Title: Stacked conservation practices reduce nitrogen loss: A paired watershed study

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Supplementary information

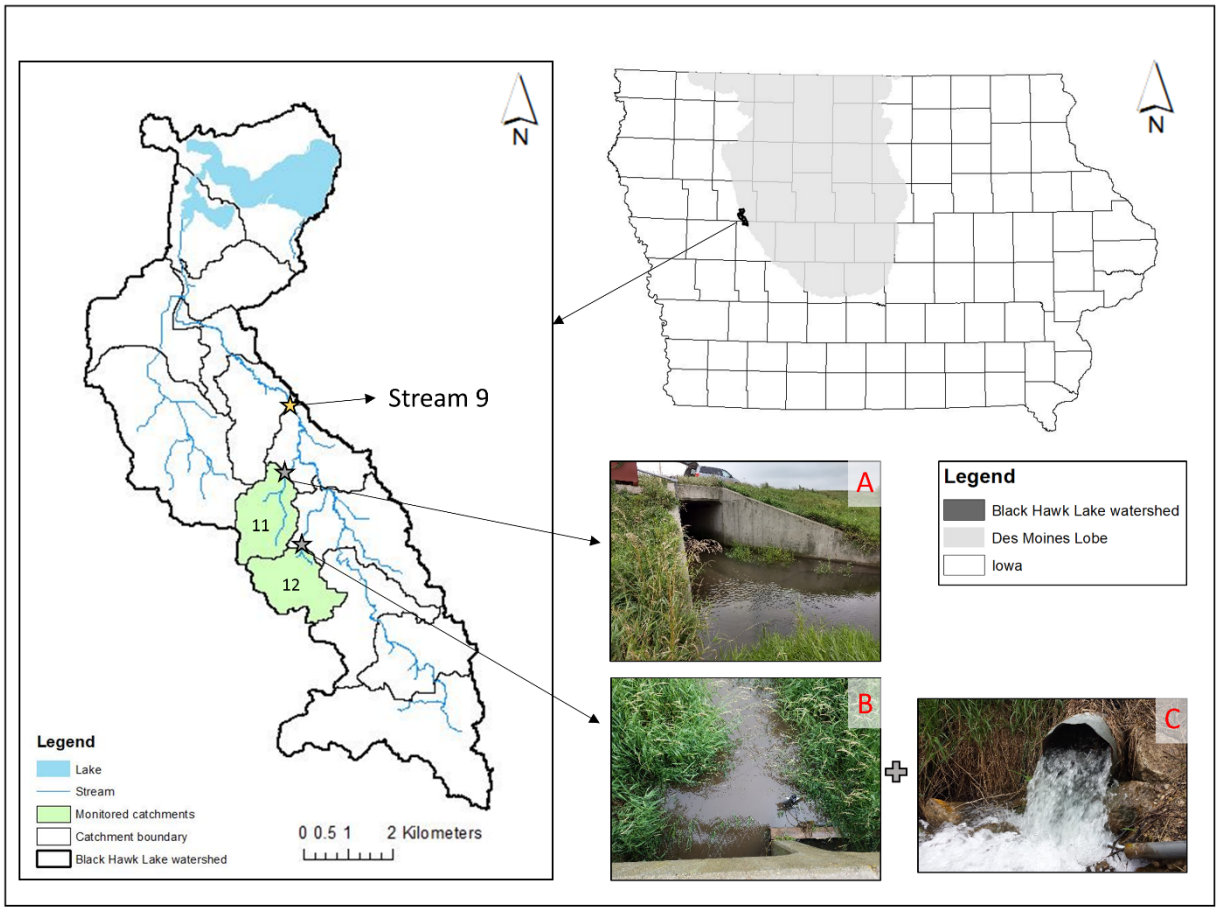


Fig. S1: Location of the Black Hawk Lake watershed within the Des Moines Lobe landform region and the state of Iowa. The locations of the two monitored catchments are shown with gray star symbols in the left figure. An additional downstream location named "Stream 9", monitored by the Iowa Department of Natural Resources, also is shown with a yellow star symbol. Pictures of the monitoring locations are shown in the bottom right of the figure: (A) surface monitoring site at Low-BMP 11; and (B) surface monitoring site and (C) tile monitoring site at High-BMP 12.

