Research Questions

- Does application of diluted urine, undiluted urine, or synthetic fertilizer increase second cutting yield in comparison to no fertilizer treatment?

- Is there a difference in second-cut hay yield between plots treated with diluted urine, undiluted urine, and synthetic fertilizer?

Raw Data

Treatment	Strip Name	KG/Hectare	Farm
synthetic	4	1390.17	Whetstone Valley Farm dry matter yield 2014
synthetic	7	1843.84	Whetstone Valley Farm dry matter yield 2014
synthetic	11	1670.68	Whetstone Valley Farm dry matter yield 2014
control	5	601.01	Whetstone Valley Farm dry matter yield 2014
control	12	875.2	Whetstone Valley Farm dry matter yield 2014
control	1	577.93	Whetstone Valley Farm dry matter yield 2014
1:1	3	1593.45	Whetstone Valley Farm dry matter yield 2014
1:1	8	1552.49	Whetstone Valley Farm dry matter yield 2014
1:1	9	1664.8	Whetstone Valley Farm dry matter yield 2014
1:0	2	1311.43	Whetstone Valley Farm dry matter yield 2014
1:0	6	1318.89	Whetstone Valley Farm dry matter yield 2014
1:0	10	1525.54	Whetstone Valley Farm dry matter yield 2014

Treatment	Strip Name	KG/Hectare	Farm
control	0	961.52	Fair Winds Farm dry matter yield 2014
control	5	839.88	Fair Winds Farm dry matter yield 2014
control	8	575.92	Fair Winds Farm dry matter yield 2014
1:1	1	1088.08	Fair Winds Farm dry matter yield 2014
1:1	3	1235.85	Fair Winds Farm dry matter yield 2014
1:1	6	1040.36	Fair Winds Farm dry matter yield 2014
1:0	2	1120.98	Fair Winds Farm dry matter yield 2014
1:0	4	1122.45	Fair Winds Farm dry matter yield 2014
1:0	7	874.95	Fair Winds Farm dry matter yield 2014

Pooled Data

Whetstone	Strip Count (n)	Mean	Stdev
Control	3	684.71	135.02
Diluted (1:1)	3	1603.58	46.41
Undiluted (1:0)	3	1385.29	99.22
Synthetic	3	1634.90	186.93
Total	12	1327.12	403.86

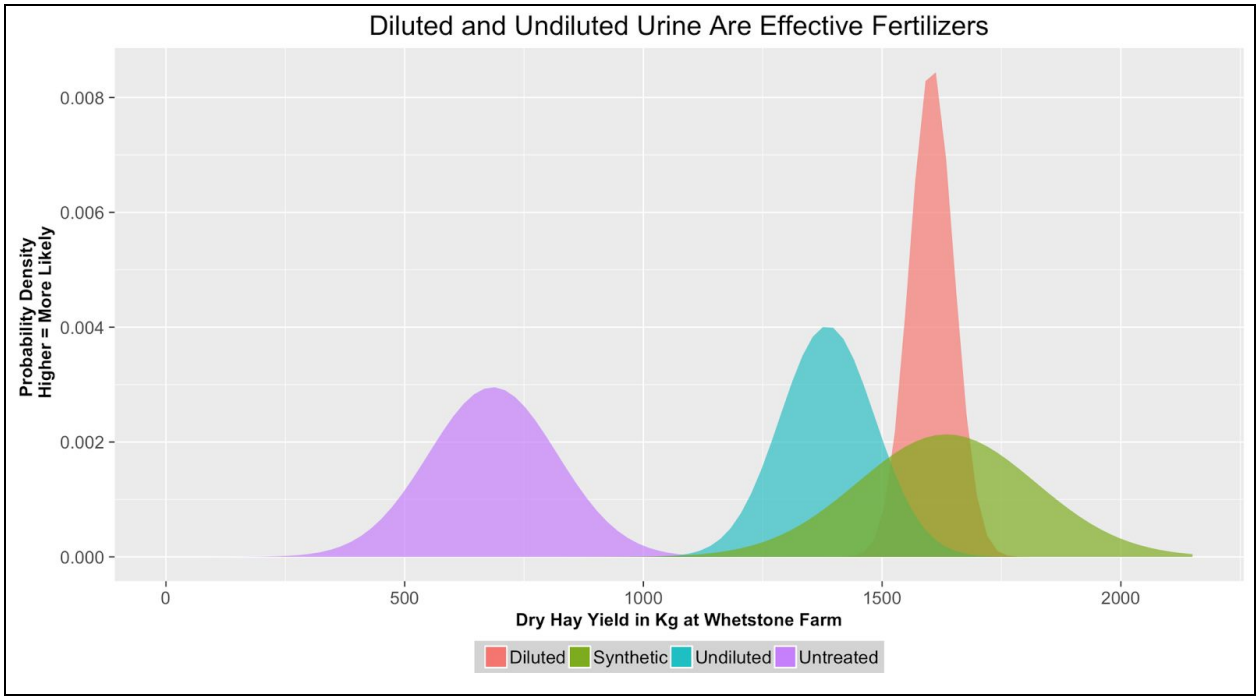
Fair Winds	Strip Count (n)	Mean	Stdev
Control	3.00	792.44	160.95
Diluted (1:1)	3.00	1121.43	209.12
Undiluted (1:0)	3.00	1039.46	282.77
Total	9.00	984.44	187.10

