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Full Length Research Paper

Assessing the effectiveness of water quality education programs in controlling soil phosphorus levels in the Beaver River Watershed, Utah

R. Mark Nelson* and Grant E. Cardon

Utah State University, Logan Utah, United States.

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Federal Environmental Protection Agency (USEPA) 319 Program funds were obtained to educate landowners on how to make improvements on their farms that would help keep manure and P-laden sediments out of the Beaver River Watershed in Utah.The primary objective of this study was to employ an integrative evaluative tool (long-term monitoring of soil P test levels) to evaluate the effectiveness of the educational efforts.The study hypothesis was that educational efforts would result in a significant change in soil P test level, thereby indicating a significant impact of the educational campaign.Over the study period between 1998 and 2009, 12% of growers sampled in the study region adjusted their P management programs so that proper nutrient sufficiency could be attained and maintained in their soils. Despite the inroads gained in effecting positive changes in grower practice over the study period, many growers (especially those whose fields were in close proximity to their dairy operations) were more affected by the high direct cost of spreading manure waste over a larger area, and ended up applying more P than the crop required. This over-application was evidenced by a little over 14% of study sites (7 of 49) showing increases in Olsen P levels of greater than 50 mg/kg over the study period. The strong influence of economic considerations on P management must be addressed in future educational programs.

Key words: Best management practices, water quality, phosphorus, manure, soil testing, fertilizer management, riparian buffers, agricultural extension.

INTRODUCTION

The Beaver River watershed is estimated to cover some 306,000 acres in Beaver County, Utah. Bordered by the Tushar mountains to the east and the Mineral mountains to the west, the estimated population is 3,700 people and is experiencing about a 0.22% increase in population growth projected through the year 2020. Approximately, 170 farms (of an average of 495 acres in size) are contained within the watershed which is comprised mostly of cow/calf and alfalfa operations with a few interspersed dairies (Utah State University, 2008).

In Utah's arid climate, water is a critically valuable resource. Competition for high quality water between farms, growing municipal and landscape uses, and local recreation is high. The Beaver River is the primary water

*Corresponding author. E-mail: mark.nelson@usu.edu.

resource in Beaver County and is prized as a local fishery, recreation area, and a valuable source of water for farm and municipal uses. Water flow and quality monitoring of the Beaver River in the early 1990's showed a variety of problems ranging from high rates of sediment load and high concentration of associated phosphorus (Beaver River Task Force, 2001). The Utah Department of Environmental Quality determined that high phosphorus levels in the Beaver river and Minersville reservoir were having a negative effect on fish development in the river and reservoir (Beaver River Task Force, 2001). In 1994, the Beaver River Task Force began addressing problems in the watershed using federal Environmental Protection Agency (USEPA) 319 Program funds to educate landowners on how to make improvements on their farms that would help keep manure and P-laden sediments out of the Beaver River. Utah State University Cooperative Extension's (USUCE) role on the task force was that of training and educational information development and dissemination. Educational programs that promote learner participation and feature practical demonstrations using local methods and data have proven to be very successful in encouraging farmers to implement projects on their own farms (Downing et al., 2007). Additionally, studies world-wide designed to determine the reasons for or against the adoption of agricultural best management by farmers, are also helpful in designing effective grower educational programs (Fernandez-Corenjo et al., 2005; Pannell et al., 2006; Saltiel et al., 1994). Therefore, an annual Beaver River Watershed Tour was established by USU CE, which for the last 15 years has showcased water quality improvement projects being conducted cooperatively by various growers and institutions in the watershed. After reviewing numerous alternatives that are commonly promoted to manage manure P (Lory, 1999) the education program was designed to include the following water quality protection projects and manure management systems: stream bank restoration, piping streams and ditches, improved fencing (stability and location), improving irrigation efficiency and uniformity, range reseeding, and improved livestock watering facilities (both physical and proper siting). Many producer meetings (annual crop schools, field days, workshops, etc.) were held over that same 15-year period to teach agricultural best management practices (BMPs). In addition to showcasing the projects noted above, focus during grower education events was given to rotational grazing with off-site watering (that is., fencing off the river and developing alternative ways to water animals off river while practicing rotational grazing to minimize over-grazing and soil disruption), and the importance of soil testing before applying manure or commercial fertilizer.

Objectives

The primary objective of this study was to employ an integrative evaluative tool (long-term monitoring of soil P test levels) to evaluate the effectiveness of the many educational events and techniques employed in the Beaver River Watershed area.