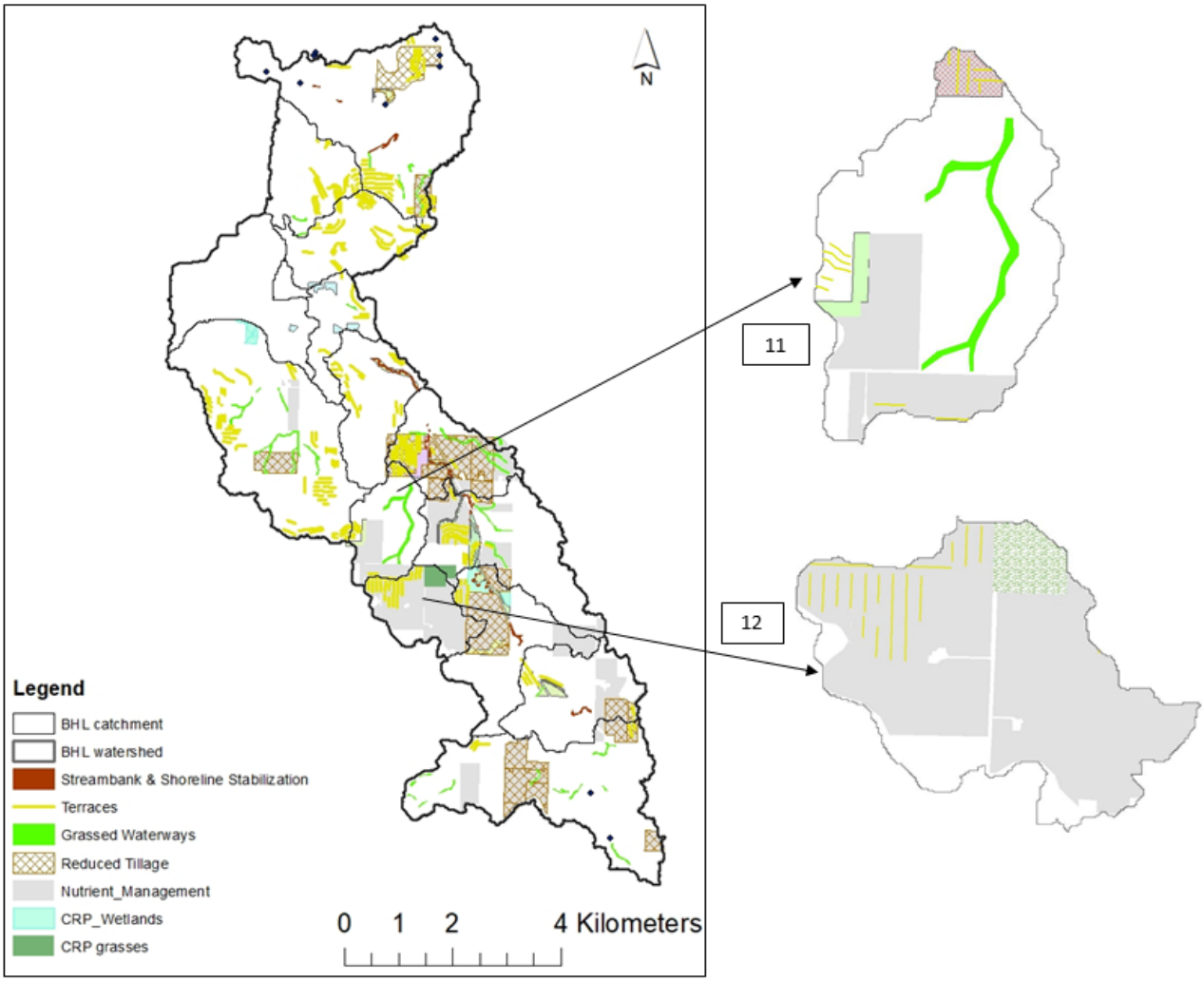


Fig. S2: Best management practices in the Low-BMP 11 and High-BMP 12 catchments in the Black Hawk Lake Watershed.

