Souris River Project – Progress Update December 2015

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Executive Summary

Background

Effects of flooding on rangeland productivity are a significant concern in the Souris River Valley (SRV). Lowland flooding is a common annual event from spring snowmelt in North Dakota. The SRV depends on the annual spring snowmelt to provide water for hay and crop production. However, flooding of high frequency and long duration has adversely affected crop production of over 40,000 acres in the SRV located in northern McHenry County. Floods may cause alteration in soil properties and fertility, which can further impact plant growth.

Objectives

This study attempted to identify the major factors that are limiting the soil quality and plant production in the SRV area and to recommend critical solutions for further land management and recovery. *The objectives of this study were to:*

- Characterize the spatial variability of various soil properties in the SRV rangelands affected by annual prolonged flooding
- Investigate the present plant species and seed bank in the soils after years of flood impacts.
- Perform an economic analysis of the impact floods have caused on rangeland in the SRV

Experimental approaches

The approach was to evaluate the existing conditions of numerous locations along the Souris River Valley and along transects away from the river at each location. This approach produced evaluations along a gradient of flooding depths and durations. The data analysis included multivariate statistics to cluster locations with similar characteristics and separate locations with divergent characteristics using soil, plant, and seedbank data simultaneously. This approach was taken since controlled flood experiments are not feasible in the study location due to 1) the flooding potential and inability to adequately contain/prevent flooding within experimental plots and 2) the duration needed to subsequently evaluate and track rangeland recovery over time (e.g., multiple years).

Preliminary results

- No clustering of locations that correlated to distance along the river, distance from river, elevation, and a categorical index of observed land wetness.
- Multiple clusters of locations were separated as differing and appeared to be more a function of post-flood land management rather than impacts of the flooding itself.
- Both invasive and native species existed on the rangelands and in their seedbanks.
- The most dominant species are Kentucky bluegrass, catnip, field pennycress, Atriplex spicata, and quack grass in descending order.

Application of results and future work

Application of the results will be made in ongoing and future direction of work and expenditure of funds which will include collaborating with NDSU faculty in the geosciences and economics to 1) overlay the soil, seedbank, and plant data with digital elevation and flood duration maps and 2) perform an economic analysis of flood water depth and duration impacts on rangelands.

Detailed report for the study of grasslands impacted by Souris River flooding

Background

Lowland flooding is a common annual event from spring snowmelt in North Dakota. The Souris River Valley (SRV) depends on the annual spring snowmelt to provide water for hay and crop production. However, flooding of high frequency and long duration has adversely affected crop production of over 40,000 acres in the SRV area located in northern McHenry County, ND. An estimated loss to the stakeholders is approximately $5,000,000 from the 2011 flooding, when floodwater remained from the early spring through late fall. As a result of the duration and extent of the 2011 flooding, native grass and vegetation did not recover in 2012. Lowlands along the river are relied upon for forage production, which have been invaded by quack grass, foxtail barley, and annual/perennial weed species (predominantly red goosefoot- *Chenopodium rebrum L.*). As a result, forage quality and quantity has dramatically decreased in the rangelands. Therefore, there is a need to understand the effects that floodwater has had on the soil properties and crop production in this area for recommendations of better management and restoration practices.

Effects of flooding on soil quality are a significant concern in agricultural lands. Floods may cause alteration in soil properties and fertility, which can further impact plant growth. Floods are considered as inputs of nutrients, organic matter, and fine particles to soils; however, various soil physical, chemical, and biological properties can alter under periodic flooding conditions. For example, the lack of oxygen prevents oxidation, decreases the reduction potential, and limits soil microbial activities (Saint-Laurent et al., 2014). The reduced soil environment can alter forms of Mn, Fe, S, and other metals by changing their solubility and redox reactions. Macronutrients can be removed from surface soils through denitrification and leaching (i.e., nitrogen) and increased surface runoff (i.e., phosphorus). Moreover, frequency, duration, and periodicity of floods are the major factors that influence the nutrient distribution and ecosystem dynamics. Additionally, influence of flooding on soil properties depends on the distance to the main channel.

