mL of every subsample were placed with a pipette into a 10 mL Hach spectrophotometer vial. In the 5 mL of the subsample, 2 mL of 1 *N* Hach sulfuric acid (H_2SO_4) and one Hach potassium persulfate powder pillow were added. Afterward, the subsamples were mixed by inverting them for 30 seconds and placing them in the COD reactor for 30 minutes to get digested. The COD reactor was heated at 150ºC. If a subsample boiled out of the vial, a new subsample was prepared. Each set of subsamples placed in the COD reactor had three standards. The standards were the blank (0 mg/L P) that was dioinized water, and two pre-made Hach standards of 0.33 mg/L of P, and 1.0 mg/L of P. The digested subsamples were left to cool. Once they were cooled down, 2 mL of Hach 1 *N* sodium hydroxide (NaOH) was added. Then the subsamples were mixed again. Then, using the blank standard, the spectrophotometer was calibrated. Once the spectrophotometer was calibrated all subsamples and the other two standards were read by the spectrophotometer. This first reading was the "initial" concentration of the subsample. Each subsample was read before adding the color reagent to account for any absorbance due to particulates in the sample. This is particularly important for unfiltered samples. Once the initial concentration values were measured, a Hach PhosVer 3® reagent powder pillow was added to each subsample. Then the subsamples were mixed one more time by inverting them for 30 seconds and left for two minutes. This time was necessary for the coloring agent to act and the subsample to develop its bluish-purple color. Afterward, each subsample was read again in the spectrophotometer. This was the "final" concentration. To get the actual concentration for each subsample its initial concentration was subtracted from its final. After the subtractions, the blank should have a concentration of 0.00 ppm and the standards of 0.33 ppm and 1.00 ppm, respectively. If the concentration values for the blank or either standard were not within the acceptable ranges (+ or – 0.03 ppm), the entire set was rerun. Finally, when a subsample had a concentration >1.10 ppm it was diluted and rerun.

Statistical Analysis

A mixed-design analysis of variance (ANOVA) was conducted on the data using the PROC MIXED procedure [33] in SAS 9.1.3. In the mixed-design ANOVA models, stream water TSS, DP, and TP concentrations were the dependent variables. For each of the dependent variables, regions, riparian land-uses, and seasons were the independent variables of the models. Difference were considered significant when the p-values <0.05. (The p-value is the probability of how much evidence there is against the null hypothesis [34]).

Results and Discussion

The highest stream water TSS concentrations were 621 mg/L in the northeastern region in reaches adjacent to the CP (fall 2003), 101 mg/L in the southeastern region, also in reaches adjacent to the CP (summer 2004), and 81 mg/L in the central region in reaches adjacent to the RF (summer 2004) (Fig. 3). In all three regions, in the springs of 2003 and 2004 there were several land-uses with no TSS detected in their stream samples. The TSS concentrations of our study reaches in most seasons were lower than the mean TSS concentration of 112 mg/L that a USGS study found [35] that included watersheds from our study. In addition, many of the TSS concentrations of our study reaches were lower than the minimum TSS concentrations of 0.3 mg/L, and none were close to the maximum TSS concentrations of 7,060 mg/L found in the same USGS study. The reason for the difference in maximum TSS concentrations is because the water samples in our study reaches were collected only during baseflow conditions. During baseflow conditions, TSS concentrations are lower compared to samples collected during high stream flow events (e.g. USGS study [35]) that have increased TSS concentrations because of erosional contributions.

In all regions, few significant differences in TSS concentrations were found among reaches adjacent to the different riparian land-uses. In the central region (Fig. 3a), in summer 2004, the reaches adjacent to the RP had the lowest TSS concentrations that were significantly different than the concentrations of the reaches adjacent to the GF (p=0.015), RC (p=0.013) and RF (p=0.001). In this same season the reaches adjacent to the RF had the highest TSS concentrations that were significantly different than the concentrations of the reaches adjacent to the CP (p=0.009). In the other two regions, only the reaches adjacent to the CP had significantly higher TSS concentrations than the reaches of all the other riparian land-uses (Figs. 3 b and c). Specifically, in the northeastern region this happened in fall