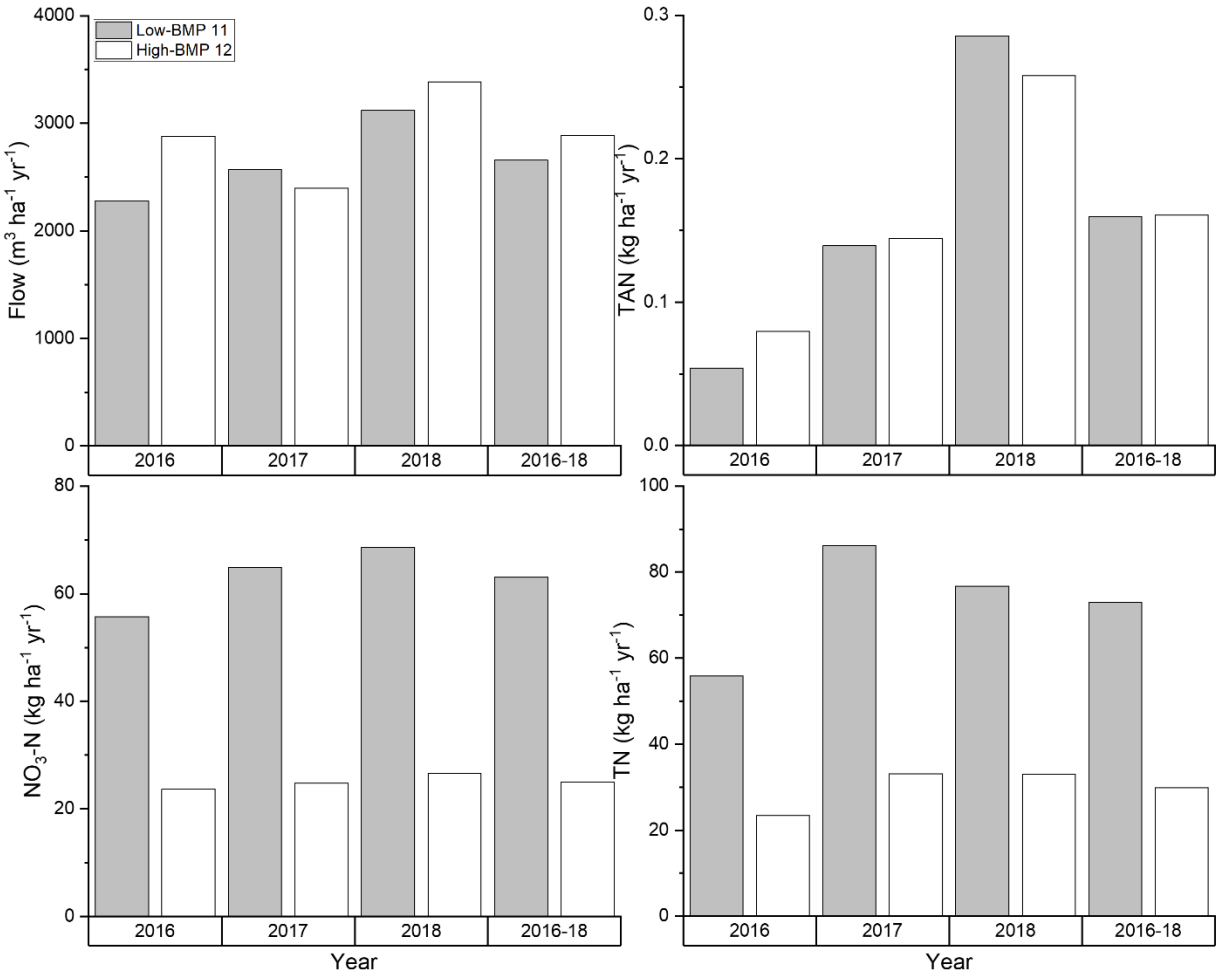


Fig. S3: Annual flow, total ammonia nitrogen (TAN), nitrate+nitrite (NO_3-N), and total nitrogen (TN) load per unit area at Low-BMP 11 and High-BMP 12. Annual flow and loads were not calculated for 2015 because monitoring equipment at site T12 was not installed until June 2015.

