HYDROLOGIC ROUTING OF FARM RUNOFF AND IMPLICATIONS FOR RIPARIAN BUFFERS

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ABSTRACT: Vegetative buffers in riparian areas, i.e. riparian buffers, are designed to reduce pollutant runoff from crop land to streams. Their impact on stream water quality depends on the extent that farm runoff passes through them in a filterable manner. We mapped field contributing areas and surface runoff pathways on four farms in southeastern Nebraska to estimate the proportion of surface runoff that passes through existing riparian buffers. Among these four farms 92, 61, 15, and 12% of the total area of crop land drains through riparian buffers. The remaining crop land either drains to streams through conveyance pathways, including grassed waterways, roadside drainageways, and subsurface pipes, or settles into low areas having no apparent outlet from the farm property. Modeled relationships indicate that the non-riparian buffer pathways are substantially less efficient at filtering pollutants from runoff than the riparian buffers. The results suggest that, on some farms, enhancements to vegetative filters in riparian areas will have limited potential to improve stream water quality because most field runoff bypasses them. To effectively reduce pollutant contributions to streams from these farms, practices are also needed that reduce runoff loads before they reach conveyance pathways.
KEY TERMS: runoff pathways; contributing area; sediment; riparian buffers; surface hydrology.

INTRODUCTION

Riparian buffer installation is an accepted management practice for reducing agricultural nonpoint source pollution of streams. Riparian buffers are strips of perennial vegetation between cultivated fields and streams that intercept field runoff and trap pollutants before they can enter streams. Buffers perform best when runoff is uniformly dispersed across large areas of buffer (Dosskey et al., 2002).

The level of impact that riparian buffer installation will have on stream water quality also depends strongly on hydrologic routing of field runoff. Substantial impact is expected when most agricultural runoff is intercepted by the buffers in a filterable manner. A major concern is that drainage enhancements and other landscape alterations (e.g., terraces, grassed waterways, field and road drainage ditches, tiles) may re-direct large portions of runoff flow around riparian buffers and to streams. Our review of research literature has not yielded any previous assessments of how large this problem might be.

Our objective was to assess the hydrologic routing of surface runoff on four farms in southeastern Nebraska that contain extensive riparian buffers in order to (i) estimate the proportion of farm runoff that is intercepted by the riparian buffers, and (ii) assess the relative need for considering other practices to control pollutant runoff from farms.

METHODS

Study Sites

Four farms were studied that represent the range of farm landscapes typical of southeastern Nebraska, from rolling hills to loess plains (Table 1). Field areas produce primarily corn, grain sorghum, and soybeans covering a total of 469 ha (1159 ac). Three of the farms are dryland and one is irrigated. Soils are typically silt loam to silty clay loam. Slopes generally range from nearly level to about 10%. Perennial streams in this region typically have low base flow and produce flashy hydrographs during summer thunderstorms, indicating that surface runoff is a dominant pathway of runoff from fields to streams.

Streams run though each of these four farms, totaling approximately 6.0 km in length (Table 1). The streams range from

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ephemeral to third-order perennial and include both channelized and relatively unmodified reaches. Riparian buffers extend the full length of these streams. They range in width (distance from field margin to stream bank) from 5 to 61 m and are typically vegetated with mixtures of trees and grass. On one farm (Hamilton), the riparian areas are vegetated entirely by grasses and are used as equipment turn lanes. None of the riparian buffer areas on these farms were intentionally designed for filtering runoff.

Table 1. Landscape characteristics of four case study farms in southeastern Nebraska.