Aboveground rangeland and belowground soil problems occurred during years where floodwaters occupied the lands for most of the growing season in the SRV. These problems include changes in soil properties and invasive plant species that invade native hay lands and croplands that can have a lasting effect. Herein, the objectives of this study were to characterize the spatial variability of various soil properties in the SRV rangelands affected by annual prolonged flooding, and to investigate the present plant species and seed bank in the soils after years of flood impacts. This study attempted to identify the major factors that are limiting the soil quality and plant production in the SRV area and to recommend critical solutions for further land management and recovery.

Research Approach

Site description

The Souris River (also known as the Mouse River) has its headwaters located approximately 50 miles southwest of Regina, Saskatchewan, Canada. The Souris River flows for 435 miles, crossing into the United States near Sherwood, North Dakota. From here, the river runs through or near the communities of Mouse River Park, Burlington, Minot, Sawyer, Velva, Towner, and Westhope. After Westhope, the river continues north until it reaches the

Assiniboine River in Canada, a tributary to the Red River. The major soil series in this region is the Ludden silty clay (fine, smectitic, frigid Typic Endoaquerts). The Souris River has a flooding history recorded since 1881. The record shows that it has had severe flooding events in the years of 1904, 1969, 1976, and 2011. With a crest of 1,562 feet above sea level on June 26, the flood of 2011 is the highest recorded in Minot's history, compared to the second highest record at 1,556 feet in 1976. In 2001, the river flooded 4,115 homes in Ward County, causing more than 11,000 people to evacuate (Minot Recovery Information).

Research Design

Controlled flood experiments are not feasible in the study location due to 1) the flooding potential and inability to adequately contain/prevent flooding within experimental plots and 2) the duration needed to subsequently evaluate and track rangeland recovery over time (e.g., multiple years). Therefore, an evaluation of the existing conditions of numerous locations along the Souris River Valley and along transects away from the river (i.e., a gradient of flooding depths and durations) was performed and data analyzed using multivariate statistics to cluster locations with similar characteristics and separate locations with divergent characteristics using all the soil, plant, and seedbank data simultaneously.

Sampling locations cover approximately 26 miles from the north (48°29'09"N -100°25'28"W) to the south (48°10'35"N -100°37'41"W) along the river (Image 1). These locations ideally represent areas affected by different flooding extent, duration, and management treatments after flooding. For example, location 1 was sprayed with 2, 4-D by the landowner after floodwater receded in 2011, but location 2 was not treated with herbicides. At location 5, a cover crop treatment was applied in 2012, and a slight vegetation difference was noticeable compared to no cover crop. At location 6, two sites were separated by a narrow ditch. One site was on higher ground than the other, thus the floodwater from 2011 receded much faster. The plant species were noticed to be different between the two sites.