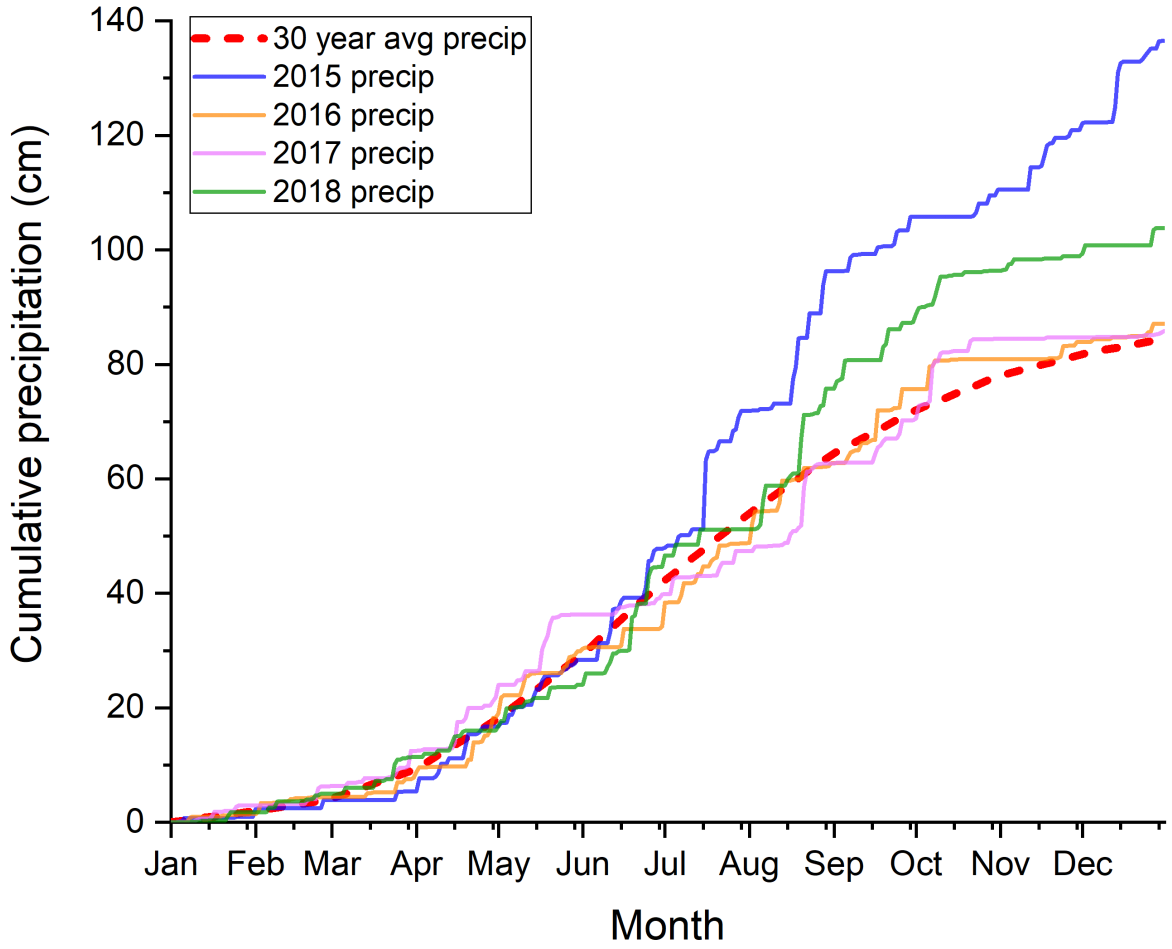