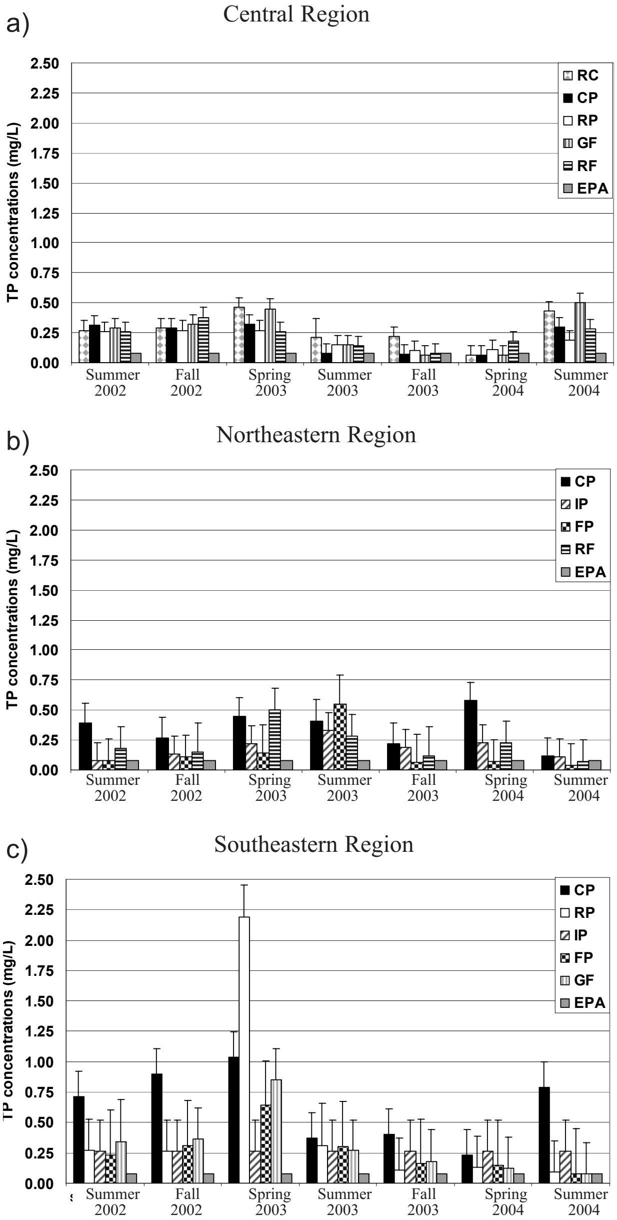

Fig. 4. Total phosphorus (TP) concentrations of the water grab samples collected seasonally (except winter) from summer 2002 until summer 2004 in three regions of Iowa: a) central, b) northeastern, and c) southeastern. The riparian land-uses adjacent to the sampled reaches were: riparian forest buffers (RF), grass filters (GF), pastures with the cattle completely fenced out of the stream (FP), continuous pastures (CP), row-crop fields (RC), rotational pastures (RP), and intensive rotational pastures (IP). In addition, the United States Environmental Protection Agency's recommended TP concentrations for the majority of the Iowa stream are presented.

2003 (all, p<0.001) and in the southeastern region in summer 2004 (all, p<0.001).

The TP concentrations of the reaches adjacent to the different riparian land-uses ranged from 0.06-0.50 mg/L in the central region, 0.04-0.50 mg/L in the northeastern region and 0.08-2.19 mg/L in the southeastern region (Fig. 4). These TP concentrations were similar to TP concentrations of U.S. Environmental Protection Agency (USEPA) studies [36-38] that reported concentrations ranging from 0-2.40 mg/L in streams of Iowa and other Midwestern states. The DP concentrations of the reaches of this study were similar to the TP concentrations and ranged from 0.04-0.45 mg/L in the central region, 0.04-0.46 mg/L in the northeastern region and 0.06-2.19 mg/L in the southeastern region (Fig. 5).

In many cases the TP concentrations of our study reaches exceeded the USEPA [39] recommended concentrations for rivers and streams for most regions of Iowa (Fig. 4). Specifically, in the central region, the TP concentrations of the reaches adjacent to the RC and RF were higher than the USEPA recommended concentration, in six out of the seven seasons that samples were collected, while the concentrations of the reaches adjacent to the GF were higher in five seasons and the reaches adjacent to CP were higher in four seasons (Fig. 4a). The TP concentrations of the reaches adjacent to the RP of this region were always higher than the USEPA recommended concentrations. In the northeastern region, the TP concentrations of the reaches adjacent to IP and RF were higher than the USEPA recommended concentration in six seasons, while the concentrations of the reaches adjacent to the CP were always higher (Fig. 4b). The only reaches with TP concentrations lower than or equal to the USEPA recommended concentration in most seasons (four out of the seven) were those adjacent to FP of this region. Finally, in the southeastern region, the TP concentrations of the reaches adjacent to CP, RP, and IP were higher than the USEPA recommend concentration in every season, while the concentrations of the reaches adjacent to FP and GF were higher in six seasons (Fig. 4c).

The high TP concentrations of our study reaches should not be completely unexpected, since other studies have found that stream TP concentrations in these regions ranked the highest in the United States [40]. Ice and Binkley [41] also found in small rural streams in the United States high TP concentrations, while Mueller and Spahr [42] reported that 97% of the reaches in their study had TP concentrations higher than the USEPA recommended regional concentration. Overall, these high TP concentrations indicate that our study reaches are impaired. This corresponds well to the stream substrate composition data of these reaches [28]. Most of our reaches were heavily embedded (having a high percentages of silts and clays) primarily because of the past agricultural land-uses that dominated the watersheds. Resuspension for the stream beds can be a major source of sediment and P in streams [43].