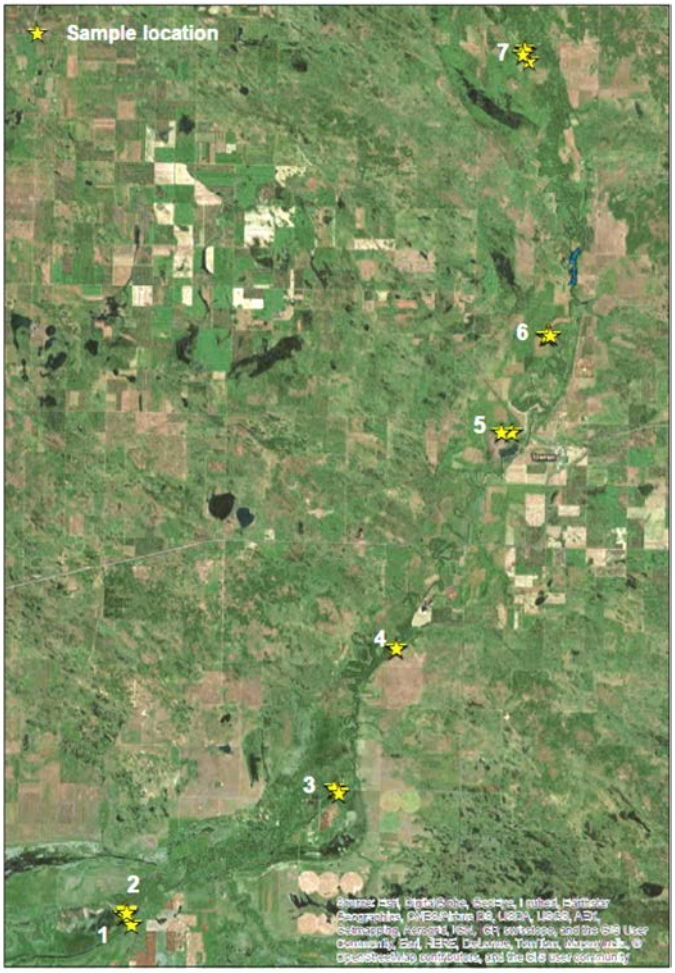


Image 1. Sample transect locations in the Souris River Valley.

Soil Sampling and Analysis

Soil sampling was conducted during August 4-7th, 2014, when the monitored gage height of the Souris River above Minot was 6 feet (USGS National Water Information System). At each sample location, 2 to 4 transects parallel to the river were selected to represent different distance to the river. On each transect, 2 to 4 1 m×1 m sites were selected for soil sampling and plant identification, with an interval of 15-20 m between two sites. Composite soil samples were taken from three depths at each 1 m^2 site, i.e. 0-6 inch, 6-12 inch, and 12-24 inch. Another surface soil sample (i.e. 0-6 inch) was collected individually for greenhouse evaluations of the viable seedbank.

Air dried and sieved soil samples were sent to the Soil Testing Lab at NDSU, Fargo, ND for chemical analysis. All soil analysis procedures followed the Recommended Chemical Soil Test Procedures for the North Central Region (RCSTP). Soil analyses included: 1:1 pH, 1:1 electrical conductivity, cation exchange capacity, total carbon and nitrogen, nitrate, ammonium, phosphorus, sulfate, potassium, calcium, sodium, iron, manganese, sand, silt, and clay.

Plant identification and Seed Bank Germination

At each sampling site, plants were classified using cover class method in each 1 m^2 quadrat. Both above ground plant cover and ground cover were recorded. Cover classes were estimated as percentages. The observed plant classes include grass, forbs, rushes, sedge, and cattail.

A 1000 cm^3 soil sample (i.e. representative of each sample quadrat) were taken from the topsoil, mixed with greenhouse soil, and spread on permeable plastic trays in an unheated greenhouse located in the Agricultural Experiment Station Research Greenhouse Complex at NDSU campus, Fargo, ND. Seedling emergence was monitored, seedlings identified and counted until no more germination occurred.

Statistical Analysis

Data from the soil analysis, vegetation and ground cover, and soil seed bank were combined and analyzed using multivariate techniques. Cluster analysis formally grouped locations with similar characteristics among all variables.

Current Findings

Soil texture ranged from 13% to 92% as clay, 1.3% to 63% as silt, and 1.3% to 78% as sand. Most of the measured soil samples contain high percentage of clay, except that soils from Location 4 and 7 have higher sand compared with other locations. The soil pH ranges from 6.4 to 8.9 for all samples, which shows a slight acidic to alkaline condition. Soil CEC values are relatively high, i.e., 17.8 to 58.2 Meq/100g (0-15 cm), 12.7 to 57.6 Meq/100g (15-30 cm), and 8.2 to 62.4 Meq/100g (30-60 cm) (Table 1). Soil EC ranged from 0.1 to 5.6 across all locations. Soil TOC content ranged from 1.1% to 7.8% in the surface soil (0-15 cm). The soils are rich in P and K, but the total content of N is relatively low.

The following properties have the highest variation (CV) among the sampling locations regardless of depths, nitrate, EC, Na, CCE, and sand. The variation can be a result of impacts of flood duration in the river valley. For instance, sampling site 7 was impacted by the 2011

flooding most severely, and the soil consists of high percentage of sand but low in clay. The surface soil has lower K, pH, and EC, but higher Fe, Ca, and Na compared with other locations.