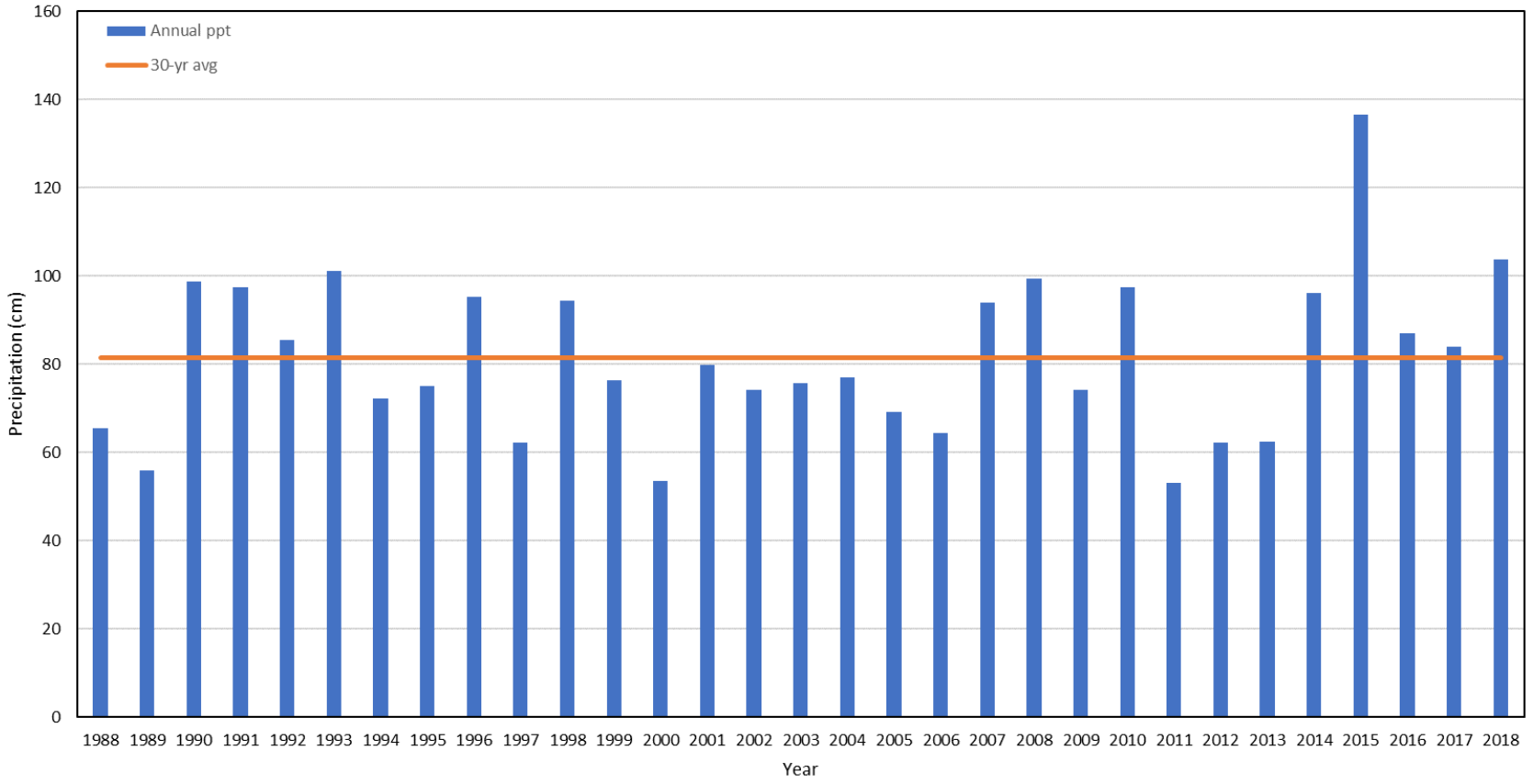