Landscape	Characteristic	Rogers	Burr	ARDC	Hamilton
General	County	Lancaster	Otoe	Saunders	Hamilton
	Topographic region	rolling hills	rolling hills	plains	plains
	Farming system	dryland grains	dryland grains	dryland grains	irrigated grains
Field runoff areas	Total area of crop fields (ha)	99	12	178	180
	No. of contributing areas identified	44	24	114	78
	Average slope (%)	4.4	3.8	2.0	2.3
	Soil texture	silt loam	silty clay loam	silty clay loam	silt loam
Riparian buffer	Total length of stream (m)	1680*	1100	1940	1260
	Vegetation	trees & grass	trees & grass	trees & grass	grass
	Avg buffer width, range (m)	35, 18-61	12, 5-40	10, 7-15	9, 9
Stream	Stream type	2nd and 3rd order	2nd order	ephemeral	ephemeral

* does not include length of channel in oxbows of sinuous reaches at Rogers farm.

Runoff Areas and Pathways

Visual assessments were made of field areas contributing to runoff and the routing of surface runoff from each one to either the stream or otherwise off the farm property. Contributing areas and runoff pathways were delineated by walking the margins of fields and identifying boundaries of each contributing area that drained to a common outlet path, including riparian buffers, grassed waterways, underground outlets, ditches, and road drainageways. The size of each field contributing area and corresponding runoff pathway was estimated. Among these farms, we identified 260 field runoff areas (Table 1).

The boundaries of field contributing areas were interpreted based on topography, microrelief, and patterns of erosion and deposition of soil and crop debris. Attention was also given to crop row direction, berms, conservation terraces, and other land shaping features that can influence runoff flow direction (Souchere et al., 1998). On topography with low slope, a surveying rod and level were used in conjunction with visual observations to help indicate direction of runoff flow. A USGS 7.5 minute topographic map with a 10 foot contour interval provided a scaled base map with reference features for each farm. Contributing area boundaries were marked on enlarged copies of the USGS maps. The size of each field contributing area was measured using a planimeter on boundaries recorded on the base map.

Corresponding runoff pathways were also located on the map and described. Area of riparian buffer was estimated by the length of field margin adjacent to the buffer times the average distance from that field margin to the stream bank. Along sinuous streams, several measurements were used to compute an average distance to the stream bank. Riparian buffer area represents that area which runoff from the field would contact if there was uniformly dispersed flow across the entire field margin through the buffer to the stream. The area of each grassed waterway and grassed road drainageway, that may also have some filtering capability, was calculated from length and width estimates made in the field.

Pollutant Trapping

Filtering capabilities of riparian buffers and other vegetated pathways on these farms was estimated using the buffer-area ratio relationships developed in Dosskey et al. (2002). Briefly, these relationships derive sediment trapping efficiency from the ratio of vegetated buffer area to contributing field area. A different relationship was developed for each farm based on riparian field and buffer conditions. While grassed waterways can also function as buffers, we expect that these developed relationships will somewhat overestimate the sediment trapping efficiency of grassed waterways on these farms because of steeper slopes and submergence of vegetation in waterways. For this reason, we used them only to make general observations.

RESULTS

Among the four farms, riparian buffers intercept surface runoff from 92, 61, 15, and 12% of the total area of crop land (Table 2). The remaining crop land either drains through conveyance pathways, including grassed waterways, roadside drainageways, and subsurface drain pipes, or settles into low areas having no apparent outlet from the farm property. The two farms on flatter landscapes (ARDC and Hamilton) contain substantial area that does not drain off the farm. Included in this latter category is a large proportion of land that drains to adjacent public road drainageways that act as retention basins for lack of outlets. When considering only crop land that drains off the farm, riparian buffers intercept almost all runoff from two of the four farms (Burr and Hamilton). On the other two farms (Rogers and ARDC), the majority of crop land drains off the farm through other pathways.

Table 2. Proportion of cropped area contributing surface runoff by type of hydrologic route on four farms in southeastern Nebraska.

Hydrologic Route	Rogers	Burr	ARDC	Hamilton
Drains to stream through riparian buffer (%)	15	92	12	61
Drains off the farm through other pathways (%)*	85	2	34	0
No apparent surface outlet from the farm (%)**	0	6	54	39

* Other pathways include grassed waterways, subsurface pipes, and roadside drainageways.
** Includes cropped area that drains into roadside drainage areas adjacent to the farm that act as retention basins with no apparent outlets.