The high TP and DP concentrations of all reaches could also have led to the few significant differences among different riparian land-uses. In the central region most significant differences were found in spring 2003 (Figs. 4a and 5a). Specifically, the reaches adjacent to RC had significantly higher TP and DP concentrations than the RF (p=0.008 and p=0.035, respectively), and only higher DP concentrations than the RP (p=0.041). In addition, during this season the reaches adjacent to GF had significantly higher DP concentrations than the RF (p=0.008) and RP (p=0.018). The only other season with significant differences was summer 2004, with the reaches adjacent to the RP having significantly lower TP concentrations than the reaches adjacent to the GF (p=0.008) and RC (p=0.027). In the northeastern region, only one significant difference was found with the reaches adjacent to CP having higher TP concentrations than the

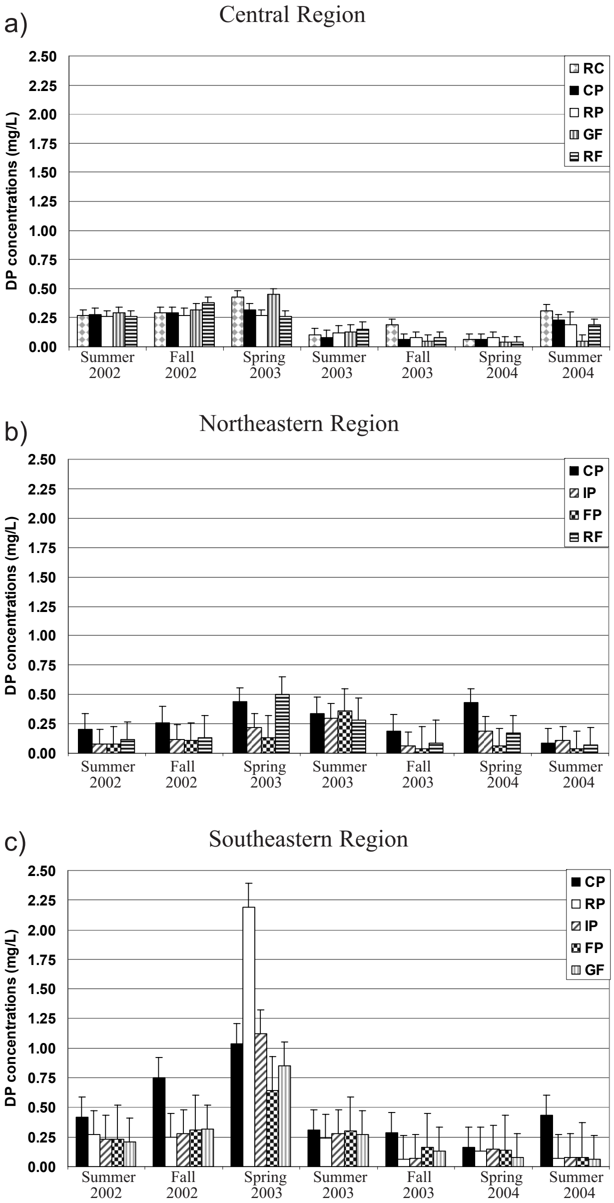

Fig. 5. Dissolved phosphorus (DP) concentrations of the water grab samples collected seasonally (except winter) from summer 2002 until summer 2004 in three regions of Iowa: a) central, b) northeastern, and c) southeastern. The riparian land-uses adjacent to the sampled reaches were: riparian forest buffers (RF), grass filters (GF), pastures with the cattle completely fenced out of the stream (FP), continuous pastures (CP), row-crop fields (RC), rotational pastures (RP), and intensive rotational pastures (IP).

reaches adjacent to the FP (p=0.033), in spring 2004 (Figs. 4b and 5b). Finally, in the southeastern region, there were significant differences only in spring 2003 (Figs. 4c and 5c). In this season the reaches adjacent to the RP had higher TP and DP concentrations than all the other riparian land-uses (all p<0.01).