Fig. S4: Annual cumulative precipitation from January 1st to December 31st for the Black Hawk Lake watershed . Precipitation data were obtained from PRISM Data Explorer (PRISM Climate Group, 2019) using the following coordinates: latitude 42.2422 (N), longitude -95.0381 (W).


Annual ppt
30-yr avg
Precipitation (cm)
160
140
120
100
80
60
40
20
0
1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
Year

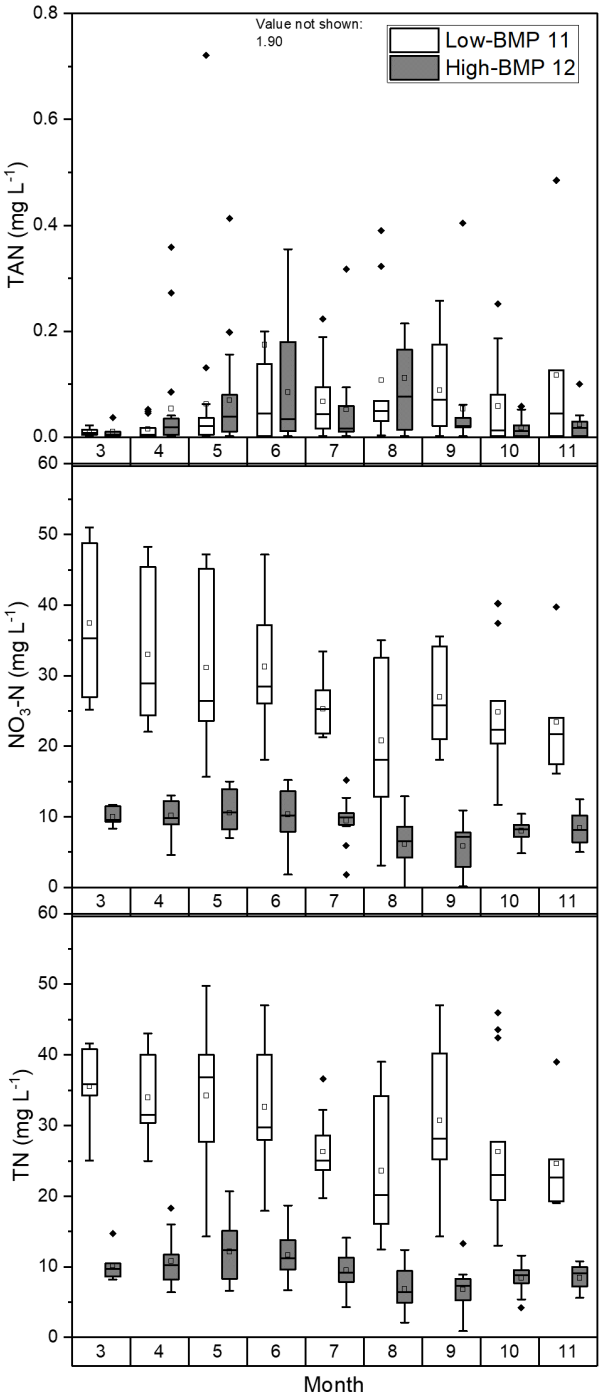


Fig. S6: 2015-2018 average monthly total ammonia nitrogen (TAN), nitrate+nitrite (NO_3-N), and total nitrogen (TN) concentrations at Low-BMP 11 and High-BMP 12. An extremely high TAN concentration (1.90 mg L^{-1}) observed at Low-BMP 11 on June 16, 2015 is not shown in Fig. S6. The upper, center, and lower lines of each box plot represent the upper quantile (Q3), median (Q2), and lower quantile (Q1), respectively. The top and bottom whiskers represent the 1.5Q3 and 1.5Q1, respectively. The square symbol (□) in each box plot represents the mean.

Table S1: Landscape and soil properties of the catchments of Low-BMP 11, High-BMP 12, and Stream 9.

Property	**Low-BMP 11**	**High-BMP 12**	**Stream 9 catchment**
Catchment area (ha)	229.4	221.2	2654.3
Row crop area (%)	94%	74%	86%
Average slope (%)	3.2	3.0	3.1
Major catchment soil types (%):			
Canisteo clay loam	3.7	14.6	6.5
Clarion loam	47.2	47.9	43.5
Coland clay loam	2.5	1.4	2.3
Nicollet loam	21.4	18.8	15.9
Webster clay loam	17.6	11.7	16.6
Soils with hydrologic soil groups C&D	25.1	32.5	31.8

Table S2: p-values for Wilcoxon Rank Sum test of significant differences of total ammonia nitrogen (TAN), nitrate+nitrite (NO_3-N), and total nitrogen (TN) concentrations between Low-BMP 11 and High-BMP 12 in 2015-18, and for the respective years.