Identified plant cover including species i.e., forbs, grass, cattails, sedge, and rushes, from which forbs and grass are the dominant plants in most of the investigated quadrats. Cattails are found at sampling location 1, 5, 6, and 7, sedges are found only at location 1 and 2, and rushes are found at location 1, 4 and 5. These locations still had overlying water during sampling process. At all sampling transects, the ground is covered by litter mostly, with some moss at the moist sites and bare ground at some of the drier sites.

The seedbank in the sampled surface soils was measured in greenhouse (Table 5). The identified species include leafy spurge, field pennycress, redroot pigweed, Kentucky bluegrass, quack grass, yellow foxtail, atriplex spicata, catnip, yellow sweet clover, Canada thistle, and absinthe wormwood. Both invasive and native species are observed. The most dominant species are Kentucky bluegrass found in 43 out of the 49 soil samples, catnip in 33 samples, field pennycress in 18 samples, atriplex spicata in 19 samples, and quack grass in 11 samples.

The multivariate analysis showed no clustering of locations that correlated to distance along the river, distance from river, elevation, and a categorical index of observed land wetness. However, multiple clusters of locations were separated as differing and appeared to be more a function of post-flood land management rather than impacts of the flooding itself.

Future Direction

Ongoing work will include collaborating with NDSU faculty in the geosciences and economics to 1) overlay the soil, seedbank, and plant data with digital elevation and flood duration maps and 2) perform an economic analysis of flood water depth and duration impacts on rangelands.

Sources

1. Minot Recovery Information: http://www.minotrecoveryinfo.com/facts/brief-history-of-flooding/
2. USGS National Water Information System: http://nwis.waterdata.usgs.gov/nd/nwis/uv/?cb_00060=on&cb_00065=on&format=gif_default&site_no=05117500&period=&begin_date=2014-08-04&end_date=2014-08-07
3. Recommended Chemical Soil Test Procedures for the North Central Region. North Central Regional Research Publication No.221 (Revised). Missouri Agricultural Experiment Station SB 1001.
4. Vendrell, P.F. and Zupancic J., Determination of soil nitrate by transnitration of salicylic acid. 1990. Soil Science and Plant Analysis. 21(13-16), 1705-1713.

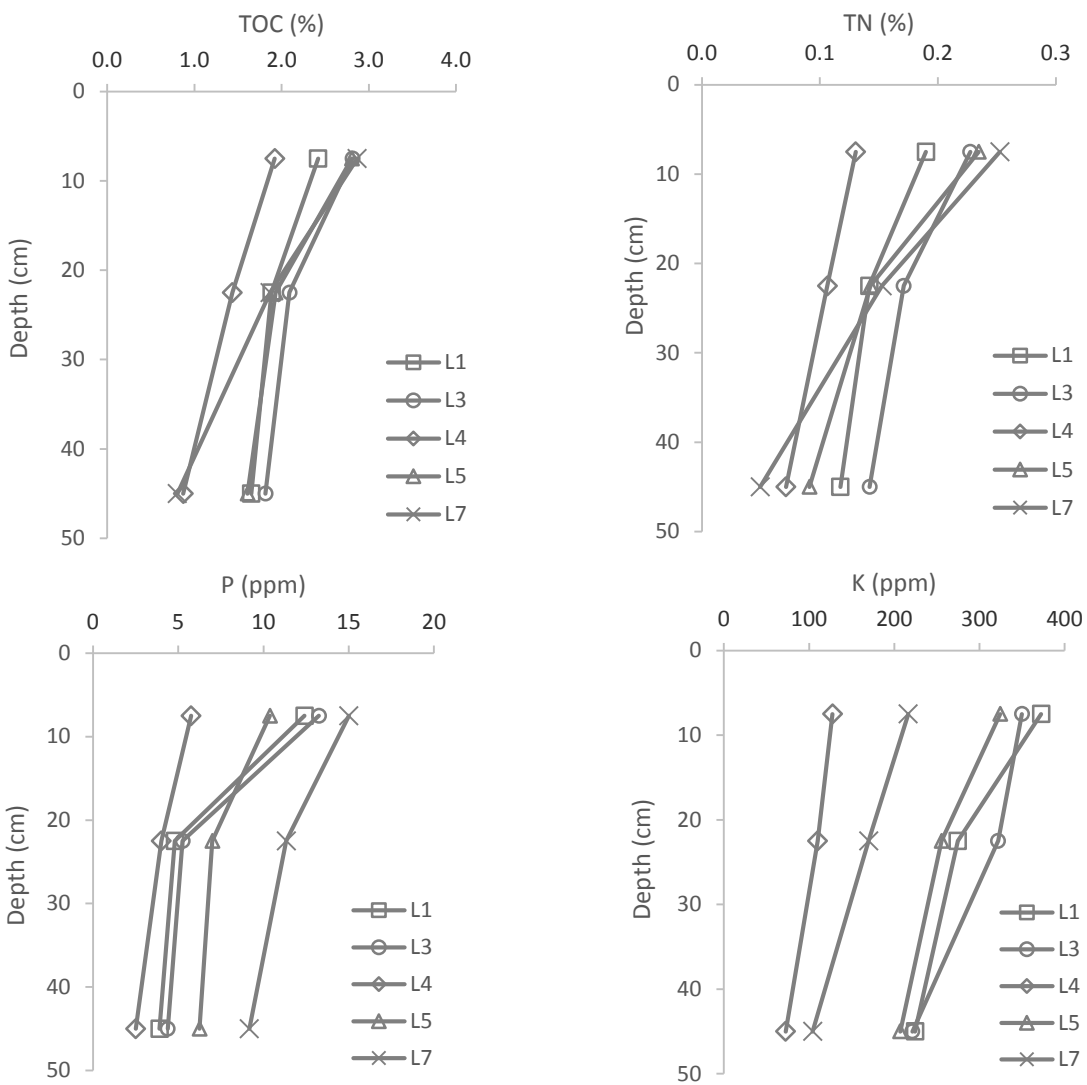
Appendix 1. Summary of statistical analysis for measured soil properties.

