Problem 7: Test for treatment effect in a paired-watershed design

Testing for the effects of BMP implementation in a paired-watershed design (Section 7.8.2.1) can be done using Analysis of Covariance (ANCOVA). ANCOVA combines the features of ANOVA with regression and is an appropriate statistical technique to use in analysis of watershed designs that compare pre- and post-BMP periods using treatment and control watershed measurements. The ANOVA example here follows the procedures of Clausen and Spooner (1993) and Grabow et al. (1999).

In Dataset 1 in file Sampledata.xlsx, Station 3 represents the control watershed; a program of BMPs was implemented between the Calibration and Treatment periods (Period = CAL and TRT, respectively). Log-transformed data are assumed to meet the requirements for parametric statistical analysis. Use the ANCOVA procedure to evaluate the effect of treatment on TP export measured at Station 1 (TPX_1) at an alpha of 0.10 (90 percent confidence level).

As noted in Section 7.8.2.1, required input data file formats may differ among statistics programs. For JMP software, the following file structure is used:

Period	logTPX_3	logTPX_1	Per_num (Indicator Variable)
Cal	X_i	Y_i	0
Cal	X_{ii}	Y_{ii}	0
Trt	x_{iii}	y_{iii}	1
Trt	x_{iv}	y_{iv}	1

For the first iteration, run a regression model with logTPX_1 as Y and independent variables (i.e., "model effects") logTPX_3, Per_num, and the Per_num*logTPX3 interaction term. The equation takes the following general form, where ε is an error term:

$$logTPX\_1 = \beta_0 + \beta_1 logTPX\_3 + \beta_2 Per_{num} + \beta_3 (Per\_num * logTPX\_3) + \varepsilon$$

The results are shown below:

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	
Intercept	-0.338544	0.083184	-4.07	<.0001*	β_0
logTPX_3	0.8694345	0.068786	12.64	<.0001*	β_1
Per_num	0.2136441	0.120933	1.77	0.0782	β_2
Per_num*logTPX_3	-0.100372	0.096838	-1.04	0.3007	β_3

The *P* values (Prob>|t|) in the above output indicate that both intercepts and slopes are significantly different from zero (β_0 and β_1) and that while the intercepts of the two period regressions differ significantly (β_2 = 0.078), the slopes do not (β_3 = 0.301). Therefore, the procedure is re-run using the reduced (without the Per_num*logTPX_3 interaction term) model ANCOVA with the following general form:

$$logTPX_1 = \beta_0 + \beta_1 logTPX_3 + \beta_2 Per\_num + \varepsilon$$

The results of running the reduced model ANCOVA are shown below:

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|	
Intercept	-0.284284	0.064653	-4.40	<.0001*	β_0
logTPX_3	0.8187918	0.048423	16.91	<.0001*	β_1
Per_num	0.1033563	0.057478	1.80	0.0731	β_2

At an alpha of 0.10, the intercepts differ significantly ($\beta_2 = 0.073$). The reduced model ANCOVA regression equations can be derived as follows:

$$logTPX_1 = \beta_0 + \beta_1 logTPX_3 + \beta_2 Per\_num$$

For CAL, Per_num = 0, so $\quad logTPX_1 = \beta_1(logTPX_3) + \beta_0$

For TRT, Per_num = 1, so: $\quad logTPX_1 = \beta_1(logTPX_3) + (\beta_0 + \beta_2)$

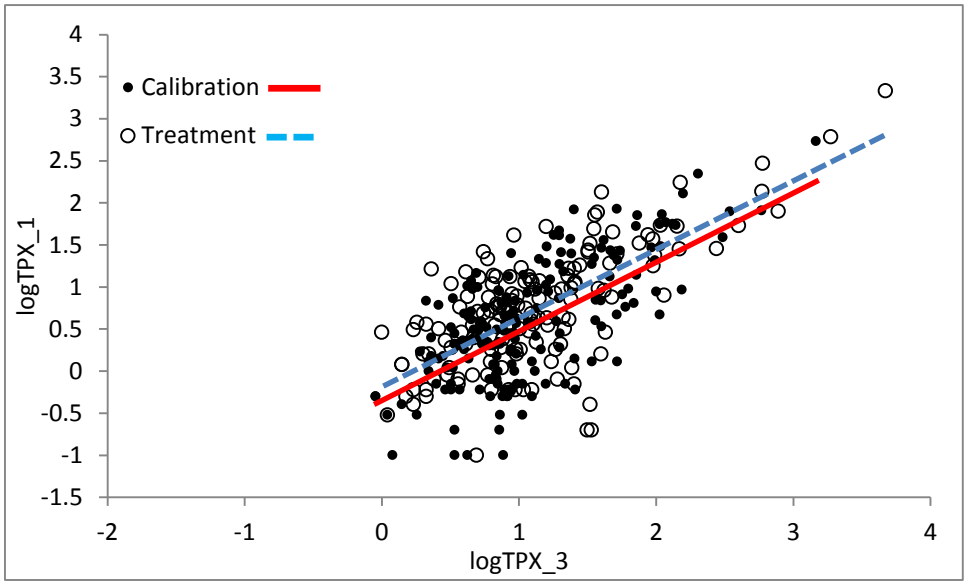
Substituting the values for the coefficients yields:

CAL: logTPX_1 = 0.82(logTPX_3) – 0.284

TRT: logTPX_1 = 0.82(logTPX_3) + (-0.2843 + 0.1034)

logTPX_1 = 0.82(logTPX_3) – 0.181

The results of the ANCOVA paired-watershed analysis can be visualized as follows:



The paired-watershed analysis suggests that TP export from the treated watershed increased significantly after treatment.

References

Clausen, J.C. and J. Spooner. 1993. Paired Watershed Study Design. 841-F-93-009. Prepared for S. Dressing, Office of Water, U.S. Environmental Protection Agency, Washington, DC. EPA 841-F-93-009. 8 p. Available at http://nepis.epa.gov/ (Accessed 9-25-2013).

Grabow, G.L., J. Spooner, L.A. Lombardo, and D.E. Line. 1999. Detecting Water Quality Changes Before and After BMP Implementation: Use of SAS for Statistical Analysis. NWQEP Notes No. 93. NCSU Water Quality Group, Biological and Agricultural Engineering Department NC State University, Raleigh, NC http://www.bae.ncsu.edu/programs/extension/wqg/issues/93.pdf (Accessed 8-28-2014).