Overall, for both TSS and P concentrations, very few significant differences were found among reaches adjacent to different riparian land-uses. In the northeastern and southeastern regions these few differences were as expected, with reaches adjacent to grazing practices with full access to the stream (CP and RP) having significantly higher concentrations than the other riparian land-uses. Many studies have shown that cattle grazing in riparian areas can degrade stream water quality [44]. Direct cattle impacts occur when they cross or stop in the streams and deposit feces or re-suspend stream bed material. Indirect cattle impacts occur when they trample the riparian soil and vegetation that can increase stream bank erosion and overland flow. In the central region some of the differences were not always as hypothesized. While reaches adjacent to RC did have significantly higher concentrations, so did reaches adjacent to conservation practices (GF and RF). Row-cropping up to the edge of the stream leaves the soil bare for significant periods of time, while heavy machinery compacts the soil, making it more susceptible to overland flow and stream bank erosion. In contrast, the presence of perennial vegetation (RF and GF) should reduce the erosional processes and non-point source pollutants. The impacts of agricultural and conservation land-uses were evident in the reaches of this study when examining stream bank erosion [17]. Specifically, the reaches adjacent to the agricultural land-uses had significantly higher stream bank erosion than the reaches adjacent to the conservation land-uses [17]. These stream bank erosion differences led us to expect more significant differences in stream water sediment and P concentrations between reaches adjacent to the conservation and agricultural land-uses.

Studies have shown that placing riparian areas in conservation land-uses (RF and GF) can mitigate non-point source pollutants from reaching the stream that originate from the riparian area itself [15-17] and its adjacent uplands [13, 14]. In the reaches of our study, the majority of their watershed areas and their upstream riparian areas were in agricultural production. This means that in the upstream reaches of our study, non-point source sediment and P could reach the stream unimpeded. This sediment and P moved in the stream water to the reaches of our study and impacted their stream water quality. Upstream reaches can provide substantial amounts of sediment and P to downstream reaches [45]. In addition, the historical legacies of the riparian areas can impact stream water quality even after the placement of conservation land-uses for several years [43]. All the riparian areas of the study reaches had been in agricultural land-uses for decades. The legacies of past agricultural land-uses in the study reaches were evident from their incised channels [17] and their heavily embedded stream beds [28]. Incised stream reaches have much higher sediment and P stream water concentrations than non-incised [46], while stream bed re-suspension of fines can substantially increase sediment and P concentrations in the stream water [43].

Based on the results of this study, it is evident that the random placement of riparian conservation practices is inefficient for improving stream water quality. A more strategic placement of the conservation riparian land-use practices is required. To have effective and efficient results in improving stream water quality, the riparian and other areas that are the major contributors of the non-point source pollutants need to be targeted and placed in conservation practices throughout the watershed. This requires a holistic watershed approach that has been made easier to adopt and accomplish with the use of models and GIS. Models and GIS can quickly located targeted areas in the entire watershed. Of course actual field observations will be required to finalize the placement of the conservation practices. In Iowa [48], soil survey information to rank buffer effectiveness and topographic and streamflow information to identify locations that conservation practices are most likely to intercept water moving towards streams have been employed. These methods prioritized conservation practice placement and improved stream water quality. In New Jersey [49] a watershed planning approach that prioritizes agricultural lands for conservation practices was based on multiple selection criteria that included soil erodibility, hydrological sensitivity, wildlife habitat, and impervious surface rate. Both Iowa and New Jersey approaches help projects and programs improve stream water quality cost effectively at scales ranging from farm-scale planning to regional policy implementation.

Conclusions

Establishing conservation land-uses in the riparian areas of agricultural watersheds should reduce stream non-point source pollutant concentrations even during baseflow conditions [47]. The results of this study do not support this suggestion because there were few significant differences in sediment and P concentrations among the conservation and agricultural riparian land-uses. In addition, while in some cases these significant differences were hypothesized, with agricultural land-uses (CP, RC, and RP) having higher concentrations, in other cases the conservation land-uses (GF, RF) had higher concentrations.

Riparian conservation land-uses are effective in reducing non-point source pollutants that originate in the riparian areas they are placed (e.g. stream bank erosion pollutants) and in the adjacent uplands (e.g. overland flow pollutants). The results of this study indicate that there are also other factors that impact stream water quality in these regions. The conservation land-uses had been established recently (5-10 years prior to the beginning of the study). As a result, the historical legacies of past agricultural land-uses still have lingering effects on the stream (e.g. embedded stream beds, channel incision) and stream water (TP concentrations higher than the recommended USEPA). Potentially, as time passes the conservation land-uses will alleviate these lingering effects and improve stream water quality. In addition, sediment and P in stream water also originate from the upstream reaches that can be a significant source. Most upstream riparian areas of our study reaches were in agricultural land-uses.

Placing conservation land-uses adjacent to all the reaches of the streams is unlikely because of limited financial resources. This suggests that a more strategic approach is required in order to reduce non-point source pollutants from watershed contributions. Diebel et al. [43] found that by targeting the areas that produce the highest 10% of sediment and P in the watershed, we can reduce stream loads by 20%. In contrast, if the bottom 10% of the areas that produce these pollutants is targeted, only 1% of the loads will be reduced. To effectively improve stream water quality, a holistic watershed approach needs to be considered by placing conservation land-uses in riparian and other areas of the watershed that are the major sources of the non-point source pollutants.

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