Exploratory Data Analysis

Assuming that the underlying data is roughly normally distributed and using the means and standard deviations calculated above to draw expected distributions for the treatments for Whetstone Farm, we can visualize expected underlying treatment effect size.

Doing so suggests that all 3 fertilizer types have a marked effect, but that differing fertilizers do not differentiate clearly among one another (i.e. there is significant overlap in their expected yield distributions).

Note that diluted urine has a higher peak because it has a lower standard deviation than the other treatments, and thus a narrower range of expected values, not because it had a greater yield.



Model Creation

$$Y_i = \alpha + \beta 1\ Synthetic + \beta 2\ Diluted + \beta 3\ Undiluted + \lambda_f + \varepsilon_i$$

In this estimation equation, we model the effect of different fertilizer treatments on crop yields relative to crop yields that did not have any fertilizer treatments. The outcome variable Y_i indexes average second cutting crop yields for 21 different farm plots across two farms.

Within farms, plots were randomly assigned one of four conditions:

1. A control condition that did not use any fertilizer treatment
2. A treatment condition that used a synthetic fertilizer
3. A treatment condition that used a diluted urine 1:1 with water
4. A treatment condition that used undiluted urine

Treatment conditions are indexed by the parameters $\beta 1$, $\beta 2$, and $\beta 3$. In order to account for between farm heterogeneity, we also include farm fixed effects, indexed by λ_f.

The omitted category in the estimation equation is the control condition and is captured by the coefficient α; the point estimate for this parameter is equivalent to the average crop yield within fams (accounting for mean differences between farms) in untreated plots.

Point estimates are measured in kilograms (kg) and are illustrated below. We estimate the model in two ways. The first corresponds to the estimation equation above; in the second, we

estimate results separately by farm. We do this because one of the treatment conditions (synthetic) is only available for the farm Whetstone, as the use of synthetic fertilizer would violate Fair Winds' organic usage agreements.

For each model, we show point estimates and standard errors that reflect average differences in crop yields between treatment and control groups; we also include tests of equality between treatment groups. In particular, we wish to know whether diluted and undiluted performed significantly better than synthetic.

Results

Linear regression, absorbing indicators

Number of obs	= 21
F(3, 16)	= 14.19
Prob > F	= 0.0001
R-squared	= 0.7842
Adj R-squared	= 0.7302
Root MSE	= 175.7289

lbsacre	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
tx						
Diluted Urine	556.6583	101.4572	5.49	0.000	341.5788	771.7379
Synthetic Fertilizer	692.5834	130.9806	5.29	0.000	414.9168	970.2499
Uniluted Urine	422.715	101.4572	4.17	0.001	207.6354	637.7945
_cons	674.24	71.98465	9.37	0.000	521.6394	826.8406
farm	F(1, 16) =		6.686	0.020	(2 categories)	

Test 1 is does synthetic = diluted; test 2 is does synthetic = undiluted

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. test 3.tx=2.tx

 ( 1)  - 2.tx + 3.tx = 0

       F(  1,    16) =    1.08
            Prob > F =    0.3148

. test 3.tx=4.tx

 ( 1)  3.tx - 4.tx = 0

       F(  1,    16) =    4.25
            Prob > F =    0.0560
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In summary, all fertilized types had a highly significant effect on yield relative to unfertilized control.

All fertilizer pairings, including diluted and undiluted urine, showed no statistically significant between group differences in yield.

However, there were observed yield differences and the sample was relatively small so we recommend additional study at a higher sample size. Moreover, there were large differences between farm effects (i.e. Whetstone was mostly larger than Fair Winds) so we recommend replicating these results at multiple sites.

These findings provide preliminary evidence of the rough equivalence in efficacy between diluted and undiluted urine and synthetic fertilizer in promoting hay yield.