	Unit	Mean	Maximum	Minimum	Median	Standard	Coefficient of	Kurtosis
0-15 cm (n = 49)								
NO_3-N	(ppm)	2.18	16.50	0.50	1.50	5.35	1.09	15.29
P	(ppm)	11.41	26.00	4.00	10.00	5.73	0.50	0.43
K	(ppm)	292.3	425.0	35.00	315.0	99.9	0.34	0.29
pH		7.60	8.50	6.50	7.70	0.51	0.07	-0.17
EC	(mmhos/cm)	1.07	3.50	0.15	0.78	0.90	0.84	1.58
SO_4-S	(lbs/Acre)	156.5	634.0	11.00	155.0	123.1	0.79	3.12
Fe	(ppm)	63.09	170.0	17.50	50.00	37.89	0.60	1.21
Mn	(ppm)	19.89	52.50	7.50	16.10	11.05	0.56	1.01
NH_4-N	(ppm)	6.72	9.30	3.10	6.50	1.32	0.20	0.21
Ca	(ppm)	4841	6300	2900	4840	605.3	0.13	3.02
Na	(ppm)	373.9	4650	12	98	694.9	1.86	30.74
CEC	(Meq/100g)	34.02	58.20	17.80	33.60	6.97	0.20	2.79
Total N	(%)	0.23	0.65	0.06	0.21	0.11	0.46	5.00
Total C	(%)	3.00	10.00	1.10	2.70	1.52	0.51	14.08
TOC	(%)	2.81	7.83	1.09	2.58	1.19	0.42	8.25
CCE	(%)	1.53	18.50	0.00	0.20	3.71	2.42	16.63
Bulk density	(g/cm3)	0.96	1.57	0.49	0.94	0.23	0.24	0.13
Sand	(%)	16.90	77.71	1.31	5.86	22.43	1.33	1.19
Silt	(%)	24.80	63.25	1.29	22.80	15.95	0.64	-0.43
Clay	(%)	58.30	91.58	12.85	61.03	20.42	0.35	-0.60
15-30 cm (n = 36)								
NO_3-N	(lbs/Acre)	2.89	19.00	1.00	2.00	3.35	1.16	15.22
P	(ppm)	6.39	25.00	2.00	5.00	4.44	0.69	7.78
K	(ppm)	245.1	395.0	65.00	260.0	87.97	0.36	-0.66
pH		7.83	8.70	6.40	7.95	0.50	0.06	2.40
EC	(mmhos/cm)	1.22	4.70	0.13	0.72	1.21	0.99	2.05
SO_4-S	(lbs/Acre)	148.0	416.0	11.00	106.5	121.8	0.82	-1.10
Fe	(ppm)	40.83	132.0	12.50	31.75	27.82	0.68	2.95
Mn	(ppm)	13.91	23.00	7.60	12.00	4.74	0.34	-1.00
NH_4-N	(ppm)	5.60	8.50	2.70	5.65	1.02	0.18	2.82
Ca	(ppm)	5042	6780	2420	5100	751.3	0.15	3.80
Na	(ppm)	448.7	1700	10.00	207.0	485.6	1.08	0.03
CEC	(Meq/100g)	35.42	57.60	12.70	35.90	9.07	0.26	0.55
Total-N	(%)	0.15	0.24	0.04	0.16	0.04	0.26	1.34
Total-C	(%)	2.03	2.70	0.90	2.00	0.32	0.16	4.28
TOC	(%)	1.89	2.66	0.80	1.95	0.37	0.19	2.96
CCE	(%)	1.21	15.80	0.00	0.55	2.65	2.18	28.13
Sand	(%)	19.20	76.53	1.13	4.23	24.93	1.30	-0.05
Silt	(%)	21.15	59.44	0.20	21.27	12.54	0.59	1.19
Clay	(%)	59.65	94.37	13.79	66.61	22.03	0.37	-0.78
30-60 cm (n = 37)								
NO_3-N	(lbs/Acre)	5.05	26.00	1.00	4.00	5.07	1.00	9.04
P	(ppm)	5.35	13.00	2.00	4.00	3.79	0.71	-0.48
K	(ppm)	185.5	290.0	35.00	205.0	68.33	0.37	0.05
pH		8.08	8.90	6.90	8.20	0.43	0.05	1.75
EC	(mmhos/cm)	1.61	5.63	0.11	0.85	1.59	0.99	0.41
SO_4-S	(lbs/Acre)	357.6	832.0	12.00	320.0	256.2	0.72	-1.46
Fe	(ppm)	33.57	79.50	7.00	28.00	17.50	0.52	0.79
Mn	(ppm)	11.76	36.50	3.30	8.80	8.38	0.71	3.26
NH_4-N	(ppm)	4.63	7.40	2.70	4.50	0.89	0.19	2.54
Ca	(ppm)	4800	7300	1400	5080	1159	0.24	2.41
Na	(ppm)	768.7	2500	6.00	496.0	779.6	1.01	-0.45
CEC	(Meq/100g)	36.82	62.40	8.20	39.50	12.80	0.35	0.18
Total-N	(%)	0.10	0.21	0.01	0.10	0.05	0.48	0.38
Total-C	(%)	1.75	2.50	0.30	1.90	0.53	0.30	1.42
TOC	(%)	1.44	2.43	0.28	1.61	0.52	0.36	0.15
CCE	(%)	2.54	12.70	0.00	1.80	2.47	0.97	7.63
Sand	(%)	18.53	79.34	1.10	3.00	28.61	1.54	-0.02
Silt	(%)	18.50	44.24	2.71	17.95	10.59	0.57	0.18
Clay	(%)	62.95	94.22	10.44	73.74	26.64	0.42	-0.49