Riparian buffers present a much greater area for filtration of runoff from these farms, relative to contributing cropped area, than non-riparian waterways (Table 3). For three farms where runoff is routed through both types of paths, ratios of buffer area to cropped area for riparian buffers are 0.48, 0.16, and 0.07, but only 0.03, 0.06, and 0.02, respectively, for non-riparian waterways. Based on the relationships developed by Dosskey et al. (2002), the non-riparian waterways on these farms are substantially less capable of trapping sediment and sediment-borne pollutants than the riparian buffers, particularly if the likely overestimation of waterway performance discussed earlier is taken into account.

Table 3. Buffer-area ratios and estimated sediment trapping efficiency of riparian buffers and non-riparian waterways on four farms in southeastern Nebraska.

	Rogers		Burr		ARDC		Hamilton	
Characteristic	Riparian buffer	Waterway	Riparian buffer	Waterway	Riparian buffer	Waterway	Riparian buffer	Waterway
Total cropped area draining off the farm (ha)	15	84	11	0.2	22	60	109	0
Total vegetative filter area (ha)	7.2	2.1	1.7	0.01	1.5	1.0	1.7	--
Ratio of buffer area to cropped area (ha/ha)	0.48	0.03	0.16	0.06	0.07	0.02	0.02	--
Estimated sediment trapping efficiency (%)*	~100	54	83	55	70	37	44	--

* Sediment trapping efficiencies are estimated using equations developed for riparian areas on these farms in Dosskey et al. (2002) that are based on the ratio of buffer area to cropped contributing area.

DISCUSSION

Installation of riparian buffers may have limited impact stream water quality in some situations. This study of four farms in southeastern Nebraska indicates that large portions of runoff from some farms is not routed through riparian buffer zones. Alternatively, surface runoff is conveyed through grassed waterways, road drainageways, and subsurface pipes that have much less capability to filter pollutants from runoff than the riparian buffers.

Accurate prediction of the proportion of surface runoff that is typically intercepted by riparian buffers also appears problematic. There was extremely high variation among our four study farms in the proportion of surface runoff that is routed through riparian buffer zones. Land shaping and drainage improvements often re-routed runoff from expected pathways based on our topographic maps. The modifications were extensive in some cases, as on Rogers farm. Under these circumstances, the use of routing assessment techniques based on topographic maps alone (e.g., Bren 1998) would have limited value. On-farm assessment of hydrologic routing was required to identify actual pathways of surface runoff on our study farms.

Farms on flatter landscapes may be less of a concern. Flatter crop land would tend to produced smaller pollutant loads in runoff and a substantial proportion of cropped area may not drain beyond the farm boundaries, instead, settling into low areas that act as retention basins. The ARDC and Hamilton farms in this study are examples of this pattern.

On rolling landscapes, however, runoff is commonly routed through stabilized conveyance pathways such as grassed waterways and subsurface pipes in order to control erosion. Conveyance pathways are generally not designed to function as pollutant traps. On such landscapes, further pollutant runoff reduction is likely to come mainly from implementation of in-field practices that retain potential pollutants in the field, i.e., source control. For example, on the rolling landscape of the Rogers farm, source control measures including conservation terraces, conservation terraces with storage basins, grass hedges, and no-till have been implemented to reduce sediment loads that enter grassed waterways and subsurface pipes. On Rogers farm sink control has also been enhanced by routing most of the grassed waterways into a common 0.25 ha settling basin, before emptying into the stream.

Without a major change in hydrologic routing of runoff from some farms, riparian buffers may be capable of intercepting only a small fraction of the surface runoff load. Source control practices in addition to riparian buffers are necessary to assure substantial reduction in pollutant runoff loads from these farms.

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