	TAN	**NO_3-N**	**TN**
2015-18	0.8379	0.0001	0.0001
2015	0.9518	0.0001	0.0001
2016	0.9925	0.0001	0.0001
2017	0.6538	0.0001	0.0001
2018	0.5836	0.0001	0.0001

Table S3: Median total ammonia nitrogen (TAN), nitrate+nitrite (NO_3-N), and total nitrogen (TN) concentrations by catchments and years.

Catchment	Year	n	TAN (mg/L)	NO_3-N (mg/L)	TN (mg/L)
Low-BMP 11	2015-18	108	0.023	26.0	28.7
	2015	38	0.028	39.9	40.0
	2016	21	0.019	23.1	23.2
	2017	21	0.015	23.7	31.0
	2018	28	0.059	24.7	25.3
High-BMP 12	2015-18	129	0.020	8.8	9.2
	2015	45	0.023	11.0	10.2
	2016	31	0.017	8.6	8.1
	2017	23	0.022	9.6	10.5
	2018	30	0.020	8.2	8.9

Table S4: Water yield and drainage ratio of Low-BMP 11 and High-BMP 12 catchments. The water yield of High-BMP 12 was not calculated for 2015 because the flow sensor was not installed until June 2015.

Year	2015	2016	2017	2018	2016 -18 avg
Catchment	**Water yield (cm)**				
Low-BMP 11	47.4	22.8	25.7	31.2	26.6
High-BMP 12		28.8	24.0	33.8	28.9
Catchment	**Outflow ratio (%)**				
Low-BMP 11	35%	26%	30%	30%	29%
High-BMP 12		33%	28%	33%	31%

Table S5: p-values for Kendall Tau trend analysis of total ammonia nitrogen (TAN), nitrate+nitrite (NO_3-N), and total nitrogen (TN) concentrations for catchments Low-BMP 11 and High-BMP 12 from 2015 to 2018.

	TAN	NO_3-N	TN
Low-BMP 11	0.5682	0.0001	0.0001
High-BMP 12	0.3765	0.0006	0.1750

Table S6: Median total ammonia nitrogen (TAN), nitrate+nitrite (NO_3-N), and total nitrogen (TN) concentrations by seasons. (Note: n = number of samples)

Catchment	**Seasons**	**n**	**TAN (mg/L)**	**NO_3-N (mg/L)**	**TN (mg/L)**
Low-BMP 11	Overall	108	0.023	26.0	28.7
	Pre-planting	20	0.005	28.9	34.0
	Early-growing	37	0.025	27.7	30.7
	Late-growing	22	0.056	24.8	24.9
	Harvest	29	0.030	23.2	25.2
High-BMP 12	Overall	129	0.020	8.8	9.2
	Pre-planting	23	0.009	9.8	10.2
	Early-growing	37	0.039	9.9	11.2
	Late-growing	31	0.022	8.2	8.0
	Harvest	38	0.018	7.8	8.2

Table S7: p-values for Linear Mixed Model Analysis of total ammonia nitrogen (TAN), nitrate+nitrite (NO_3-N), and total nitrogen (TN) concentrations between seasons.

Low-BMP 11	**TAN**	**NO_3-N**	**TN**
Overall	0.3501	0.0059	0.0002
Pre vs early	0.0059	0.4982	0.3709
Early vs late	0.2083	0.0199	0.0024
Late vs harvest	0.2553	0.7537	0.6076
Pre vs harvest	0.0307	0.0053	0.0193
High-BMP 12	**TAN**	**NO_3-N**	**TN**
Overall	0.0200	0.0001	0.0001
Pre vs early	0.0086	0.8136	0.4937
Early vs late	0.9705	0.0044	0.0001
Late vs harvest	0.0122	0.8140	1.0000
Pre vs harvest	0.6636	0.0001	0.0002