Appendix 2. Pearson's correlation coefficients between soil properties (n = 122).

	NO_3	P	K	pH	EC	SO_4	Fe	Mn	NH_4	Ca	Na	CEC	TN	TC	TOC	CCE	Sand	Silt	Clay
NO_3	1.000																		
P	0.195*	1.000																	
K	-0.005	0.343**	1.000																
pH	0.060	-0.399**	-0.227*	1.000															
EC	0.029	0.051	0.128	0.233*	1.000														
SO_4	0.036	-0.023	-0.025	0.245**	**0.827****	1.000													
Fe	0.081	0.496**	0.034	-0.790**	-0.089	-0.091	1.000												
Mn	-0.119	0.305**	0.363**	-0.337**	0.230*	0.099	0.472**	1.000											
NH_4	0.014	0.347**	0.701**	-0.446**	-0.122	-0.280**	0.291**	0.459**	1.000										
Ca	0.176	-0.145	0.268**	0.344**	0.389**	0.226*	-0.203*	0.032	0.109	1.000									
Na	-0.068	-0.040	0.047	0.279**	**0.827****	**0.751****	-0.140	0.140	-0.215*	0.259**	1.000								
CEC	0.033	-0.090	0.333**	0.367**	**0.799****	**0.688****	-0.223*	0.156	0.032	**0.745****	**0.747****	1.000							
TN	0.196*	0.281**	0.288**	-0.307**	-0.025	-0.126	0.336**	0.249**	0.574**	0.252**	-0.134	0.144	1.000						
TC	0.197*	0.152	0.045	-0.032	0.027	-0.030	0.155	0.122	0.320**	0.281**	-0.056	0.180	**0.898****	1.000					
TOC	0.211*	0.261**	0.232*	-0.221*	0.008	-0.081	0.264**	0.207*	0.493**	0.278**	-0.089	0.169	**0.969****	**0.950***	1.000				
CCE	0.039	-0.241**	-0.495**	0.504**	0.064	0.128	-0.240**	-0.186*	-0.352**	0.116	0.068	0.098	0.152	0.521*	0.228*	1.000			
Sand	-0.137	-0.002	**-0.624****	-0.164**	-0.318	-0.282**	0.286**	-0.137	-0.387**	-0.489**	-0.261**	-0.582**	-0.220	-0.112	-0.235*	0.291**	1.000		
Silt	0.173	0.050	0.290**	0.028	-0.008	-0.050	-0.176	-0.097	0.169*	0.175*	-0.040	0.075	0.088	0.083	0.152	-0.154	-0.426**	1.000	
Clay	0.045	-0.029	0.508**	0.162**	0.353	0.339**	-0.207*	0.209*	0.322**	0.430**	0.310**	**0.592****	0.188	0.073	0.167	-0.226*	**-0.839****	-0.136	1.000

* $p < 0.05$; ** $p < 0.01$



Appendix 3. Vertical distribution of selected soil properties in the soil profile at different locations