The study hypothesis was that educational efforts and implementation of soil and grazing management BMPs would result in a significant change in soil P test level, thereby indicating a significant impact of the educational campaign of USU CE. To accomplish this objective, the following specific tasks were undertaken:

1. Obtaining initial soil tests to measure phosphorus levels in hay fields and pastures along the Beaver River at the beginning of the educational campaign.
2. Repeating soil tests on the same fields at the end of a decade of water quality improvement education and project application.
3. Comparing the two sets of soil test values to assess any positive changes in soil P level, and interviewing farmers to find out why they felt the phosphorus levels either increased or decreased on their individual fields.

METHODOLOGY

Many of the hay fields and pastures sampled were fairly small in size but several large hay fields and pastures were also tested. The hay fields and pastures ranged in size from 1 acre to over 200 acres. The average size was 32 acres. In 1998 soil samples were taken in the irrigated meadows along the Beaver River between Beaver City and the Minersville Reservoir. In 2009, the same hay fields and pastures were sampled again to see if phosphorus levels had changed since 1998. A total of 49 hay fields and pastures were sampled.

Each field was randomly sampled to a depth of 12 inches (30 cm) in at least six separate locations and the soil from each location was composited. The composite soil samples from each field were sent to the Utah State University Analytical Laboratories (USUAL) for Olsen (Ammonium Bicarbonate) Extractable P analysis.

Data from the 1998 and 2009 data sets were compared, and a histogram of soil P test levels was contrasted for the two data sets. An ANOVA test on the two distributions was undertaken to test the difference in the means of the two sample sets. Categorical evaluation was also undertaken to classify each soil test result using the interpretive levels used by USUAL. This was done to evaluate the "migration" of soil test results between the categories of "deficient" (<15 mg/kg Olsen P), "sufficient" (15 to 30 mg/kg Olsen P), and "high"(> 30 mg/kg Olsen P) with respect to crop need over the time period of the sampling.

RESULTS AND DISCUSSION

A histogram showing the distribution of Olsen Extractable P for the two sampling dates is given in Figure 1. The relative distribution indicates a shift in the data over the sampling period where fewer fields fall in the two groups above "sufficient" (the groups between approximately 30 to 70 mg/kg). However, it appears that some of these fields may have migrated to both lower and higher levels of analysis. There is a significant rise in the number of

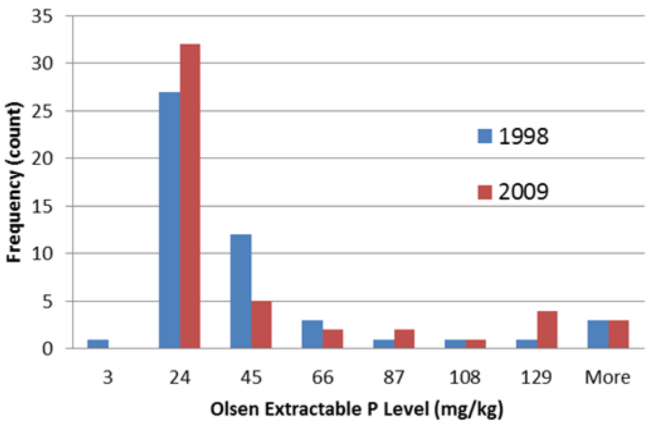

Figure 1. Histogram of Olsen P test levels in each year of the study.

Table 1. Statistical comparison of log-transformed sample means.

Variable	1998	2009
Mean	1.332	1.360
Variance	0.159	0.185
Observation	49	49
Pearson correlation	0.727	
Hypothesized mean		
Difference	0.000	
df	48	
T stat	-0.634	
P(T≤t) one- tail	0.265	
T critical one-tail	1.677	
P(T≤t) two- tail	0.529	
T critical two-tail	2.011	

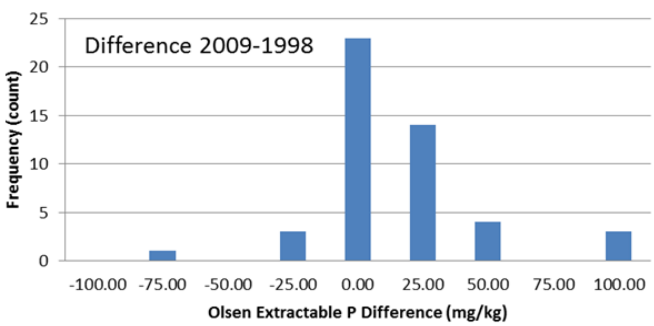

Figure 2. Histogram of the difference in Olsen-Extractable P test between 2009 and 1998.

observations in the "sufficient" category (15 to 30 mg/kg) indicating a net improvement over the sampling period in soil P management. It is desirable that all fields would fall in this category indicating grower attention to maintaining soil P levels conducive to optimal crop growth without over- or under-fertilizing.