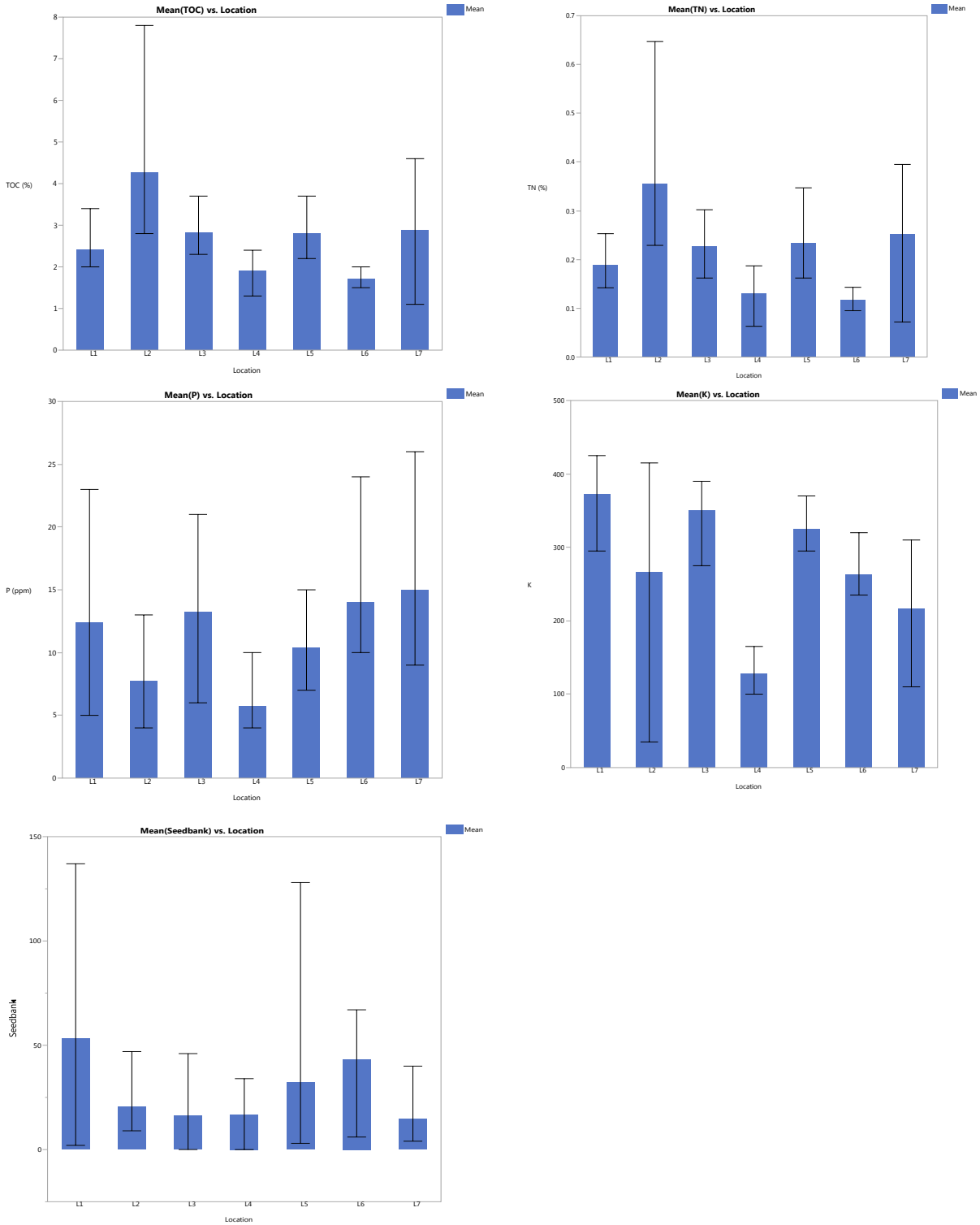
Appendix 4. Plant and ground cover in quadrats

	Location 1				Location 2				Location 3				Location 4		Location 5				Location 6		Location 7		
Transect	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**1**	**2**	**3**	**4**	**1**	**2**	**1**	**2**	**3**
Plant cover																							
Forbs	10	10		5	5	3	6	2	1	1	1	1	8	5	5	2	2	2	8	7	6	5	6
Grass	5	4	12		11	12	8	11	11	10	11	11	6	8	3	2	7	9	5	4	6	9	8
Cattail	1	4													3	8			3	3	2	4	4
Sedge		4			1																		
Rushes			1	12									2				8	5					
Ground cover																							
Litter	5	4	12	15	14	11	14	12	14	14	13	13	15	15	15	15	15	15	15	15	12	15	13
Bare ground	9	6	4			4	1	3	1	2	3	1		2							9	1	5
Moss	2				4	3					5	8	5	1							3	11	3

Class: 1. <1%; 2. 1-2%; 3. 2-5%; 4. 5-15%; 5. 15-25%; 6. 25-35%; 7. 35-45%; 8. 45-55%; 9. 55-65%; 10. 65-75%; 11. 75-85%; 12. 95-95%; 13. 95-98%; 14. 98-99%; 15. >99%.

Appendix 5. Measured soil seedbank in surface soils (n=49)

Plant species	Counts	Minimum	Maximum
Leafy spurge	4	1	20
Field pennycress	18	1	63
Redroot pigweed	2	1	4
Kentucky bluegrass	43	1	37
Quack grass	11	1	11
Yellow foxtail	4	1	3
Atriplex spicata	19	1	124
Catnip	33	1	27
Yellow sweet clover	3	1	3
Canada thistle	5	1	2
Field pussytoes	2	1	1
Absinthe wormwood	2	1	1



Appendix 6. Soil nutrient levels (TOC, TN, P, and K) and seedbank measured in surface soils (n = 49). Bars represent mean values, and error bars reprent ranges.