Unfortunately, there seems to have also been a net increase in the number of fields having very high soil test levels (> 50 mg/kg). Figure 2 is a histogram of the frequency of the difference between 2009 and 1998 Olsen-Extractable P levels (negative values indicate a decrease, positive values indicate an increase over the time period). Seven fields showed an increase of more than 50 mg/kg (Figure 2) from 1998 to 2009. Based on follow up grower interviews in 2009, it appears that those fields with large increases in Olsen-Extractable P were situated in close proximity to dairies and the growers found it financially prohibitive to transport their manure waste to fields further away. This is consistent with the finding of Saltiel et al. (1994) where economic factors were shown to be the most important factors affecting the adoption of sustainable agricultural practices. Manure applications in such economically-dominated situations in our study, were at levels higher than crop P demand, resulting in the buildup of Olsen-Extractable P over the study period.

Because the data is clearly log-normally distributed (Figure 1), to compare the means of the two data sets, the data was log transformed and processed using an ANOVA-based t-test. Table 1 contains the results of the statistical comparison which clearly show that the two means are not significantly different. This indicates that there were essentially just as many sites that increased in Olsen-Extractable P, as deceased, resulting in no shift in the mean over the study period. Interestingly, the mean is between 21 and 23 mg/kg which is in the middle of the sufficiency range, indicating that growers on the whole are targeting that level of extractable P over the study area even if individual growers chose to make P management decisions using criteria other than plant need.

The number and percentage of the total fields falling in a given interpretive category of Olsen-Extractable P are given in Table 2 which provides another indication of the impact of the educational campaign on soil P management. The data show a consistent migration of soil P level toward the "sufficient" category from both high and deficient levels. If one bases an evaluation of the impact of the educational campaign on the statistical difference in the mean value of Olsen-Extractable P over the study period, or on a histogramatic distribution of soil P level over time, the real effect of the educational effort may be missed. The data in Table 2 show that a substantial number of growers (over 12%) have taken plant need into account in the management of soil P. Many growers that had high initial test levels reduced P input and moved into the "sufficient" category over the study period. Also, growers with low initial soil P test levels, improved P management to their advantage by increasing P inputs and bringing their soils up to sufficient levels. The latter was a surprising finding in the data.

Table 2. Number of sites with indicated Olsen P test levels in each year of the study.

Year	Low (<15 ppm)	Adequate (15 to 30 ppm	High (>15 ppm)
1998	19(38.8%)	12(24.5%)	18(36.7%)
2009	16(32.7%)	18(36.7%)	15(30.6%)
Change	-3(-6.1%)	+3(+12.2%)	-3(-6.1%)

More emphasis in the educational campaign was given to effecting a reduction in high soil P test levels due to environmental issues associated with off-site transport of excess P. The overall improvement of soil P management toward meeting and maintaining sufficiency levels for optimal crop performance was initially overlooked when analyzing the results, but certainly helps show the impact of educating growers about the levels of the nutrients needed.

Conclusion

Over 12% of growers sampled in the study region adjusted their P management programs so that proper nutrient sufficiency could be attained and maintained in their soils. This response to the educational program undertaken to train growers on crop P need and the consequences of P mismanagement, is a strong indicator of the campaign's effectiveness.

Despite the inroads gained in effecting positive changes in grower practice over the study period, many growers (especially those whose fields were in close proximity to their dairy operations) were more affected by the high direct cost of spreading manure waste over a larger area, and ended up applying more P than the crop required. This over-application was evidenced by a little over 14% of study sites (7 of 49) showing increases in Olsen-Extractable P levels of greater than 50 mg/kg over the study period. The strong influence of economic considerations on P management must be addressed in future educational programs.

Future educational programs should be developed to help growers appropriately value and personalize the potential environmental costs of P mismanagement (such as local surface water quality degradation, fishery health, etc.), provide options for handling the volume of manure waste that can serve as economically viable alternatives to disposal rates of application on crop land, and on other field P management options such as new crop rotations with higher P use potential, etc. These additional educational efforts may help growers driven by economic-based decisions, to more fully consider the need to balance P applications with crop need.

Conflict of Interest

The author(s) have not declared any conflict of interests.

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